Internet of Things UK: Programme Evaluation Scoping Study and Baseline

Report to the Department for Culture, Media & Sport

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SQW

Contents

Contact:	Osman Anwar	Tel:	0131 243 0729	email:	oanwar@sqw.co.uk
Approved by:	Bruce Macdonald Director	Date:	24 March 2017		

Key Points

1. SQW was commissioned by the Department for Culture Media and Sport (DCMS) to undertake a scoping and baseline study to inform the evaluation of the Internet of Things UK (IoT UK) Programme. The programme consists of five projects: the CityVerve IoT smart city demonstrator in Manchester; two health and social care IoT test beds in Surrey (dementia) and the West of England (diabetes); the PETRAS research hub; work by the Digital Catapult and Future Cities Catapult; and two accelerator schemes for IoT hardware SMEs.

2. We recommend the programme evaluation address seven key evaluation questions. These reflect the intended programme outcomes summarised in the overall logic model and theory of change for the programme set out in section 2.

Key evaluation questions - To what extent has the programme:

- Demonstrated economically viable IoT applications, products & services?
- Led to scaling-up of IoT activity by programme participants?
- Led to replicated IoT activity beyond the programme?
- Led to additional growth in beneficiary SMEs (GVA and employment)?
- Enhanced the international reputation and attractiveness of the UK for IoT investment and activity?
- Influenced stakeholders (e.g. standards bodies, policy makers, investors) beyond the programme?
- Generated and shared learning and knowledge on IoT for programme participants?

3. The programme evaluation should be conducted in two phases: a 'light touch' interim evaluation in mid 2017 (calendar year); and a final evaluation in the second half of 2018/early 2019 (calendar year).

4. We recommend the interim evaluation assess the overall programme using a formative (process) approach to evaluation, focusing on *how* the programme is being delivered in practice. We propose a mixed set of research methods (outlined

in section 3): analysis of monitoring data, stakeholder consultations with participating organisations, and case studies with SME beneficiaries.

5. For the final evaluation, we propose the same research methods as for the interim phase, and also including analysis of secondary data (see section 3 and Annex B for baseline indicators), stakeholder consultations with non-participating organisations, and a telephone survey of SME beneficiaries (see section 3). We recommend that the theory-based technique – contribution analysis – is used to assess the cause and effect of the programme for both the interim and final evaluations (outlined in section 3).

6. The monitoring and evaluation of the IoT UK programme should be overseen by its sponsors, advised by the IoT UK Programme Board. At an operational level, we recommend that a smaller evaluation steering group is established - reporting to the programme sponsors (see section 4).

1. Introduction

1.1 The Internet of Things (IoT) is a global market[1] which offers enormous potential for improving the performance of products and services, to the benefit of consumers and suppliers – including providers of public services. Although challenging to define, it can be described as where *'physical objects are connected to share data with each other and people - to help make decisions'*[2] or alternatively '*the network of physical objects that contain embedded technology to communicate and sense or interact with their internal states or the external environment'*[3].

1.2 Recognising the potential associated with IoT, the Government is investing up to £32 million in the Internet of Things UK Programme (IoT UK) over the period 2015 to 2018, to help advance UK's development and adoption of IoT for economic and social benefit. The programme consists of five projects[4]: the CityVerve IoT smart city demonstrator in Manchester[5]; two health and social care IoT test beds[6]; the PETRAS[7] Research Hub; work by the Digital Catapult and Future Cities Catapult[8]; and two accelerator schemes for SMEs specialising in IoT hardware[9]. While the scale of this investment is modest in the context of the size of the global IoT market, it is intended to act as a catalyst for UK development, activity and enterprise with IoT: helping to coordinate and leverage the wider resources and capabilities available in industry and public sector organisations, and across the UK research base.

1.3 In July 2016, SQW was commissioned by the Department for Culture Media and Sport (DCMS) to undertake a scoping and baseline study to inform the evaluation of the IoT UK Programme.

Objectives

1.4 The study objectives were to develop an evaluation framework for the IoT UK, specifically:

[1] The global IoT market in 2020 was estimated to be $1.7 trillion: IDC Worldwide Internet of Things Forecast, 2015-2020. (June 2015).
[2] DCMS (2016) Internet of Things UK: Programme Overview. Slides.
[3] Gartner Tech Research: http://www.gartner.com/technology/research/internet-of-things/
[4] For the purposes of this report, we refer to these five elements as 'projects' within the overall IoT programme. In practice, however, many of the individual activities are themselves managed as programmes – each with several or even numerous contributing projects/workstreams.
[5] http://www.cityverve.org.uk/
[6] Funded by the Department of Health (Office for Life Sciences) and managed as part of the wider NHS England Test Bed Programme: https://www.england.nhs.uk/2016/01/embracing-innovation/
[7] PETRAS refers to research in 'privacy, ethics, trust, reliability, acceptability and security'. For further information, please see https://www.petrashub.org/
[8] https://iotuk.org.uk/
[9] http://www.rgaiot.com/

- develop an overall logic model and theory of change for the programme, plus logic models for its five constituent projects
- review existing and proposed new programme 'metrics'
- develop an appropriate evaluation methodology to enable a process, impact and economic evaluation of the programme including:
  - methodology to establish a baseline for the programme
  - a counterfactual (or if this is not possible, an alternative approach) against which outcomes of the programme can be compared.

Approach

1.5 Our approach to this study has involved:

- an inception meeting with DCMS to discuss and clarify the scope of the study
- desk-based review of: programme documentation, including the business case existing and proposed programme metrics, project specific documentation, monitoring and progress information
- development of a programme level logic model and theory of change, plus logic models for each of its five projects
- stakeholder consultations with 31 representatives from DCMS, Innovate UK, EPSRC, Digital Catapult, Future Cities Catapult, Office for Life Sciences, NHS England, Tech UK, and key partners involved in the five projects (see Annex A for full list of consultees)
- assessment of existing and proposed new programme 'metrics' relating to each of the five projects and overall programme
- a progress meeting with DCMS to discuss emerging findings from the stakeholder consultations, review of programme metrics, and key evaluation questions
- presentation at the Manchester CityVerve Evaluation Partners Meeting hosted by the University of Manchester[10]
- research into relevant baseline indicators from secondary data

[10] Meeting held on 10th November 2016 with representatives from Digital Catapult, Future Cities Catapult, University of Manchester, Manchester City Council, Cisco, and Future Everything.

- development of an evaluation methodology and plan for the programme.

Structure of this report

1.6 This report is structured as follows:

- section 2 presents an overall logic model and theory of change for the programme, and a logic model for each of the programme's five projects
- section 3 sets out the proposed evaluation approach and methodology
- section 4 outlines the proposed governance, timings and budget for the programme evaluation.

1.7 There are two annexes:

- Annex A provides a list of stakeholders consulted in the course of this study
- Annex B presents various baseline indicators, providing a snapshot of how the UK currently compares to other countries in the IoT arena.

2. Logic models

2.1 This section sets out the logic model and theory of change for the IoT UK programme, plus logic models for each of the five component projects of IoT UK: Manchester CityVerve, health and social care test beds, PETRAS, Digital and Future Cities Catapults, and the two accelerator schemes.

Theory of change for the overall IoT UK programme

2.2 The **context** for the programme is that that IoT offers enormous potential for improving the performance of many existing (and new) products and services, to the benefit of consumers and suppliers – including users and providers of public services. Various developments have recently improved the commercial case for implementing IoT solutions, including advances in sensor and battery technologies, low power wireless communications, and developments in data management, storage, analytics and applications. The UK has established strengths in certain areas, including its digital infrastructure, and tech sector, emerging IoT companies, and a relevant and strong research base. As set out in Government Chief Scientist Sir Mark Walport's 2014 report[11], and government publications and public statements, there are also policy ambitions for the UK to be a leading player in the IoT, for economic and social benefit.

2.3 The **rationale** for government intervention includes that the size and nature of scientific, innovation and technological challenges for the development and successful adoption of IoT are too large for individual private actors to tackle alone. In many cases (public and private sector), IoT applications have not yet been proven at scale and the solutions to challenges and benefits remain uncertain, which contributes to a perception of high risk amongst suppliers, buyers, investors, and end-users of goods and services. Concerns over potential risks such as privacy and security also hamper adoption at scale. Targeted publicly-funded intervention can help address these issues, leading to more efficient socio-economic market outcomes.

2.4 In response to this, the key **inputs** include the Government's investment, now of up to £32 million over three years (2015 to 2018), plus cash and 'in-kind' contributions from a large number of programme delivery partners. The Government investment includes up to £9.8 million for Manchester CityVerve, £6 million for two IoT test beds in health and care, over £9 million for the PETRAS research hub, £3 million for the work of the Digital Catapult and the Future Cities

[11] Government Office for Science (2014) The Internet of Things: making the most of the Second Digital Revolution. A report by the UK Government Chief Scientific Adviser: Sir Mark Walport.

Catapult, and just under £1 million for SME accelerator schemes. There are also management, monitoring and governance inputs from the programme sponsors: DCMS, Innovate UK, and the Engineering and Physical Sciences Research Council (EPSRC).

2.5 The programme **activities** are directly related to the work of the five constituent projects of the programme: Manchester CityVerve, health and social care test beds, PETRAS, Digital and Future Cities Catapults, and SME accelerator schemes. The activities are wide ranging; in summary they involve work on IoT relating to research, innovation, technology, enterprise, communication, co-ordination and collaboration.

2.6 There are various intended **outputs** for each of the constituent projects (such as numbers of SMEs supported, numbers of devices installed, research paper publications and citations etc.). The high level programme outputs could be considered to be the successful establishment and completion of the five projects, plus dissemination of programme-level and project-level learning, and interim and final evaluation reports for the overall programme.

2.7 These outputs are intended to lead to a number of important **outcomes**: improved learning and knowledge on IoT for programme participants; improved economic viability of IoT applications, products and services; scaling-up of IoT activity by programme participants; replicated IoT activity beyond the programme; additional growth in beneficiary SMEs; enhanced international reputation and attractiveness of the UK for IoT investment and activity; and a positive influence on stakeholders (e.g. policy makers, IoT buyers and suppliers) beyond the programme.

2.8 If these outcomes are successfully achieved over time, then it is envisaged that the **impacts** from the programme will include: improved economic competitiveness of UK businesses in IoT markets; economic impacts in terms of increased UK gross value added (GVA) and employment, including through enhanced productivity and increased exports; and wider social and environmental benefits for UK citizens and society enabled by IoT applications.

2.9 The logic model for the overall programme is summarised overleaf, followed by logic models for each of the five constituent projects. These have been informed by our review of programme documentation and refined through stakeholder consultations.

IoT UK programme logic model [1]

Context

- IoT offers enormous potential for improving the performance of products and services, and benefiting buyers (including in the public sector), suppliers, and citizens
- Trends encouraging development and adoption of IoT include: advances in sensor and battery technology; low power wireless communications; and data management, storage, analytics and applications
- Countries leading in IoT R&D and adoption will have advantages in terms of economic, social and environmental development
- The UK has established advantages for competing in IoT (e.g. digital infrastructure; UK IoT companies; research base; industry strengths, e.g. advanced electronics, software development; consumers who are early technology adopters)

Rationale for intervention

- Wider rationale for government investment in research and innovation, including with emerging technologies
- Markets are likely to under-provide IoT standards, regulation and solutions
- Information asymmetry and uncertainty, for example specialist technical and/or market knowledge of IoT is a barrier to public sector and other buyers' and citizens' awareness of IoT and benefits of using IoT technologies and services
- Buyer and pubic concerns, for example privacy, security and ethical risks, and challenges such as collaboration and data management are also likely to hamper IoT adoption
- Network failures, for example due to lack of coordination or fragmentation in collecting, analysing, and sharing data (on e.g. health, transport, environment) at local and regional levels
- Targeted publicly-funded intervention can help address these issues, leading to more efficient socio-economic market outcomes

Inputs

- Government investment of up to £32m over three years (2015 to 2018)
- Management/governance inputs from sponsors - DCMS, Office for Life Sciences, NHS England, Innovate UK and EPSRC, and from the Digital and Future Cities Catapults
- Cash and 'in-kind' contributions from a large number of delivery partners

Activities

- Five IoT UK projects: collaborative R&D - CityVerve smart city demonstrator Manchester and two health and care demonstrators in Surrey (dementia) and West of England (diabetes); the PETRAS IoT Research Hub; Digital and Future Cities Catapults; and accelerator schemes for IoT hardware businesses
- This work relates to: research, innovation, technology, enterprise, communication, co-ordination and collaboration

IoT UK programme logic model [2]

Intended outputs

- Five projects completed by 2018 (March and August)
- Dissemination of programme-level and project-level learning to participants and wider interest groups, particularly UK public sector
- Evaluation of the programme

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Intended outcomes

- Improved economic viability of IoT applications, products and services
- Scaling-up of IoT activity by programme participants
- Replicated IoT activity beyond the programme
- Additional growth in beneficiary SMEs
- Enhanced international reputation and attractiveness of the UK for IoT investment and activity
- Positive influence on stakeholders (e.g. policy makers) beyond the programme
- Improved learning and knowledge for IoT UK programme participants

↓

Intended impacts

- Improved economic competitiveness of UK IoT businesses
- Economic impacts (increased UK GVA, employment, productivity, cost savings, exports)
- Social benefits (e.g. environment, health, better public services and infrastructure)

Manchester CityVerve logic model [1]

Context

- IoT offers enormous potential for improving the performance of products and services, to the benefit of buyers (including in the public sector), suppliers, and citizens
- Increasing connectivity and access to public information presents opportunities for local authorities to manage cities more cost-effectively, and improve services for citizens
- Cities around the world are using IoT and other smart city technologies
- The global market for smart cities applications could be $400 billion p.a. by 2020 (Arup, 2013)
- Manchester has devolved powers and responsibilities (e.g. NHS budget): its authorities have stated commitments to innovative solutions to local needs and challenges, focus on the continued growth of the digital economy, and more efficient and effective local services

Rationale for intervention

- Wider rationale for government investment in science and research because the size of the scientific, innovation and technological problem is too large for individual private actors to tackle
- Markets are likely to under-provide standards, regulation and solutions
- There is information asymmetry and uncertainty as a result of high levels of specialised technical and/or market knowledge relating to IoT which limits the awareness, accessibility and benefits of using smart city technologies and data (e.g. travel, health, energy) by 'central purchasers' (e.g. local authorities, NHS and social care providers) and the general public
- Rationale for Innovate UK funding industry/public sector led collaborative R&D
- Network failures due to lack of coordination (or fragmentation) in collecting, analysing, and sharing data at city level
- Potential for publicly-funded R&D projects to help address these issues, improve public infrastructure and services, and generate positive spillover effects (e.g. network, knowledge and market)

Inputs

- Government (DCMS) funding of up to £9.78m ((2016 to 2018; grants from Innovate UK); cash contributions from delivery partners (Cityverve consortium) £5.89m, plus 'in-kind' contributions
- ICT infrastructure and services supplied by Cityverve participants and other businesses, e.g. telecoms, sensors, devices, software, data services
- Management and governance inputs by 20+ Cityverve consortium members including: Manchester City Council, Cisco, BT, Siemens, Ordnance Survey, Central Manchester University Hospitals NHS Foundation Trust, Transport for Greater Manchester, University of Manchester, Manchester Metropolitan University, Manchester Science Partnerships, SMEs, and the Future Cities Catapult

Activities

Large collaborative R&D programme; underpinning and central "digital infrastructure platform" on which IoT solutions (see below) provide access to a range of data to firms, public sector organisations and others

19 "work packages" to design, build, and test IoT technologies and applications across four themes:

- Health and social care (e.g. chronic conditions, wellness, nursing home care)
- Transport and travel (e.g. bus stops, road safety, cycling)
- Energy and environment (e.g. lighting, parking, air quality monitoring)
- Culture and public realm (e.g. work with the community, social media, art)

Manchester CityVerve logic model [2]

Intended outputs

- Platform developed, devices and infrastructure installed, services running and “use cases” demonstrated and implemented by 2018; and work with small businesses and public communications. For example:
  - Two IoT art installations
  - 1,200 “talkative” bus stops; 2,000 road safety devices; 6,000 water monitoring devices
  - Smart lights and smart parking sensors
  - Four competitions (and showcase workshops) p.a. (each funding at least four start-ups or SMEs)
  - Public communications
  - Business models developed for smart city IoT services/infrastructure

Intended outcomes

- Greater effectiveness and efficiency of the relevant public services and utilities
- Improvement in the quality and cost effectiveness of the relevant IoT/ smart city solutions
- Increased proportion of local businesses and local residents/workers aware of the local projects; improved attitudes (perceptions of benefits) towards these kinds of projects
- Improved communication, co-ordination and collaboration between public and private organisations in Manchester (and with other towns and cities)
- Network, knowledge and market positive spillovers generated
- Spillover learning on cities applications of IoT for other UK “central commissioners” of public infrastructure and services (e.g. local authorities) and providers (businesses)
- Increased opportunities for commissioners and providers to be aware of and consider using these technologies to address local requirements
- Demonstrating the value of CityVerve or specific innovations within the programme, and to other areas/cities
- Testing/ proving IoT and related technologies e.g. improved data accessibility, sharing and analysis
- Replicability, scalability, and sustainability of CityVerve, or specific innovations, to other areas/cities, and associated business opportunities
- IoT Innovations open/accessible to others (e.g. through the use of Hypercat standards)

Intended impacts

- Improvements in Manchester public services for citizens
- Improved economic competitiveness of UK businesses offering smart city related goods and services
- Improved international global reputation of Manchester as a smart city
- Economic impacts (increased UK GVA, employment, productivity, cost savings, exports)
- Improved public sector efficiency and effectiveness
- Wider social benefits (e.g. health, environment, transport, culture)

Health and social care IoT test beds logic model [1]

Context

- IoT offers enormous potential for improving the performance of products and services, to the benefit of buyers (including in the public sector), suppliers, and citizens
- NHS England's *Five Year Forward View* (2014) introduced 'Test Bed' sites: local projects for health and care innovation
- Test Beds combine technologies and service innovation, testing them together in service delivery and generating evidence in 'live' clinical settings
- Currently seven Test Beds, including two using IoT: Diabetes Digital Coach (West of England) and Technology Integrated Health Management for people with dementia (Surrey)

Rationale for intervention

- The Test Beds Programme seeks to address three problems that have constrained innovation in the NHS: (i) innovations are often implemented in isolation from each other, and from the infrastructure on which they depend (infrastructural failure); (ii) innovations are often introduced on top of existing working practices and infrastructure (network and infrastructural failure); (iii) lack of robust evidence about the effects of innovations in the real world (e.g. clinical settings) as opposed to experimental or research settings (information failure)
- Test Beds aim to address these failures through enabling self-management of health conditions, providing real-time data about a person's health; bringing together different innovations (also leading to spillover effects)
- Reduce barriers and increase opportunities for NHS and business collaboration

Inputs

- Up to £6m government (DoH) funding: grants from Innovate UK
- Two collaborative R&D IoT projects in Surrey (dementia) and the West of England (diabetes)
- Management and governance inputs by sponsors and delivery partners: research institutes, private firms (tech sector) NHS trusts, clinical commissioning groups
- Private firms' cash and "in-kind" investment

Activities

- Test existing technology, e.g. devices, data services, software
- Build and test applications/ labs and platforms to support devices
- Recruit participants and volunteers (e.g. trials)
- Train participants and volunteers
- Conduct technical pilot
- Conduct full trial
- Evaluation of results and reporting
- Develop proposals for future applications of technology
- Communications, including with affected people (with diabetes and dementia) and the general public

Health and social care IoT test beds logic model [2]

Intended outputs

- Devices & platforms used and updated (Surrey: 350 people with dementia [and 350 in control group not using device]; Digital Diabetes Coach (West of England): 12,000 people over two years)
- Production of real-time data
- Evaluation reports
- Proposals for future applications of innovations and technology

Intended outcomes

- Development of new, improved health services and/or more efficient ways of delivering the services (e.g. time/cost)
- Innovators/businesses demonstrate the value of IoT innovations to participating health service/ICT commissioners and other potential buyers
- Increased public sector awareness of the potential benefits of IoT in health and care and the goods/services available
- Improved health/outcomes for participants (service users)
- Increased self-management of conditions by participants (service users)
- Opportunities identified for IoT applications to address NHS requirements
- Improved integration between primary, secondary and social care
- Increased NHS learning capability
- Greater adoption of IoT technologies
- Development of partnerships between public and private sector organisations
- Financial / operational sustainability of the Test Beds

Intended impacts

- Increased UK reputation and competitiveness in health IoT technologies
- Enhanced citizen health and wellbeing
- Economic impacts (increased UK employment due to healthier workers; and time and cost savings for NHS)

PETRAS research hub logic model [1]

Context

- IoT offers enormous potential for improving the performance of products and services, to the benefit of buyers (including in the public sector), suppliers, and citizens
- Government and others' stated aims for UK performance and international standing for science, research and innovation
- As well as opportunities, IoT brings significant challenges, threats and risks e.g. privacy, economics, ethics, security, public trust, user acceptability
- The UK is strong in IoT research; and there is strong international competition

Rationale for intervention

- Wider rationale for government investment in science and research because the size of the scientific, innovation and technological problem is too large for individual private actors to tackle
- Markets are likely to under-provide standards, regulation and solutions
- The network nature of IoT leads to high spillovers, which lead to the private sector underinvesting in R&D
- Addressing challenges with IoT could reduce barriers to its UK development and adoption; expand or even open new markets
- Academic-led research can inform other publicly and privately-funded IoT projects and interventions
- UK has a strong research base in IoT, but there is scope to improve the wider "innovation ecosystem" – e.g. collaboration and "feedback loops" between academic researchers, industry and IoT buyers and users

Inputs

- Led by University College London, Imperial College London and seven other research institutions, with 60+ public/private/voluntary sector partners in specific projects
- Government funding (DCMS): £9.8m (2016-2018); grants from EPSRC; £13m+ cash and 'in-kind' contributions from consortium partners
- Monitoring and governance by research institutions: PETRAS Steering Board, operations group, research and user group

Activities

- PETRAS IoT Research Hub: large programme of inter-disciplinary, academic-led research
- Numerous projects (one to three years) on "cross-cutting" research themes (privacy, economics/ethics, trust, reliability, acceptability and security); and pilots of IoT applications ("use cases")
- Two 'calls' by the Hub for applications for research funding: the first to address gaps arising from initial projects; the second focusing on impact. Funds from the Hub to further projects aligned to the Hub's research themes
- Knowledge transfer activities, e.g. 'impact champion' roles and events, to assist collaboration with other IoT UK projects, engage research users and policy makers
- Activities to showcase research outputs and outcomes to a wider audience e.g. website, workshops for the public
- Activities to facilitate collaboration between projects, and internships and secondments between participating research institutions and partners

PETRAS research hub logic model [2]

Intended outputs

- At least 20 IoT "use case" pilot projects over three years; with at least two industrial / public sector / end-user partners per project
- Increased funding for research by participants in the Hub from other sources
- Published academic research papers and articles; citations of these by others
- New IoT goods, services or intellectual property developed

Intended outcomes

- Increased understanding of the opportunities and challenges from IoT
- Greater identification and influencing of solutions to opportunities, challenges and risks arising from the development and adoption of IoT applications , e.g. privacy, public trust, security, standards and interoperability, IoT "architecture", social and behavioural barriers
- Increased IoT-related research and development in the UK
- Increased collaboration between the organisations participating in PETRAS and beyond
- Increased awareness and demonstration of PETRAS issues
- PETRAS researchers' work and solutions are available to, and implemented by, policy makers
- Perceived value and relevance of pilot projects by UK and international buyers and suppliers
- Improved management and governance of IoT applications in the UK, e.g. current and potential buyers, suppliers/provider, regulators and policy makers

Intended impacts

- Enhanced reputation of UK IoT-related academic research: UK regarded as international centre of excellence
- Economic impacts (increased UK GVA, employment, productivity, cost savings, exports)
- Increased UK competitiveness within IoT markets
- Social benefits of IoT (health, environmental, social, improved service delivery)

Catapults logic model [1]

Context

- IoT offers enormous potential for improving products and services, to the benefit of consumers and suppliers, and public infrastructure
- IoT could generate c.$19 trillion for the public and private sectors globally within the next decade (source: Cisco)
- Digital Catapult (DC) and Future Cities Catapult (FCC) are two of the 11 Catapult Centres in the UK designed to help close the gap between concept and commercialisation, unlock opportunities and reduce innovation risk for innovators, entrepreneurs and SMEs
- DC helps grow UK's digital economy by rapidly advancing UK's best digital ideas to market
- FCC advances urban innovation by bringing together cities, businesses and universities to develop the solutions cities need for a strong economy, resilient environment and an improved quality of life

Rationale for intervention

- Increase the pace of development and adoption of IoT in businesses and the public sector in the UK
- There is risk and uncertainty for IoT firms and the public sector as a result of high levels of specialised technical and/or market knowledge relating to IoT
- Capability failure exists where firms lack needed skills, resources, absorptive capacity to capture the opportunities in IoT
- Institutional failure means new mechanisms are needed to coordinate, manage and focus delivery of IoT technologies, applications and services
- Potential to generate positive spillover effects – these externalities are not factored into by private providers of business support for IoT

Inputs

- Up to £4m Government (DCMS) funding over three years (summer 2015 to March 2018) - grants from Innovate UK to the Digital and Future Cities Catapults, plus 'in-kind' contributions from partners
- Digital and Future Cities Catapult staff and events, services and facilities for UK entrepreneurs and businesses in IoT
- External consultancy services selected through competitive procurement to deliver particular activities

Activities (Digital Catapult)

- Communications to raise awareness of what IoT can do for organisations and encourage adoption of IoT (e.g. case studies showing economic and social impact of IoT implementations in the UK; blogs; research and analysis on IoT activity in the UK; publications (e.g. analysis, guidance); presentations at conferences
- Activity to help accelerate and develop commercial IoT solutions for market - interventions for early stage UK firms and researchers (e.g. "Boost scheme for SMEs"; "clinics"; "thematic research days")
- Co-ordinate, communicate, support and "amplify" the overall IoT UK programme and its projects (e.g. establishing a community of interest; IoT UK website and "brand"; programme management; meetings with UK and international businesses, public sector, investors)

Activities (Future Cities Catapult)

- IoT "investment case toolkit": guidance to assist local authorities in constructing investment cases for IoT interventions
- IoT "performance in use portfolio": methodologies/ impact frameworks to measure the impact of IoT solutions in specific areas (economic, social, environmental)
- Support Manchester CityVerve; use tools and techniques developed by FCC to monitor, analyse and optimise benefits of CityVerve IoT interventions
- "Standards in use" guidance: how city authorities can assess themselves against smart city standards; role of the city council in technology R&D (e.g. demonstrator) projects; resource tool for city demonstrators; communications on the potential of IoT for cities; report on IoT adoption among cities in the UK

Catapults logic model [2]

Intended outputs

- Digital Catapult: no. of publications of different types; no. of events delivered for SMEs and other organisations; no. and types of SMEs participating in events; no. and types of SMEs supported (incl. mentoring); analysis of IoT activity published online; no. and type of presentations; growth of IoT UK community; IoT technologies developed, tested and deployed; programme management, e.g. co-ordination, reports, risk identification and management
- Future Cities Catapult: publication and operationalisation of the Performance in Use Portfolio (impact frameworks); publications of: IoT Investment Case Toolkit; resource toolkit; reports; blogs and short films; no. and types of SMEs engaged with CityVerve; IoT technology tests using CityVerve; IoT opportunities created for cities

Intended outcomes

- Increased UK awareness and R&D and investment in / adoption of IoT technologies and applications, including smart cities
- Commercialisation of IoT technology and products by SMEs
- Improved business and innovation support for IoT SMEs
- Increased trade and investment in and adoption of UK IoT solutions
- IoT UK programme achieves "more than the sum of the parts", e.g. collaboration/ knowledge-sharing between projects and participants; SME participation; opportunities for SMEs in R&D projects; communications

Intended impacts

- Increased competitiveness and global reputation for UK in IoT markets
- Economic impacts (SME growth, increased UK GVA, employment, productivity, exports)
- Wider social benefits (health, environmental, improved service delivery

Accelerator schemes [1]

Context

- IoT offers enormous potential for improving the performance of products and services, to the benefit of buyers (including in the public sector), suppliers, and citizens
- Design and manufacture costs of IoT hardware has fallen in recent years, whilst demand for hardware has increased, driven by falling costs and shift towards cloud-based applications
- The number of start-up businesses and SMEs manufacturing hardware prototypes has increased rapidly, with high demand from these firms for business and finance support, e.g. angel investment, crowdfunding
- Start-up businesses and SMEs find it challenging to get products to markets and grow

Rationale for intervention

- There is information asymmetry and uncertainty as a result of high levels of specialised technical and/or market knowledge relating to IoT hardware which limit firms' access to IoT support (finance, innovation and wider business support)
- Potential to generate positive spillover effects (e.g. network, knowledge) – these externalities are not factored into by private providers of business and innovation support services for IoT hardware businesses
- Capability failure exists where IoT hardware innovators/ firms lack the necessary skills, resources, absorptive capacity to capture opportunities to commercialise products
- Particular challenges arise for these firms between development of hardware protoype, a minimum viable product to manufacturing at scale ("valley of death")
- As a result of these failures, mechanisms are needed to coordinate, manage and focus delivery of IoT technologies, applications and services - including accelerators to help companies overcome challenges
- Incentivise provision of specialist "design to manufacture" services for IoT businesses in the UK

Inputs

- Up to £980k Government (DCMS) funding (June 2016 – March 2017) - Innovate UK procurement. Funds to be determined for possible additional schemes in 2017/18
- Cash and "in kind" contributions from two accelerators: R/GA Ventures and Startupbootcamp

Activities

- The two accelerator schemes IoT hardware businesses to participate
- Two accelerators work with selected small and medium sized IoT hardware businesses (c. 20) over several months
- 'Design-to-manufacture services' for participating IoT hardware businesses, to help them bring their products to market, including: mentoring; legal and financial advice; events (e.g. marketing; software development; hardware design & production); networking with potential business partners e.g. manufacturers, investors, customers; help with securing finance e.g. facilitating access to investors/venture capitalists; presentations by participating businesses; follow-up finance or other assistance
- Communications, e.g. websites, blogs

Accelerator schemes [2]

Intended outputs

- 20 IoT hardware businesses (SMEs) receive support from the two accelerators
- Development by these businesses of their existing prototype technology or products; and their business/investment cases
- No. and type of events and networking opportunities
- At least two participating businesses receive additional (private) funding within year one (from each accelerator)

↓

Intended outcomes

- Increased provision in the UK of “design-to-manufacture” services for IoT hardware SMEs
- Commercialisation of participating businesses’ IoT products
- Participating SMEs contribute to / benefit from the wider IoT UK programme
- Increased investment in and business growth (turnover, employment, exports) of participating SMEs
- Increased capabilities of the IoT hardware companies in the development of IoT technologies

↓

Intended impacts

- Increased UK reputation within global IoT markets as a location for IoT innovation and enterprise
- New, potentially high value UK IoT hardware businesses
- Economic impacts (increased UK GVA, employment, productivity, cost savings, exports)

3. Proposed evaluation approach and methodology

3.1 In this section we present our recommended approach and methodology for the evaluation of the IoT programme. First we summarise the indicative numbers of programme participants and beneficiaries, in order to provide context for the proposed methodology. We then set out our recommended overall approach, and then we propose the specific methods to be used for the interim and final evaluations.

Numbers of programme participants and beneficiaries

3.2 It is important to have an idea of the eventual numbers of participants and beneficiaries associated with the IoT UK programme, as this influences the selection of appropriate research tools to address the key evaluation questions. It also helps to inform the resource required to ensure sufficient coverage. Table 3-1 gives an indicative estimate of the number (and types) of participants and beneficiaries by project. This has been informed by the logic models (section 2), our review of documents, and initial information from sponsors and project leads. It should be noted that this is only an indicative picture at this stage. Aggregating across the five projects, we estimate that the numbers for the overall IoT UK programme are in the order of:

- 100-150 programme participants (taking part in one of the projects)
- 100-150 business beneficiaries (SMEs and large firms)
- 100-200 public sector and university/research organisation beneficiaries.

3.3 It is worth pointing out that the indicative estimates above are statistically 'small'. In addition, there will be potentially hundreds of citizens who will be direct beneficiaries of the programme, through outputs of particular projects. For example, Manchester CityVerve focuses on the 'Corridor Manchester'[12], an area with a workforce of 60,000 (half in knowledge-intensive sectors); and the health and social care IoT test beds aims to improve services for people with diabetes and dementia.

[12] Corridor Manchester is an Innovation District, south of Manchester city centre, running the length of Oxford Road from St Peter's Square to Whitworth Park, and West from Higher Cambridge Street to Upper Brook street in the East. See: http://www.corridormanchester.com/

Table 3-1: Estimated number of project participants and intended beneficiaries

Project	No. of participants	Indicative estimate of no. of project beneficiaries
Manchester CityVerve	• 20+ delivery partners: Manchester City Council, large businesses, SMEs, universities, transport and health authorities	• The Manchester 'Corridor' covers 243 hectares and has 60,000 workforce, of which over half are employed in knowledge-based sectors • The Corridor houses 72,000 students, and the largest clinical academic campus in Europe • 50 SMEs
Health and social care IoT test beds	• Diabetes Digital Coach (DDC) in the West of England, 20 delivery partners: ➢ Public sector: Academic Health Science Network consisting of: clinical commissioning groups (7), acute trusts (6), community providers (5), mental health trusts (2) ➢ Universities (3), charities (2), large businesses (1), SMEs (8) • Technology Integrated Health Management for people with dementia in Surrey, 20 partners: ➢ Surrey County Council, large businesses, SMEs, universities, and health authorities	• DDC: people with diabetes (c.12,000), national public sector initiatives (8), healthcare payers, healthcare providers, companies supplying IoT goods and services (numbers not available for this latter group; difficult for the project lead to estimate at this stage) • Information for the Surrey project not available at the time of this report
PETRAS	• Research teams in 9 UK universities; 60+ partners and funders in specific PETRAS projects (public sector, businesses, government)	• Not available at the time of this report
Digital Catapult and Future Cities Catapult	• Not available at the time of this report	• Not available at the time of this report
Accelerator schemes	• 2 accelerator schemes (R/GA Ventures, Startupbootcamp)	• 20 SMEs for in-depth support (2016/17) – cohort of 10 SMEs per accelerator • 5 SMEs who secure additional finance within one year of receiving the support from the accelerators • 100 SMEs engaged with the accelerators.

Source: DCMS; IoT UK component project leads; SQW

Overall approach

Challenges of evaluating the IoT programme

3.4 Evaluating the IoT programme faces a number of important challenges, which we briefly discuss below.

The programme has 'complicated' and 'complex' characteristics

3.5 The open, iterative and collaborative way in which innovation is conducted means that the benefits from policies and interventions in research, technology and innovation such as IoT UK are frequently indirect and sometimes unintended, as results are diffused through the innovation network system (Jordan, 2010)[13]. The evaluation literature emphasises that the specific characteristics of an intervention has implications for the selection of evaluation design and methods. For instance, Rogers (2008)[14] pointed out that interventions can be:

- 'simple' – standard, single component to the programme, where the cause and effect is linear and predictable
- 'complicated' – multiple components and partners to the programme; recipients get something different; works in expected ways in different contexts; multiple causality
- 'complex' – multiple partners to the programme; outcomes are emergent (cannot be pre-determined) and uncertain; cause and effect are not well defined.

3.6 We consider the IoT UK programme to exhibit both 'complicated' and 'complex' features. It has multiple components and partners to the programme (e.g. Manchester CityVerve alone has over 20 delivery consortium members delivering numerous work packages) with emergent and uncertain outcomes. The five projects can be considered relatively risky, for example with innovative research, products, services and IoT applications being developed and tested. This gives rise to a range of uncertainties which makes it difficult to accurately predict what types of outcomes will occur and when, and very difficult to accurately measure the specific contribution of the programme to any outcomes.

There are substantial lags involved

3.7 Many of the benefits arising from the programme will only be fully realised several years hence. For example, some original research initiated under the PETRAS

[13] Jordan, G. (2010) A Theory-Based Logic Model for Innovation Policy and Evaluation', Research and Evaluation, Vol.19 No.4.
[14] Rogers, P. (2008) Using Programme Theory to Evaluate Complicated and Complex Aspects of Interventions.

funding may take some years before being formally published in a peer reviewed journal, and evidence of the impacts of these publications (e.g. in terms of citations in other published work) will then take further time to emerge. Practical demonstrations of IoT applications may take several months to develop and implement in Manchester CityVerve and the health projects; quantification of the benefits of these applications may then take months or years; and the subsequent spillover benefits in terms of other locations piloting or implementing such IoT applications will also take years.

3.8 There is therefore a tension for the programme evaluation: between the need to capture relevant learning early enough to inform policy decisions in the next few years, and the need to allow enough time for the full benefits of the intervention to be realised and measurable.

The programme evaluation needs to be coordinated with project-level evaluations

3.9 Some of the projects – notably Manchester CityVerve and the health and social care test beds – involve substantial evaluation workstreams, for example in order to assess the costs and benefits of the applications demonstrated. Work on the programme evaluation will need to be coordinated with these project-level evaluation activities, to ensure that work is not duplicated, and to avoid 'evaluation fatigue' for delivery partners beneficiaries.

We need to avoid 'losing the wood for the trees' in terms of 'metrics'

3.10 In the early stages of this study we collated a long-list of over 100 metrics which could feasibly be used to track progress and evaluate the IoT programme. These were based on the suggestions from DCMS and other sponsors and several of the delivery partners, plus others from consultees. Our list included metrics for each of the five projects of the programme, plus some overall metrics applicable across most of the projects. We initially assessed these against the following criteria: appropriateness/ relevance to rationale; quantitative or qualitative; potential data sources; feasibility of data collection; feasibility of attributing changes in metric to the programme; and overall priority (in light of overall objectives).

3.11 However, it became apparent to us that proposing a long list of indicators for the IoT UK programme would be counter-productive, as this could potentially obscure the extent of progress on *what really matters*. Furthermore, as noted above, some projects will be undergoing their own evaluations and developing their own project-level KPIs/metrics. Additional/different project-level metrics tracked for the programme evaluation could potentially lead to duplication, confusion and unnecessarily onerous monitoring and evaluation research effort.

3.12 We also suggest that the word 'metric' is not a particularly helpful word for the purposes of our study, as it tends to suggest a *quantified* indicator. But *"not everything that counts can be counted… and not everything that can be counted counts"*, and in some areas it was clear that *qualitative* assessments of progress would be more meaningful than attempts to assign a number to an indicator (especially where attribution to the programme is, in practice, very difficult, due to factors discussed above). It was therefore agreed with the study steering group that we would switch our focus from a 'review of metrics' to an approach centred around the **key questions** that the programme-level evaluation needs to answer.

Key evaluation questions

3.13 We identified and agreed seven key evaluation questions for the programme, in discussion with the study steering group. These reflect the intended programme outcomes summarised in the overall programme logic model in section 2, and are therefore concentrated on the important overall benefits that the programme was intended to bring about. The evaluation questions take into account the programme initiators' and sponsors' desire for the programme overall to amount to 'more than the sum of the parts' of its five constituent projects and workstreams.

Key evaluation questions

To what extent has the programme:

- Demonstrated economically viable IoT applications, products & services?
- Led to scaling-up of IoT activity by programme participants?
- Led to replicated IoT activity beyond the programme?
- Led to additional growth in beneficiary SMEs (GVA and employment)?
- Enhanced the international reputation and attractiveness of the UK for IoT investment and activity?
- Influenced stakeholders (e.g. standards bodies, policy makers, investors) beyond the programme?
- Generated and shared learning and knowledge on IoT for programme participants?

Assessing additionality

3.14 The issue of **additionality** is at the heart of evaluation, and is relevant to each of the above evaluation questions: i.e. how much has been achieved that would otherwise not have happened in the absence of the programme?

3.15 Quantifying a **counterfactual** scenario (what would have happened otherwise) is almost always technically challenging, but is especially problematic for this programme, given the diversity of its constituent projects, the complex nature of the innovation and IoT 'ecosystem', the intended spillover benefits, the relatively modest size of the publicly-funded investment, and the time lags involved.

3.16 Our assessment of the pros and cons of three generic approaches to assessing the programme counterfactual/additionality is set out below.

Table 3-2: Approaches for assessing counterfactuals/additionality

Approach	Pros	Cons
Randomised Controlled Trials (comparing the outcomes for a randomly assigned treatment group vs those for a randomly assigned control group)	• Considered to be the 'gold standard' of evaluation, where feasible, as this provides the most convincing evidence on the net benefits that can be attributable to an intervention • Well suited to (and often used for) health-related interventions, for assessing the effects of treatments on health outcomes	• Most of the projects do not lend themselves to the RCT approach, and have not been designed as such (exception being the health and social care test beds, for which RCTs are being used for project-level evaluations of health outcomes)
Quasi-experimental methods (e.g. difference-in-difference analysis, comparing the changes in outcomes (pre- vs post-treatment) for a treatment group and a constructed control group)	• Where feasible, these approaches can provide convincing evidence on the causal effect of the intervention on the outcomes of interest • Increasingly used to assess business support-related interventions (over extended time periods)	• The majority of the funding for this programme (Manchester CityVerve and PETRAS) does not lend itself to this approach, due to the difficulty of identifying credible control groups: ➢ For CityVerve: the intervention is *supposed to* have spillover benefits for other UK cities, so using other UK cities as a control group is not sensible. UK and overseas comparator cities would have confounding factors (such as other national or local smart city programmes) ➢ For PETRAS: there is selection bias inherent in terms of the universities involved in the winning funding proposal, as these are likely to have already been particularly active on

Approach	Pros	Cons
		IoT and / or relevant areas of research. Again, there are *supposed to be* spillover benefits for the rest of the UK research base, including through collaborations with PETRAS researchers. This makes construction of a UK-based control group problematic. Overseas comparators will have confounding factors, such as their own national-level programmes • This approach is potentially viable for assessing net benefits to beneficiary SMEs, but only if the evaluation is intended to span several years – e.g. an evaluation in say 2021, of the impacts over the period 2016 to 2020. This is due to the considerable time lags in terms of measurable outcomes (and in terms of data availability on outcomes for the treatment and control groups)
Contribution analysis (see below for description)	• Feasible to do for this programme, even if the evaluation is required to report in relatively short timescales in order to inform future decision-making (e.g. by end 2018) • Builds on the logic models developed in the course of this study • Careful questioning of consultees seeks to distinguish the extent to which any outcomes can be attributed to the programme, as opposed to being the result of other factors	• Regarded as providing less robust evidence for the causal effect of an intervention than RCT or quasi-experimental approaches (when these are feasible).

Source: SQW

Our preferred approach for this programme evaluation: contribution analysis

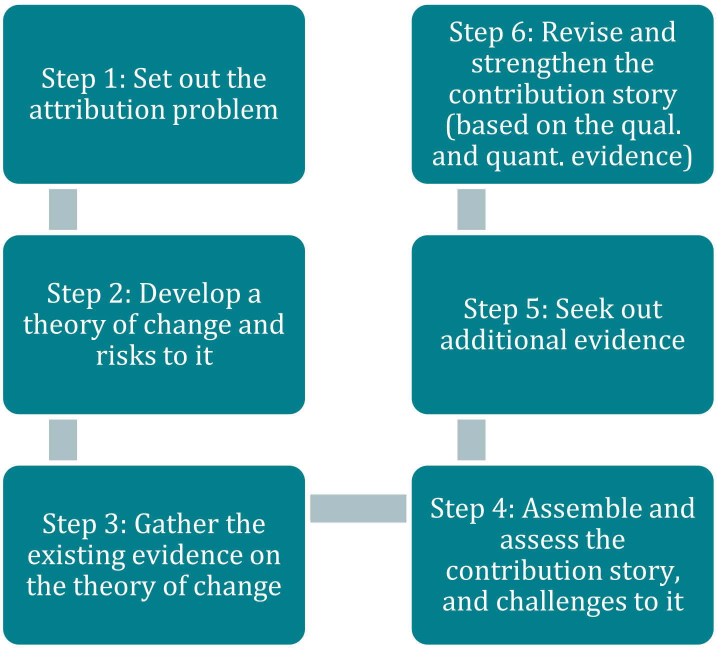
3.17 Taking into account limited evaluation resource and timescales for evaluation of government interventions, consideration needs to be given to what is timely, practical and cost-effective. Given the 'small' number of programme beneficiaries (in a statistical sense), the complicated and complex characteristics of the programme as discussed in section 2 (e.g. multi-partners, uncertain and emergent outcomes), and the pros and cons of the generic approaches discussed above, it is recommended that *theory-based* techniques to assess the cause and effect are used to assess early effects, including to understand process issues (see, for example, White and Phillips, 2012)[15].

3.18 Evaluation literature and practice indicates that theory-based approaches such as contribution analysis (CA) can be used to increase confidence that the intervention has had an impact (Befani and Mayne, 2014)[16]. Instead of examining *"what would have happened in the absence of the intervention?"*, CA asks "*is there strong evidence that the intervention – rather than other factors – was critical in causing the outcomes observed/reported?"*. It allows the evaluator to build up evidence to demonstrate the contribution made by the programme to the outcomes in question, while also identifying the other factors which may have plausibly contributed to (e.g. market opportunities, business strategy, regulations, other interventions).

3.19 In short, it develops a 'contribution story' about the influence that the intervention itself (instead of other factors) has made to observed outcomes. This is based on a six step process Mayne (2008)[17] of evidence gathering and analysis to compare an intervention's postulated theory of change to the evidence of what happened in practice (Figure 3-2). If followed correctly, this can provide an 'implicit' counterfactual for assessing an intervention.

[15] White, H., & Phillips, D. (2012) Addressing attribution of cause and effect in small n impact evaluations: towards an integrated framework, International Initiative for Impact Evaluation Working Paper 15.
[16] Befani, B. and Mayne, J. (2014) Process Tracing and Contribution Analysis: A Combined Approach to Generative Causal inference for Impact Evaluation, IDS Bulletin, Vol. 45 No. 6.
[17] Mayne, J. (2008) Contribution Analysis: An Approach to Exploring Cause and Effect, ILAC Brief 16.

Figure 3-1: Six steps of contribution analysis



Source: Mayne (2008)

3.20 A plausible association can be made if the following are satisfied: a reasoned theory of change is set out; the intervention's activities have been implemented as articulated in the theory of change; the sequence of expected results can be shown to have occurred; and other influencing factors have shown not to have made a difference.

3.21 In practice, the evidence gathered for contribution analysis can come from various research methods, including: analysis of monitoring information, analysis of secondary data, stakeholder consultations, beneficiary surveys and case studies. The proposed research methods are discussed below.

Research methods

3.22 Having formulated the key evaluation questions (summarised above in the box after paragraph 3.13), we considered how best to answer each one through evaluation.

3.23 In general, our consultees suggested, and we agree, that the programme evaluation's emphasis ought to be on *qualitative* methods, and focus on outcomes and impacts (rather than outputs). This partly reflected the nature of the individual projects, and what was considered most practical for evaluation. Table 3-3 sets out the key evaluation questions and proposes how each one can best be answered.

Table 3-3: Key evaluation questions for IoT UK and summary of how best to answer these

To what extent has the programme…	How best to answer through evaluation	Proposed research methods
Demonstrated economically viable IoT applications, products and services?	• Identify which (if any) IoT applications have been proved by the programme to be economically viable • Estimate the proportion of programme (fully allocated) spend on these	• Stakeholder consultations with participants • Case studies on any applications demonstrated to be economically viable • Analysis of monitoring data (on programme expenditure)
Led to scaling-up of IoT activity by programme participants?	• Through qualitative research with participants, identify which, if any, of the activities funded by the programme have been scaled-up (through additional non-IoT UK funds) by participants, as a result of the programme's initial funding • Quantify the extent of scaling up, using the measures most applicable to those specific activities (e.g. additional connected infrastructure and services, additional IoT researchers)	• Stakeholder consultations with participants • Case studies on any scaled-up IoT activity by participants • Analysis of monitoring data (on outputs relevant to the scaled-up activities)
Led to replicated IoT activity beyond the programme?	• Through qualitative research with participants, identify which, if any, of the activities funded by the programme have led to replicated activity elsewhere, funded and implemented by non-participants • Quantify the extent of this, using the measures most applicable to those specific activities	• Stakeholder consultations with participants • Case studies on any replicated IoT activity by non-participants • Analysis of monitoring data (on outputs relevant to the replicated activities)
Led to additional growth in beneficiary SMEs (GVA and employment)?	• Assess this through a programme-level survey of all SME participants and beneficiaries (e.g. improved employment and turnover) • Programme-level in order to avoid double-counting, and to ensure that consistent questions are asked across projects, and to assess value to SMEs of any cross-project interactions • Consider econometric approaches if the number of observations is large enough	• Telephone survey of SME beneficiaries • Case studies of specific SME beneficiaries • Analysis of monitoring data (SME beneficiary database)

To what extent has the programme…	How best to answer through evaluation	Proposed research methods
	(data linking and comparing versus matched non-beneficiaries), and if DCMS intends to commit to a longer-term evaluation (e.g. reporting in 2021)	
Enhanced the international reputation and attractiveness of the UK for IoT investment and activity?	• Assess this through qualitative research with participants and non-participants e.g. large multinational corporations (MNC), venture capitalists, plus three quantitative measures: ➢ Through the programme-level survey of SME beneficiaries, the attributable GVA growth associated with overseas exports ➢ Through interviews with IoT-active large MNCs and venture capitalists, especially those with an existing presence in the UK, the extent to which they perceive that the programme has enhanced the UK's reputation and attractiveness for IoT, and any attributable additional UK-based activity (e.g. inward investment) ➢ Attributable additional non-UK IoT researchers at PETRAS universities • Provide context for this assessment through an update and expansion of the baseline indicators for the UK vs international comparators presented in Annex B.	• Stakeholder consultations with participants • Stakeholder consultations with large multinational (IoT-active) non-participants • Telephone survey of SME beneficiaries • Analysis of secondary data: IoT-active researchers at PETRAS universities • Analysis of secondary data for context: ➢ updating the readily replicated baseline indicators presented in Annex B (from Google Trends, LinkedIn, itjobswatch) ➢ bibliometric analysis of the UK's (and PETRAS's) share of IoT articles, citations, and highly cited articles, by year ➢ analysis of UK's share of IoT patenting activity (updating the IPO's analysis of 2014) - DCMS could ask the Intellectual Property Office to refresh their 2014 report 'Eight Great Technologies: The Internet of Things - A Patent Overview'
Influenced stakeholders (e.g. standards fora, policy makers) beyond the programme?	• Assess this through qualitative research with participants and relevant non-participant stakeholders.	• Stakeholder consultations with participants • Stakeholder consultations with non-participants e.g.: relevant Government departments; Intellectual Property Office; local authorities; techUK; Tech City UK; British Standards Institution; other relevant

To what extent has the programme…	How best to answer through evaluation	Proposed research methods
		organisations in transport, health, security.
Generated and shared learning and knowledge on IoT for programme participants?	• Cannot be fully reflected through quantitative metrics • Assess through qualitative research with programme participants • Supplemented with headline quantified indicators from the PETRAS project: bibliometric stats on published papers of participating researchers	• Stakeholder consultations • Analysis of monitoring data and secondary data (on PETRAS publications and citations)

Source: SQW

3.24 Figure 3-2 summarises the proposed research methods, in general terms.

Figure 3-2: Summary of proposed research methods

Analysis of monitoring data	•To assess progress against the programme's outputs, and profile beneficiaries and participants
Analysis of secondary data	•To provide context for the evaluation's assessment on the extent of the programme's outcomes and impacts
Stakeholder consultations	•To obtain views from stakeholders on the progress of the programme, processes of implementation, perceived benefits attributable to the programme, and lessons learned
Telephone survey of beneficiaries	• To obtain feedback from targeted beneficiaries (e.g. SMEs) on their experiences of the programme's activities and benefits
Case studies	•To conduct further in-depth analysis with a small number of beneficiaries/activities, describing any benefits and exploring the extent to which these can be attributable to the programme

Source: SQW

3.25 We suggest that the programme evaluation should be conducted in two phases:

- A 'light touch' interim evaluation in mid 2017 (calendar year), to develop an initial view on the extent to which the programme is meeting its intended outputs and outcomes.
- A final evaluation in the second half of 2018/early 2019 (calendar year), to provide a more informed picture of the benefits attributable to the programme as it reaches its conclusion.

3.26 Bearing in mind the timings of these phases, we suggest that the interim evaluation need not undertake resource-intensive secondary data analysis, nor surveys of beneficiaries. The mapping of research methods to the evaluation phases is therefore as shown in the table below.

Table 3-4: Summary of research methods per programme evaluation phase

	Interim evaluation	Final evaluation
Analysis of monitoring data	Yes	Yes
Analysis of secondary data		Yes
Stakeholder consultations	Yes	Yes
Telephone survey of beneficiaries		Yes
Case studies	Yes	Yes

Source: SQW

3.27 It is worth mentioning here that we do not consider it necessary or appropriate to measure the size and value of the UK 'IoT sector'. The markets are far too broad for a meaningful and cost-effective survey of the 'IoT market' as a whole; there are no straightforward set of Office for National Statistics (standard industrial classification – SIC) codes to analyse; and no widely accepted metrics for the state of IoT development, activity and adoption. Even if such work was undertaken, the high levels of churn and pace of developments would make it very difficult to construct a comparable cross-section of respondents at a given point in the future.

3.28 More specific details on the proposed methods for the interim and final evaluations are presented in the following sub-sections.

Interim evaluation

3.29 The interim evaluation will need to assess the overall programme using a formative (i.e. process) approach to evaluation, focusing on *how* the programme is actually being delivered in practice - identifying what does and does not work well, and why – drawing out lessons for future delivery of the programme, and for future government-funded research and innovation projects.

3.30 In addition, the interim evaluation will also need to evidence early assessment of progress towards outcomes by the programme. To achieve this, we propose mixed set of research methods for this evaluation phase: analysis of monitoring data, stakeholder consultations, and beneficiary case studies (covering a mix of qualitative and quantitative information). The results from these should be triangulated and brought together using contribution analysis to test the extent to which early outcomes/changes in behaviour are as a result of the programme.

Analysis of monitoring data

3.31 The monitoring for the IoT UK programme involves the leads for each project reporting to Innovate UK on a quarterly basis on technical, business and finance areas (essentially reporting progress against project delivery plans)[18]. In turn, Innovate UK provides DCMS with written updates on progress for each project every quarter. These include achieved and future milestones, project issues and risks, and financial forecasts etc. It will be helpful for the future evaluator if these year-end summaries were also made available. Importantly, the analysis will need to help to inform progress against the key evaluation questions identified in Table 3-3.

3.32 The interim evaluation's analysis of monitoring data should focus on the period from programme start to March 2017, and should include:

- actual and expected inputs (financial)
- achievement versus target of key project output measures, identifying reasons for any under (or over) performance
- any outcome/impact measures gathered by the projects: in particular, the information on publications, citations and impact maintained by the PETRAS project on Researchfish and its own impact database
- profiles of the various participants and beneficiaries to date (including a breakdown by sector, firm size, geography, nature of involvement etc.)
- summaries of any research and analyses already undertaken for project-level evaluations, including the key findings of any participant/beneficiary surveys.

Stakeholder consultations

3.33 For the interim evaluation, we suggest undertaking approximately 30-35 qualitative consultations with organisations participating in the programme, as shown in Table 3-5.

Table 3-5: Interim evaluation – proposed stakeholder consultations

Project	Approximate number of consultations
Manchester CityVerve	• 6-8 organisations: City Council, universities, participating businesses (large and SMEs), other public authorities (transport and health)
Health and social care IoT test beds	• 6-8 organisations: lead organisations (NHS) from the West of England and Surrey, plus partners (public and private)

[18] For the PETRAS project, monitoring reporting is to EPSRC who in turn report to Innovate UK and DCMS.

Project	Approximate number of consultations
PETRAS	• 6-8 organisations: lead universities, plus research project partners (public and private)
Digital Catapult and Future Cities Catapult	• 5 organisations: Digital Catapult and Future Cities Catapult, plus other delivery partners
Accelerator schemes	• 2 organisations: accelerators R/GA and Startupbootcamp
Programme sponsors	• 5 organisations: DCMS, Innovate UK, EPSRC, NHS England, Office for Life Sciences.

Source: SQW

3.34 We suggest that these consultations could be a mix of face-to-face and telephone discussions. The purpose would be to capture perceptions on the extent to which the programme has addressed each of the key evaluation questions identified in Table 3-3, and to gather views on the processes of delivery (including linkages between the different component projects), activities, any early signs of outcomes for beneficiaries, and the overall lessons learned. The consultations will also provide an opportunity to gather any data which stakeholders may hold.

Case studies

3.35 For this phase of the evaluation, it would be helpful to obtain an initial view on the extent to which the intended benefits are actually being realised, based on direct feedback from beneficiaries. Rather than proposing an extensive survey at this stage (when it will arguably be too early for most beneficiaries to comment on the benefits), we suggest developing a few (six to ten) case studies, focusing on SMEs engaged in the programme.

3.36 In selecting such cases, consideration ought to be given to a number of factors including: project, level and type of involvement, firm size, sector, and geography. If possible, it would be helpful for some of these case studies to include SMEs which have been engaged in more than one of the programme's projects, in order to gain some insights into inter-project synergies and issues.

3.37 The focus of these case studies would be on gathering insights into the experiences of a few SME beneficiaries to date, including their motivations for being involved, activities undertaken, delivery process, and any benefits as result of the programme to date, and those expected in the future. This information should help to provide feedback on the 'customer journey' to complement the views of stakeholders, and could potentially identify opportunities for improving the way in which the programme is delivered.

Final evaluation

3.38 We suggest that the final evaluation should be undertaken in the second half of 2018.

3.39 It should be noted that, even in late 2018, it will still be a relatively short period of time for tangible outcomes and impacts to have been realised since the programme was operationalised. Many of the programme's benefits are still likely to remain in the future, as yet. However, in order to capture as good a view as possible at this stage of the benefits to date, and those anticipated in the future, we propose a research programme involving:

- analysis of monitoring data
- analysis of secondary data
- stakeholder consultations with participants and non-participants
- telephone interviews with beneficiaries
- case studies.

Analysis of monitoring data

3.40 The analysis of monitoring data for the final evaluation should update the equivalent analysis undertaken for the interim evaluation, using data for the period up to September 2018.

3.41 Additionally, for any IoT activities identified by stakeholders as being scaled up as a result of the programme, or replicated beyond the programme (for example in other UK cities, as a result of seeing the work of the Manchester CityVerve demonstrator), this task would seek to quantify the extent of such activities.

Analysis of secondary data

3.42 By the time of the final evaluation, we suggest that it would also be worth revisiting an analysis of relevant secondary data, in order to provide context for the evaluation: to see what, if any, differences in the UK's relative position in IoT can be observed. This will not necessarily be able to definitively attribute any observed differences to the programme, but it will inform the contribution analysis.

3.43 We suggest that this analysis could involve:

- updating the readily replicated indicators presented in Annex B (from Google Trends, LinkedIn, itjobswatch), and comparing them to the baseline position
- bibliometric analysis of the UK's (and PETRAS universities') share of IoT articles, citations, and highly cited articles, by year
- analysis of UK's share of IoT patenting activity.

3.44 We envisage the bibliometric analysis going well beyond the partial picture presented in Annex B, using a comprehensive commercial bibliometric database such as Clarivate Analytics' (formerly Thomson Reuters') Web of Science, or Elsevier's SciVal (based on Scopus). A specific research area could be defined for such an analysis, based on the keyword 'Internet of Things' and potentially other relevant keywords. Such an analysis would complement the information on research directly generated through the programme, from Researchfish and PETRAS's own impact database, as it would provide the broader context of the UK's (and PETRAS universities') relative performance in this area over time.

3.45 The analysis of IoT patenting activity would replicate the methodology used by the Intellectual Property Office in 2014, using the latest available data. At the time of the final evaluation, it would be helpful for DCMS to ask the Intellectual Property Office to refresh their 2014 report 'Eight Great Technologies: The Internet of Things - A Patent Overview'.

Stakeholder consultations

Stakeholder consultations with programme participants

3.46 We suggest that the final evaluation should include approximately 50-60 qualitative consultations with organisations which have directly participated in the programme, as shown in Table 3-6.

Table 3-6: Final evaluation – participant stakeholder consultations

Project	Approximate number of consultations
Manchester CityVerve	• 15 organisations: City Council, universities, participating businesses (large and SMEs), other public authorities (transport and health)
Health and social care IoT test beds	• 10 organisations: lead organisation (NHS) from the West of England and Surrey, plus partners (public and private)
PETRAS	• 15 organisations: lead universities (9), plus research project partners (public and private)

Project	Approximate number of consultations
Digital Catapult and Future Cities Catapult	• 10 organisations: Digital Catapult and Future Cities Catapult, plus other delivery partners
Accelerator schemes	• 5 organisations: accelerators and related delivery partners
Programme sponsors	• 5 organisations: DCMS, Innovate UK, EPSRC, NHS England, Office for Life Sciences.

Source: SQW

3.47 These consultations could be a mix of face-to-face and telephone discussions. For the face-to-face interviews, it would be worth exploring (where appropriate) if some of these can be conducted as group sessions (e.g. 2 to 4 individuals from the same, or even different organisations in the same session). Aside from being efficient, it may help to get a more rounded or balanced perspective bearing in mind some of the complicated and complex characteristics of the programme.

3.48 The consultations would be focused on capturing views on the progress towards the key evaluation question set out in Table 3-3. In addressing these, it would be useful to re-visit the programme's logic model to explore if and how the activities followed through to the outputs, outcomes and impacts as originally postulated. Importantly, based on the CA approach discussed earlier in this section, it will be important to explicitly set out and discuss any other *relevant* factors (e.g. economic environment, market opportunities, regulations, other interventions) which could feasibly have contributed to the observed outcomes and impacts.

Stakeholder consultations with non-participants

3.49 In addition, we suggest that the final evaluation should also include approximately 10 to 20 consultations with relevant organisations which have not themselves directly participated in the programme's activities, but which would have informed perspectives on the extent to the programme's wider outcomes.

3.50 We suggest these consultations primarily focus on three key evaluation questions - to what extent has the programme:

- led to replicated IoT activity beyond the programme?
- influenced stakeholders beyond the programme?
- enhanced the international reputation and attractiveness of the UK for IoT investment and activity?

3.51 Relevant non-participants will have to be identified through discussions with the programme and project leads. Given the catalytic nature of the programme, there should be various non-participating stakeholders who have come across the programme through their relationships or interactions with the lead organisations. For example, other cities (councils) may have expressed interest in learning about the work of Manchester CityVerve; or wider NHS policy may have been shaped by the experience of the health and social care test beds. Relevant trade associations such as Tech UK would also be able to offer their perspectives on the programme.

3.52 For the key evaluation question relating to the international reputation and attractiveness of the UK for IoT investment and activity, we suggest seeking consultations with IoT-active large MNCs with a presence in the UK, exploring their perceptions of the UK's relative position in IoT, the extent to which they perceive that the programme has enhanced the UK's reputation and attractiveness for IoT, and any attributable additional UK-based activity (inward investment).

Telephone survey of SME beneficiaries

3.53 About three years since the start of the programme, it should be possible for the final evaluation to obtain views from a wider sample of SME beneficiaries on the benefits observed as a result of participation in the programme (including estimates of employment and GVA impacts).

3.54 As above, the beneficiary interviews should also explore other relevant factors which could feasibly have contributed to the same outcomes and impacts.

3.55 It is not clear exactly how many beneficiaries there will be by the end of the programme, but based on current information we envisage around 100 to 150 business beneficiaries. Based on this estimate, we would suggest seeking telephone interviews with approximately 30 to 50 SMEs, lasting about 30 minutes per interview.

Case studies

3.56 To provide further qualitative insights into how the programme has led to specific benefits, we suggest that the final evaluation should include about 10 to 15 case studies, informed by face-to-face discussions with relevant parties.

3.57 The selection of such case studies will need to be undertaken in discussion with the programme and project leads, but may include:

- examples of specific scaling-up of IoT activity in participating organisations, attributable to the programme
- examples of IoT activity replicated beyond the programme

- examples of IoT applications proved to be economically viable by the programme
- SME beneficiaries for each of the five projects
- public sector beneficiaries
- examples of how the programme's activities have influenced stakeholders beyond the programme.

3.58 The point of such case studies is to provide insight into how the programme has generated benefits, so they will tend to be the leading examples of the programme's success stories.

4. Evaluation management

Governance and management

4.1 The monitoring and evaluation of the IoT UK programme should be overseen by its sponsors, advised by the IoT UK Programme Board. At operational level, we would suggest establishing a small evaluation steering group - reporting to the programme sponsors - consisting of the programme lead, a DCMS economist, representatives of other sponsors, and from each of the five projects.

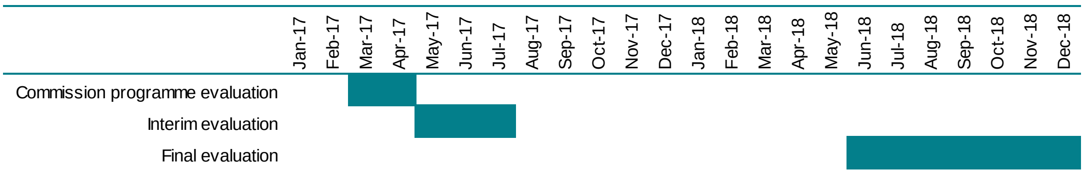
4.2 The evaluation steering group would be responsible for reviewing and approving the programme evaluation plans, research tools and deliverables. It would also coordinate the various programme-level and project-level evaluation activities, in order to minimise duplication of effort and research burden on delivery partners and beneficiaries, and to help share evaluation learning and good practice between strands. For example, (i) the project leads could notify and share information with and/or seek approval from the evaluation steering group on the timing and nature of project-level evaluation activities; and (ii) a programme wide database of beneficiary contacts could be developed[19], subject to any data confidentiality/transfer issues.

4.3 The programme evaluation should, in our view, be undertaken by experts separate from the programme delivery partners/sponsors, in order to ensure that the findings are – and are seen to be – entirely objective. This work could either be resourced internally by DCMS, or commissioned from an appropriate external services provider. For an initiative of this importance and profile, an external evaluation would normally be commissioned.

Timescales

4.4 The proposed timescales for the interim and final evaluation are summarised in the Gantt chart below.

Figure 4-1: Proposed programme-level evaluation timescales



Source: SQW

4.5 The bulk of the work for the interim evaluation in 2017 should be scheduled for May to July 2017. By this time, the IoT UK programme will be about half way

[19] Including record of any approach for project-level evaluation activities.

through its operations which should allow sufficient evidence to be collected on the process issues i.e. focusing on how the programme is being delivered as described in section 3 above.

4.6 The work for the final evaluation will take longer, and we would suggest planning for this to occur between June 2018 and December 2018[20]. As the IoT UK programme is expected to end by late 2018, it makes sense to plan the evaluation during the dates proposed above in order to ensure the level and quality of the engagement with the evaluation by delivery teams, stakeholders and most importantly beneficiaries (though primary research) is maximised. To be clear, the proposed timings are consistent across the five constituent projects of the IoT UK programme.

4.7 It would be best to commission both stages of the evaluation from the same supplier, in order to ensure consistency of approach – with an option for a contract break point after the first phase.

Budget

4.8 Our recommended approach is designed to allow the programme evaluation to generate robust evidence on progress and benefits, while minimising the research burden for beneficiaries and for the delivery teams. It also takes into account that substantial project-level evaluation activities are already planned or underway for Manchester CityVerve and the health test beds. We would suggest allowing for an amount in the order of £100k to cover the programme-level evaluation costs: c. £35k for the interim evaluation in 2017, and £65k for the final evaluation in 2018.

[20] Whilst recognising that evaluation report may run/get finalised in first quarter of 2019.

Annex A: List of consultees

A.1 We are very grateful to Helen Mainstone and Jose Seisdedos of DCMS for steering this assignment, and to the following other people consulted in the course of our study.

Table A-1: List of consultees

Consultee	Organisation	IoT programme aspect
Alberto Garcia Mogollon	British Standard Institute	Catapults
Arun Chinnaraj	NHS England	NHS Test Beds
Awais Rashid	Lancaster University	PETRAS
Ben Hawes	Department for Culture Media & Sport	Manchester CityVerve
Caroline Gorski	Digital Catapult	Catapults
Dan Hodges	Innovate UK	Overall programme
David Dowe	Previously at Digital Catapult	Catapults
Elizabeth Dymond	West of England Academic Health Service	NHS Test Beds
Emil C Lupu	Imperial College London	PETRAS
Emily Hough	NHS England	NHS Test Beds
Finlay Kelly	Future Cities Catapult	Catapults; Manchester CityVerve
Graca Carvalho	University College London	PETRAS
Halil Uzuner	Imperial College London	PETRAS
Jean-Francois Fava Verde	Innovate UK	Manchester CityVerve; Accelerators
Jeremy Watson	University College London	PETRAS
Jessica Rushworth	Digital Catapult	Catapults
John G Baird	EPSRC	PETRAS
John Rigby	University of Manchester	Manchester CityVerve
Jonny Voon	Innovate UK	Manchester CityVerve; Accelerators
Li Yao	Sparta Digital (SME)	Manchester CityVerve
Madeline Carr	Cardiff University	PETRAS
Mark Nassar	Office for Life Sciences	NHS Test Beds
Matthew Evans	Tech UK	Overall programme
Matthew Fox	Future Cities Catapult	Catapults

Consultee	Organisation	IoT programme aspect
Mike Short	Telefonica	PETRAS
Nick Chrissos	Cisco	Manchester CityVerve
Nigel Davies	Lancaster University	PETRAS
Rachel Cooper	Lancaster University	PETRAS
Stephen Browning	Innovate UK	Manchester CityVerve; Accelerators
Steve Turner	Arup (formerly Manchester City Council)	Manchester CityVerve
Tim McGarr	British Standard Institute	Catapults
Vin Sumner	Click and Links (SME)	Manchester CityVerve

Annex B: Baseline indicators

B.1 Given the broadness and fuzziness of the Internet of Things arena, there are no widely-accepted metrics for the state of IoT development, activity and adoption as such. We do not have a straightforward set of SIC codes to analyse, for example.

B.2 However, we can obtain some insight into the UK's relative position through the use of unconventional datasets. None of these provide a completely accurate or comprehensive picture of the state of the IoT; but, in combination, they provide a reasonable sense of where the UK currently is placed relative to other countries.

B.3 In the sections below, we present data on:

- IoT relative search frequency
- IoT LinkedIn membership
- IoT job ads
- IoT patenting activity
- IoT journal articles.

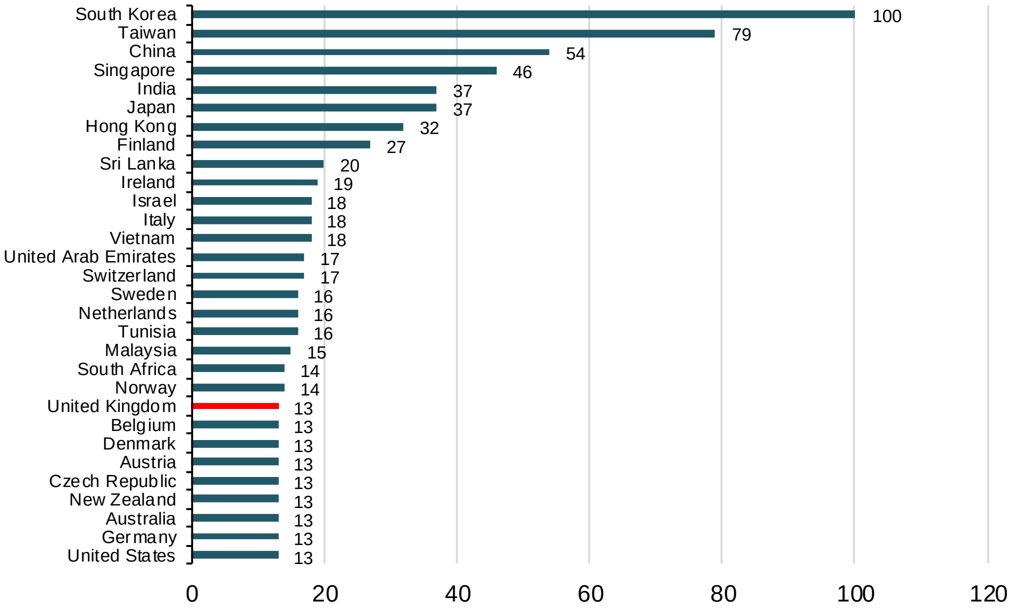
IoT relative search frequency

B.4 One measure of the level of interest and activity in IoT in different countries is the extent to which people are searching for information about IoT on the web. The Google Trends tool (www.google.com/trends) is useful for this, as it presents information on the relative search frequencies over time.

B.5 This tool normalises to 100, such that the relative search frequency peaks at a value of 100 in the chosen period for the selected terms/topics. By specifying the query in terms of Google's 'topics' rather than specific search terms, our data captures searches in any language supported by Google: search terms are language specific, whereas topics are not.

B.6 A comparison of the share of searches on Google associated with the Internet of Things topic (Figure B-1) suggests that South Korea has had the largest share of Google searches related to IoT over the last five years, with an index of 100. Several other Asian countries follow (Taiwan, China, Singapore, India, Japan, Hong Kong), with Finland appearing to be the Western country with the highest relative search frequency for IoT, with an index of 27. The UK's index is 13, alongside countries such as Australia, Germany and the United States. This means that the Internet of Things topic share of all Google searches in South Korea has been 7.7 times that in the UK (100/13) over the last five years.

Figure B-1: Relative search frequency on Google for the Internet of Things topic over the last 5 years, by country (normalised to a maximum of 100)



Source: Google Trends

B.7 However, the above relative shares of searches (for IoT) may be skewed by different stages of country development (extent of internet penetration) and/or by differences in market share for Google's search engine. For example, the segment of the South Korea population using Google (rather than Naver) may be more technically-minded than the overall population of internet users in South Korea.

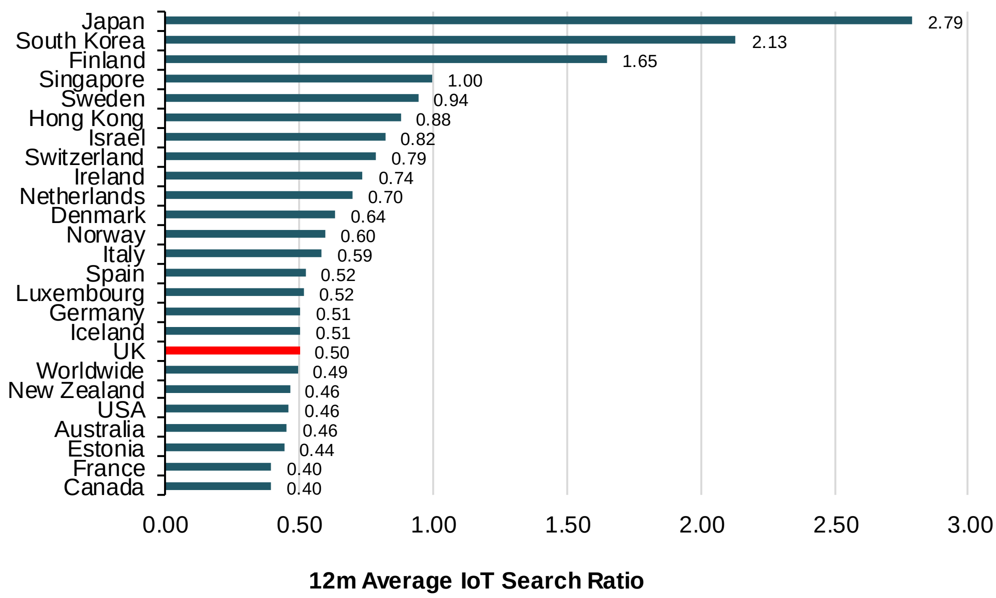
B.8 To attempt to adjust for this, relative search frequencies have been compared for selected countries, between two 'topics' on Google Trends: Internet of Things, and Computer Hardware. For each country, the index is normalised to show 100 for the peak search frequency in the period (across the two terms). Including the generic Computer Hardware topic as a denominator allows us to make more meaningful comparisons between countries (how much more/less IoT was searched for relative to searches re computer hardware, in each country).

B.9 Our 'IoT Search Ratio' metric is the IoT search frequency index divided by the Computer Hardware search frequency index in each month.

B.10 Averaged over the last 12 months, this measure paints a somewhat different picture, with Japan appearing to be the most IoT-interested country over the last year, though South Korea and Finland also show up strongly (Figure B-2). The UK is broadly in line with the worldwide average: its IoT Search Ratio of 0.50 indicates that the Internet of Things topic was searched for about half as much as the Computer Hardware topic over that period in the UK.

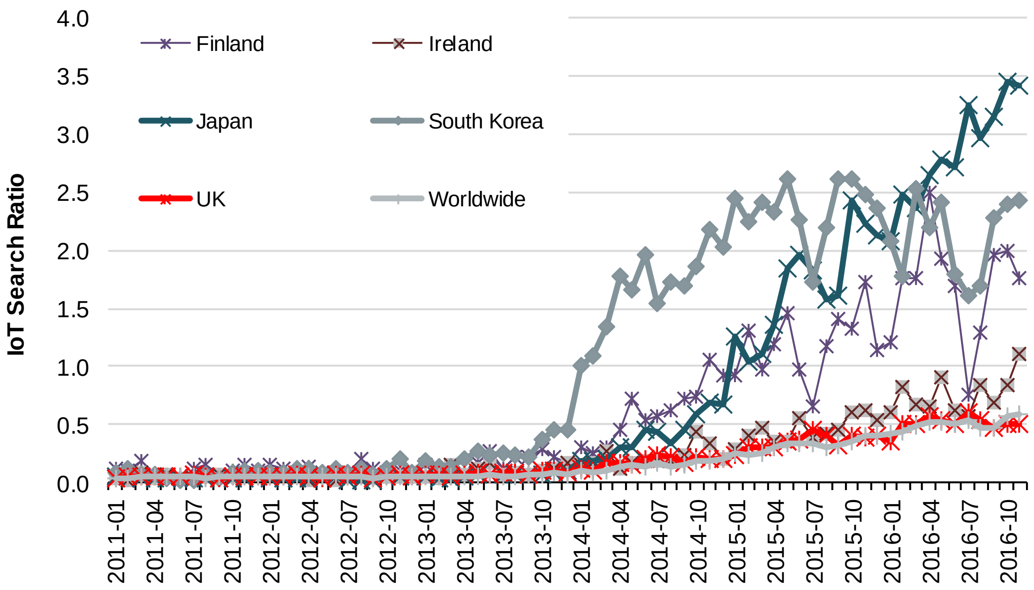
B.11 Plotting this ratio over time for selected countries (Figure B-3) illustrates how the interest in IoT 'took off' at different times in different parts of the world: South Korea, then Finland, then Japan.

Figure B-2: Average 'IoT Search Ratio' over the period December 2015 to November 2016, for selected countries (ratio of searches related to the Internet of Things topic divided by searches related to the Computer Hardware topic on Google)



Source: SQW analysis of data from Google Trends

Figure B-3: 'IoT Search Ratio' over time, for selected countries (ratio of searches related to the Internet of Things topic divided by searches related to the Computer Hardware topic on Google)



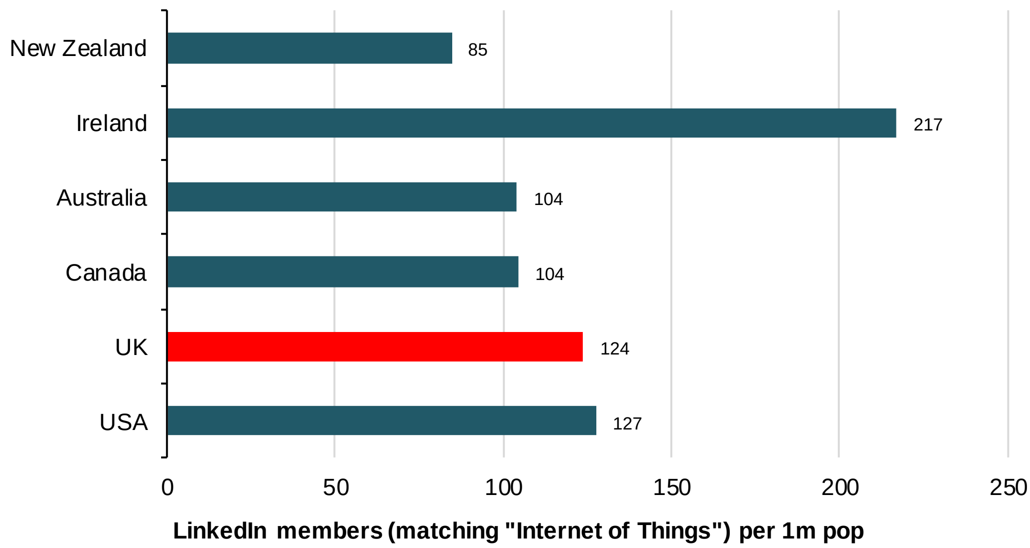
Source: SQW analysis of data from Google Trends

IoT LinkedIn membership

B.12 The social networking tool LinkedIn is another source of interesting data. By searching on relevant terms, we can observe how many LinkedIn members have profiles which mention those terms. The most obvious (and widely used) relevant term here is 'internet of things'. This currently (December 2016) returns about 8k LinkedIn members within the UK, versus 43k members in the United States.

B.13 Comparing the ratio of LinkedIn members returned by this search to the total population for the major English-speaking countries (remembering that these LinkedIn searches are language specific), we find that the UK (124 matching LinkedIn members per 1 million people) is broadly in line with the United States (127). It is striking, however, that Ireland's ratio (217) is much higher than that observed for the UK: an observation which would align with the findings above re the relative search frequencies for IoT in Ireland and the UK.

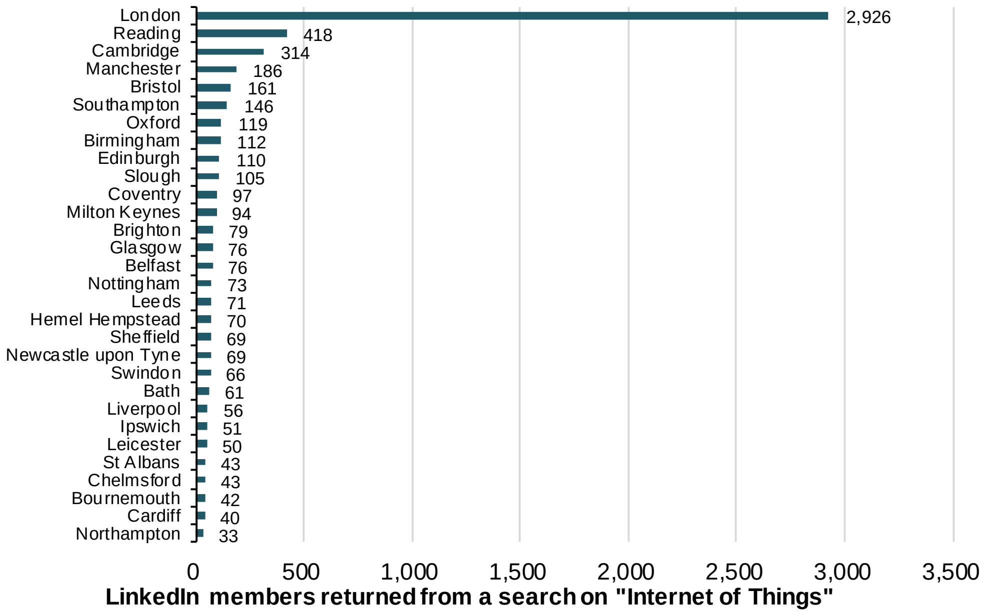
Figure B-4: LinkedIn members matching the search term "Internet of Things", per 1 million population



Source: SQW analysis of LinkedIn data, December 2016, and UN World Population Prospects estimate for 2016 populations

B.14 Drilling down into the data on LinkedIn members based in the UK, Figure B-5 emphasises the dominance of London, with 2.9k of the UK's 8.1k LinkedIn members matching the term "Internet of Things'. The next most important locations for IoT-related people appear to be Reading, Cambridge, Manchester and Bristol – though it should be remembered that breakdowns by sub-national geographic locations on LinkedIn are fairly crude ('Manchester' will not include everyone in the Greater Manchester area, for example).

Figure B-5: LinkedIn members matching the search term "Internet of Things", for selected UK locations



Source: SQW analysis of LinkedIn data, December 2016

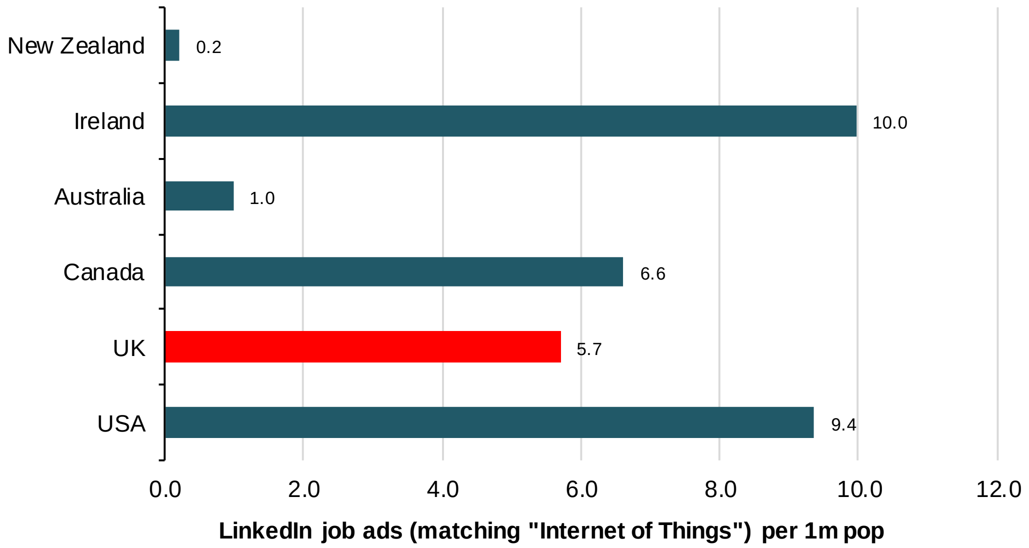
IoT job ads

B.15 Job adverts are another indication of activity in the IoT arena. We have looked at two data sources here: LinkedIn and itjobswatch.co.uk.

B.16 Taking a similar approach to that described above, for the major English-speaking countries, we find (Figure B-6) that the UK again has many fewer LinkedIn job ads matching 'Internet of Things' (5.7 per 1 million population) than is the case in Ireland (10.0).

B.17 By this measure, the United States (9.4) and Canada (6.6) are also well ahead of the UK. This could *potentially* be an indication of greater hiring activity in IoT in Ireland, the US and Canada than there currently is in the UK. However, an alternative explanation is that employers in these countries may have a greater propensity to use LinkedIn for advertising vacancies than their counterparts in the UK.

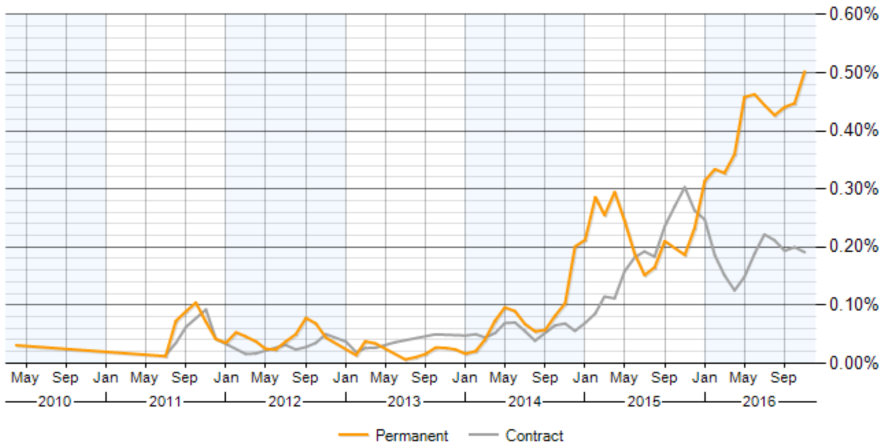
Figure B-6: LinkedIn job ads matching the search term "Internet of Things", per 1 million population



Source: SQW analysis of LinkedIn data, December 2016, and UN World Population Prospects estimate for 2016 populations

B.18 Time series data on IoT hiring activity in the UK can be found on itjobswatch.co.uk. This website aims to 'present a concise and accurate map of the prevailing UK IT job market conditions' using data sourced from IT recruitment services. Figure B-7 below shows that about 0.5% of latest IT job ads in the website's Miscellaneous category[21] cite Internet of Things (or IoT): still a relatively low proportion of advertised IT jobs, but dramatically up from about 0.1% over the last two years.

Figure B-7: Job ads citing Internet of Things (or IoT) as a proportion of all IT jobs with a match in the Miscellaneous category



Source: itjobswatch.co.uk

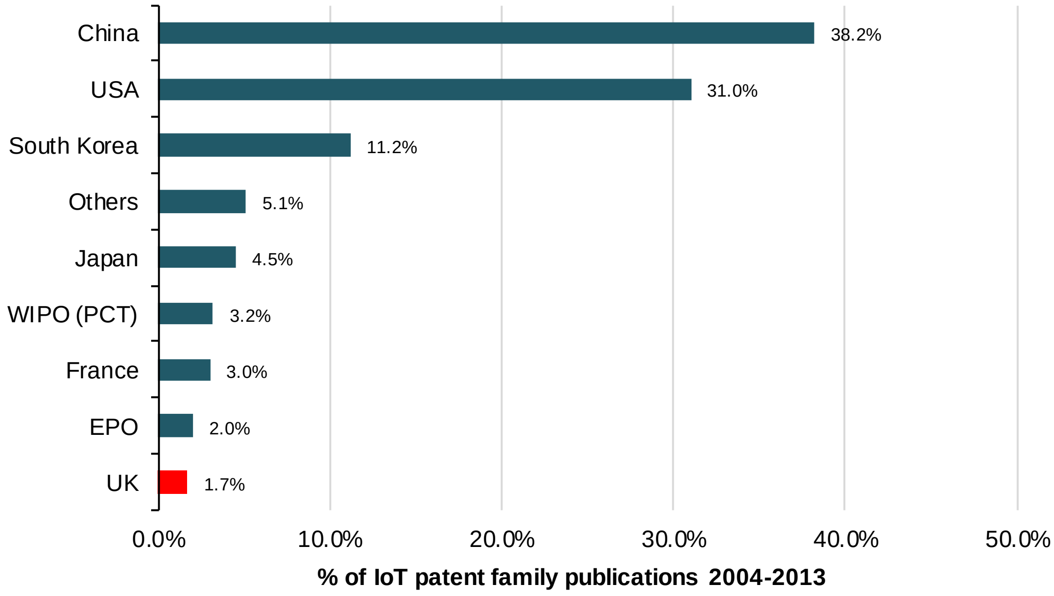
[21] The Miscellaneous category accounts for c 40% of advertised IT jobs

IoT patenting activity

B.19 The UK's Intellectual Property Office undertook a comprehensive analysis of patenting activity related to IoT in 2014. Repeating that analysis is beyond the scope of this study, but it is helpful to recap some of their key findings from 2014.

B.20 On a pure volume basis, Figure B-8 emphasises the dominance of China, the United States, South Korea and Japan in terms of IoT patenting. The UK accounted for 1.7% of the c. 10k IoT patent family publications over the 2004 to 2013 period analysed.

Figure B-8: Proportion of patent family publications per priority country (country in which the patent family was first filed)[22]



Source: UK Intellectual Property Office, 2014, Eight Great Technologies: The Internet of Things - A Patent Overview

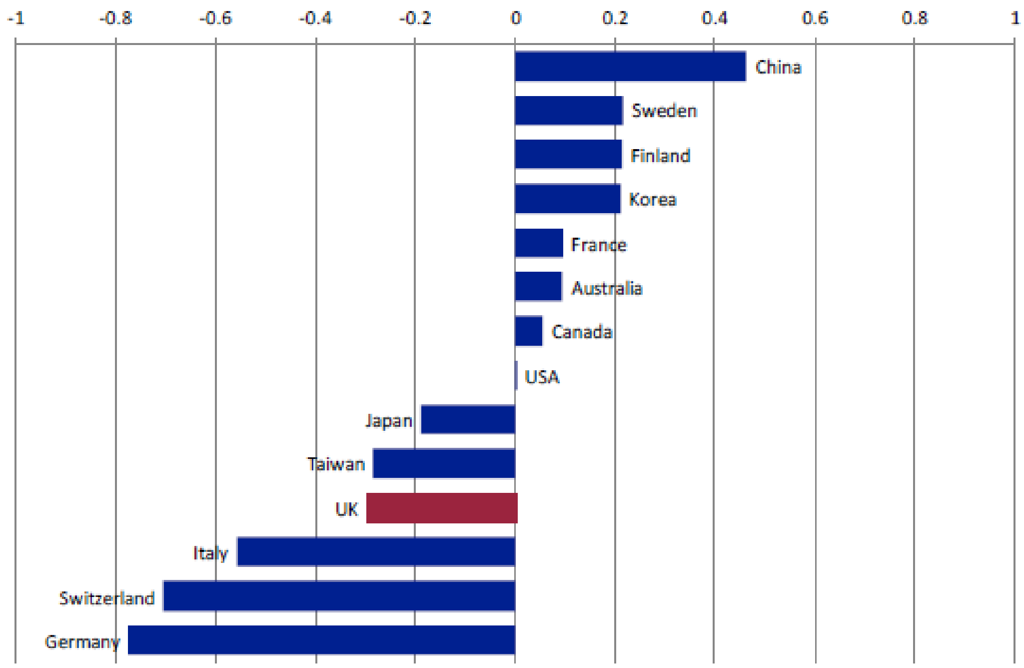
B.21 A somewhat different picture emerges when the levels of IoT patenting activity are compared with each country's overall level of patenting activity (Figure B-9).

B.22 Using a logarithmic 'relative specialisation index' (RSI) which is zero when the country's share of IoT patenting activity matches its share of overall patenting activity, the IPO found that China, Sweden, Finland and South Korea were relatively specialised in IoT, while the United States' IoT patenting activity was in line with its overall patenting levels, and the UK was amongst those countries which had lower shares of IoT patenting than of overall patenting. The RSI of -0.3

[22] International patent applications and European patent applications may be made through the World Intellectual Property Organization (WIPO) and the European Patent Office (EPO) respectively.

for the UK indicates that the UK's share of IoT patents was about half of its share of overall patents over that period[23].

Figure B-9: Relative specialisation index (in IoT) by applicant's country, 2004-2013



Source: UK Intellectual Property Office, 2014, Eight Great Technologies: The Internet of Things - A Patent Overview

IoT journal articles

B.23 A comprehensive bibliometric analysis of publications related to Internet of Things is beyond the scope of this study – though we suggest that that could and should feature in the final evaluation of the programme. For the purposes of this scoping report we have sampled some publication data from two freely available sources: Google Scholar; and the IEEE Xplore database.

B.24 According to Google Scholar there are five publications that explicitly match "Internet of Things" in the journal title. These are shown in the table below, together with their h5 index and h5 median according to Google Scholar[24].

Table B-1: Publications including "Internet of Things" in their titles

Publication	h5-index	h5-median
IEEE Internet of Things Journal	18	34
IEEE International Conferences on Internet of Things, and Cyber, Physical and Social Computing	13	27

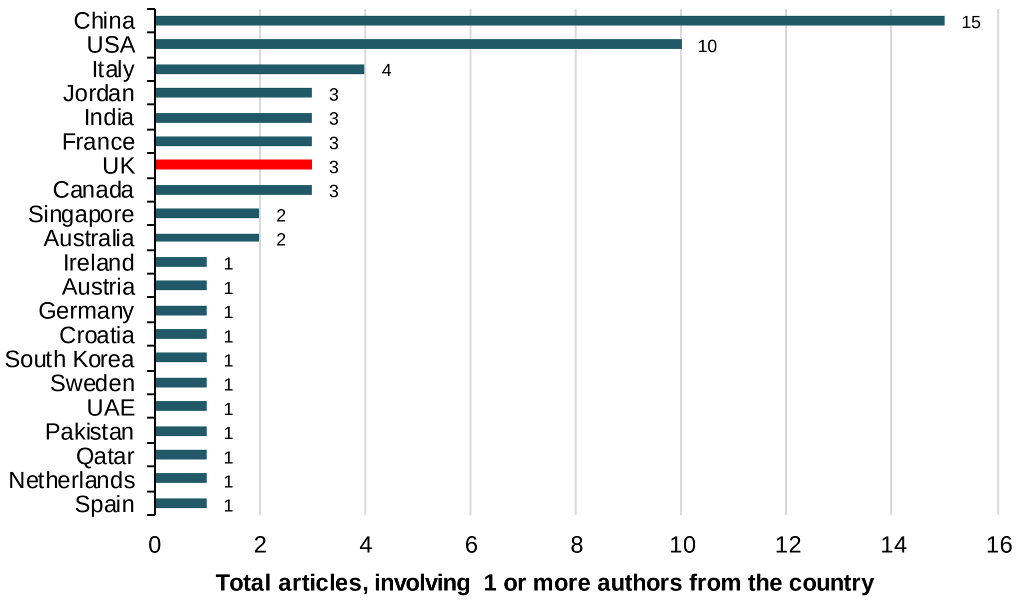
[23] RSI = $\log_{10}[(n_i/n_{tot})/(N_i/N_{tot})]$. When RSI=-0.3, the ratio in square brackets is $10^{(-0.3)}$=0.50
[24] h5-index is the h-index for articles published in the last 5 complete years. It is the largest number h such that h articles published in 2011-2015 have at least h citations each. h5-median for a publication is the median number of citations for the articles that make up its h5-index.

Publication	h5-index	h5-median
International Conference on Future Internet of Things and Cloud (FiCloud)	9	14
International Conference on Identification, Information and Knowledge in the Internet of Things	3	4
International Conference on Green Computing and Internet of Things	2	2

Source: Google Scholar, December 2016

B.25 Looking at the countries in which each of the authors is based, for the 45 articles within the h5 indices for these journals (which are the most highly cited articles in these journals), we see that authors based at institutions in China were involved in 15 (33%) of the articles, and authors based at institutions in the US were involved in 10 (22%) of the articles. Authors based at institutions in the UK were involved in 3 (7%) of the articles.

Figure B-10: Number of articles involving one or more authors from the country, of the 45 articles in the h5-indices of journals including 'Internet of Things' in their name



Source: SQW analysis of data from Google Scholar and the individual articles, December 2016

B.26 This is a very partial view, however, and we should not put much weight on the shares per country indicated in Figure B-10. The above five journals contain just a fraction of the articles relevant to the Internet of Things, and the sample of h5 index articles is very small at just 45 (indicating that these are not high impact journals as yet).

B.27 A somewhat more representative picture can be obtained using the IEEE Xplore digital library, which is a resource for discovery of and access to scientific and technical content published by the IEEE (Institute of Electrical and Electronics Engineers) and its publishing partners, including more than four-million full-text documents from some of the world's most highly cited publications in electrical engineering, computer science and electronics.

B.28 Downloading metadata for the 1,000 most highly cited articles over the period 2007 to 2016, for the publications covered by the IEEE Xplore database, to which the keyword 'Internet of Things' had been applied, we find that the UK's share of these articles[25] was 48 (4.8%), compared with 115 (11.5%) for the United States and 166 (16.6%) for China .

B.29 These 48 UK-led articles are listed in the table below, to give a flavour of the topics and institutions involved in these relatively highly-cited IoT publications from the IEEE Xplore database. Again, it should be noted that this is only a partial view, and a more comprehensive bibliometric analysis would be warranted for the programme's final evaluation.

[25] On the basis of the country of the lead author's institution

Table B-2: UK-led articles, of the 1,000 most highly cited articles tagged with "Internet of Things" keyword, in the IEEE Xplore database, for 2007 to 2016

Document Title	Authors	Lead Author Affiliations	Publication Title	Article Citation Count
Smart objects as building blocks for the Internet of things	G. Kortuem; F. Kawsar; V. Sundramoorthy; D. Fitton	University of Lancaster	IEEE Internet Computing	274
Compressed Sensing Signal and Data Acquisition in Wireless Sensor Networks and Internet of Things	S. Li; L. D. Xu; X. Wang	College of Engineering, Swansea University, Swansea, UK	IEEE Transactions on Industrial Informatics	90
Embedded web services	Z. Shelby	SENSINODE LTD.	IEEE Wireless Communications	80
A survey on facilities for experimental internet of things research	A. Gluhak; S. Krco; M. Nati; D. Pfisterer; N. Mitton; T. Razafindralambo	University of Surrey	IEEE Communications Magazine	76
Securing the Internet of Things: A Standardization Perspective	S. L. Keoh; S. S. Kumar; H. Tschofenig	School of Computing Science, University of Glasgow Singapore, Singapore	IEEE Internet of Things Journal	34
Prototyping Connected Devices for the Internet of Things	S. Hodges; S. Taylor; N. Villar; J. Scott; D. Bial; P. T. Fischer	Microsoft Research Cambridge, UK	Computer	26
Guest Editorial Introduction to the Special Section: 4G Healthâ€”The Long-Term Evolution of m-Health	R. S. H. Istepanaian; Y. T. Zhang	Kingston University, London, UK	IEEE Transactions on Information Technology in Biomedicine	24
Service modelling for the Internet of Things	S. De; P. Barnaghi; M. Bauer; S. Meissner	Centre for Communication, Systems Research, University of Surrey, Guildford GU2 7XH., United Kingdom	2011 Federated Conference on Computer Science and Information Systems (FedCSIS)	17

Document Title	Authors	Lead Author Affiliations	Publication Title	Article Citation Count
A Comprehensive Ontology for Knowledge Representation in the Internet of Things	W. Wang; S. De; R. Toenjes; E. Reetz; K. Moessner	Centre for Commun. Syst. Res., Univ. of Surrey, Guildford, UK	2012 IEEE 11th International Conference on Trust, Security and Privacy in Computing and Communications	16
From Data to Actionable Knowledge: Big Data Challenges in the Web of Things [Guest Editors' Introduction]	P. Barnaghi; A. Sheth; C. Henson	University of Surrey	IEEE Intelligent Systems	16
Edge Mining the Internet of Things	E. I. Gaura; J. Brusey; M. Allen; R. Wilkins; D. Goldsmith; R. Rednic	Department of Systems Engineering, Cogent Computing, Coventry University, Coventry, U.K.	IEEE Sensors Journal	15
Educating the Internet-of-Things Generation	G. Kortuem; A. K. Bandara; N. Smith; M. Richards; M. Petre	The Open University, UK	Computer	15
Self Managed Security Cell, a Security Model for the Internet of Things and Services	P. d. Leusse; P. Periorellis; T. Dimitrakos; S. K. Nair	Newcastle Univ., Newcastle upon Tyne, UK	2009 First International Conference on Advances in Future Internet	13
Cognitive Machine-to-Machine Communications for Internet-of-Things: A Protocol Stack Perspective	A. Aijaz; A. H. Aghvami	Centre for Telecommunications Research, King’s College London, London, WC2R 2LS, U.K.	IEEE Internet of Things Journal	13
A Distributed Consensus Algorithm for Decision Making in Service-Oriented Internet of Things	S. Li; G. Oikonomou; T. Tryfonas; T. M. Chen; L. D. Xu	Fac. of Eng., Univ. of Bristol, Bristol, UK	IEEE Transactions on Industrial Informatics	12

Document Title	Authors	Lead Author Affiliations	Publication Title	Article Citation Count
SimIC: Designing a New Inter-cloud Simulation Platform for Integrating Large-Scale Resource Management	S. Sotiriadis; N. Bessis; N. Antonopoulos; A. Anjum	Sch. of Comput. & Math., Univ. of Derby, Derby, UK	2013 IEEE 27th International Conference on Advanced Information Networking and Applications (AINA)	10
The Impact of Rank Attack on Network Topology of Routing Protocol for Low-Power and Lossy Networks	A. Le; J. Loo; A. Lasebae; A. Vinel; Y. Chen; M. Chai	School of Engineering and Information Sciences, Middlesex University, London, U.K.	IEEE Sensors Journal	10
Recent Advances in Industrial Wireless Sensor Networks Toward Efficient Management in IoT	Z. Sheng; C. Mahapatra; C. Zhu; V. C. M. Leung	School of Engineering and Informatics, University of Sussex, Brighton, U.K.	IEEE Access	9
Lightweight Management of Resource-Constrained Sensor Devices in Internet of Things	Z. Sheng; H. Wang; C. Yin; X. Hu; S. Yang; V. C. M. Leung	School of Engineering and Informatics, University of Sussex, Sussex, U.K.	IEEE Internet of Things Journal	8
Supporting interaction with the Internet of Things across objects, time and space	F. Kawsar; G. Kortuem; B. Altakrouri	School of Computing and Communications, Lancaster University, UK	2010 Internet of Things (IOT)	7
SmartCampus: A user-centric testbed for Internet of Things experimentation	M. Nati; A. Gluhak; H. Abangar; W. Headley	Centre for Communication Systems Research, University of Surrey, Guildford, GU2 7XH, UK	2013 16th International Symposium on Wireless Personal Multimedia Communications (WPMC)	7
A multi-modal sensor infrastructure for healthcare in a residential environment	P. Woznowski; X. Fafoutis; T. Song; S. Hannuna; M. Camplani;	Faculty of Engineering, University of Bristol, BS8 1UB, UK	2015 IEEE International Conference on Communication Workshop (ICCW)	7

Document Title	**Authors**	**Lead Author Affiliations**	**Publication Title**	**Article Citation Count**
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