INTERNET OF THINGS

The New Government to Business Platform

A REVIEW OF OPPORTUNITIES, PRACTICES, AND CHALLENGES

WORLD BANK GROUP

Table of contents

Acknowledgments

This publication was funded by a data innovation grant from the Trust Fund for Statistical Capacity Building (TFSCB), a multidonor trust fund managed by the Development Economics Data Group (DEC-DG) at the World Bank. The Innovations in Development Data (IDD) pilot window of TFSCB supports testing and scaling of new approaches, technology, and collaboration for more effective and efficient data collection, management, and use to build the capacity of government agencies, and other development stakeholders, to monitor and accomplish the Sustainable Development Goals (SDGs).

Several people provided input and contributed to the report. At the World Bank, the project was led by Prasanna Lal Das. Srikanth Mangalam, Public Sector Innovation Specialist, was the lead consultant. Dr. Mehmet Yuce, Professor at Monash University, Australia was the subject matter expert on IoT. Nexleaf Analytics, a not-for-profit firm in California, USA, undertook a marketplace survey. Stefan Beisswenger and Asset Bizhen provided local knowledge and expertise from Germany and Kazakhstan. Jeevan Mohanty provided information on the current work in India. The project team would also like to thank Yeraly Beksultan in Kazakhstan for his feedback and input. Maja Andjelkovic, Carlo Maria Rossotto, Syed A. Mahmood, and Trevor Monroe were the peer reviewers of the report. Ganesh Rasagam and Dahlia Khalifa provided overall guidance. Alla Morrison and Grant James Cameron served as the liaison with TFSCB.

The authors of the report would like to also acknowledge the significant contribution of experts and practitioners (listed in the table below) from outside the World Bank who provided input to the report.

Name	Organization	City/Country
Shawn Slack	City of Mississauga	Canada/ Mississauga
Sven Tretrop	City of Mississauga	Canada/ Mississauga
Wilson Lee	Technical Standards and Safety Authority	Canada/ Toronto
Roger Neate	Technical Standards and Safety Authority	Canada/ Toronto
Andrew Horseman	Ontario Tire Stewardship	Canada/ Toronto
Carmelina Macario	Resource Productivity and Recovery Authority	Canada/ Toronto
Mary Cummins	Resource Productivity and Recovery Authority	Canada/ Toronto
Mohammed Abdulla Shael AlSaadi	City of Dubai	Dubai/ United Arab Emirates
Siim Sikkut	Ministry of Economic Affairs and Communication (Government of Estonia)	Estonia
Anna Piperal	e-Estonia	Estonia
Doris Pold	e-Estonia	Estonia
Peep Poldsamm	Estonian IoT Association	Estonia
Margus Püüa	Estonia e-Governance Academy	Estonia
Uuno Vallner	Estonia e-Governance Academy	Estonia
Alanus von Radecki	Fraunhofer Institute	Germany
Steffen Braun	Fraunhofer Institute	Germany
Nora Fanderl	Fraunhofer Institute	Germany
Constanze Heydkamp	Fraunhofer Institute	Germany
Petra Steffens	Fraunhofer Institute	Germany
Mike Weber	Fraunhofer Institute	Germany
Jens Tiemann	Fraunhofer Institute	Germany
Inka Woyke	Fraunhofer Institute	Germany
Christine Brockmann	Rhine Neckar Metro	Germany
Thomas Langkabel	Initiative D21 and Microsoft Germany	Germany
Christian Hammel	Technologiestiftung Berlin	Germany/ Berlin

Name	Organization	City/Country
Andrea Brauning	City of Ludwigsburg	Germany/ Ludwigsburg
Georg Pins	City of Mannheim	Germany/ Mannheim
Nina Kruppenbacher	City of Mannheim	Germany/ Mannheim
Banchhanidhi Pani	City of Rajkot	India/ Rajkot
Taisuke Matsuzaki	Kobe City	Japan/ Kobe City
Stephen Ullathorne	Gas Tag	United Kingdom
Adrian Webb	Gas Tag	United Kingdom
Helen Mainstone	Department for Digital, Culture, Media and Sport (Government of U.K.)	United Kingdom
Amy Taylor	Digital Catapult	United Kingdom
Idris Jahn	Digital Catapult	United Kingdom
Matthew Fox	Future Cities Catapult	United Kingdom
Tom Leaver	Future Cities Catapult	United Kingdom
Isabella Myers	Independent Consultant	United Kingdom
Lorraine Hudson	The Open University	United Kingdom
Theo Tryfonas	University of Bristol	United Kingdom
Rebecca di Corpo	University of Bristol	United Kingdom
Sophie Ross-Smith	University of Bristol	United Kingdom
Nina Purcell	United Kingdom Food Standards Agency (Government of U.K.)	United Kingdom
Kevin O'Malley	Bristol City Council	United Kingdom/ Bristol
Penny Evans	Knowle West Media Centre	United Kingdom/ Bristol
Geoff Snelson	City of Milton Keynes	United Kingdom/ Milton Keynes
Vijay Sankaran	IBM	United States of America
V. K. Shankar	Intel Corporation	United States of America
Sundip Doshi	AerNos	United States of America
Olzhas Sartayev	JSC «Astana Innovations»	Kazakhstan
Zhanat Dubirova		
Olexand Chuprina		
Bakhytzhan Ualikhan		
Aktore Barlybayev		
Azat Kudaibergenov	Department of Information Technologies of Astana	
Tursyngali Zhakenov	Astana Passenger Transport Office	
Esenaliyev Anuarbek	Astana Energy Department	
Arsen Kozhanov	Department of Public Utilities of Astana	
Alzhan Abdrakhmanov	JSC «National Infocommunication Holding «Zerde»	
Baysatov Yerbol	Astana City Construction Management	
Rinat Ramazanovich	Housing Inspectorate of Astana	
Miras Maratovich	Management of natural resources and regulation of nature management in the city of Astana	
Kairat Akhmetov	Korkem Telecom	
Asset Issekeshev	Mayor of Astana	
Malika Bekturova	Deputy Mayor of Astana	
Serik Kurmanov	JSC «Kazakhstan Industry Development Institute»	
Tangul Abdrazakova	JSC «Kazakhstan Industry Development Institute»	
Vladimir Turekhanov	Kazakhstan Association of Automation and Robotics	
Kurmangaliyeva Bikesh Darovna	JSC «Kazakhtelecom»	
Arman Doskaliyev		
Chief (or deputy) physician	City polyclinic #7	
Ivan Urievich	LLP «Astana Tazartu»	
Orakbay Nurlan Kalabayevich		
Ingundinov Nurlan	LLP dispatch center of state entity «Astana Passenger Transport Office»	

EXECUTIVE SUMMARY

Executive Summary

The Internet of things (IoT), or its sibling, Internet of everything (IoE), has gone from being a buzzword to almost an imperceptible part of our lives. It is so prevalent that we barely notice it anymore. Our phones contain a variety of sensors that constantly record and transmit enormous amounts of information without us noticing or being aware of it; our houses and cars are "smarter" than ever before; our public infrastructure (street lights, elevators, escalators, roads) contains myriad sensors that are essential for their maintenance and our safety; and factories—even those producing low-tech products—have begun to embrace the "industrial Internet" (powered by IoT). Businesses, especially in developed countries, have been quick to seize the potential of IoT. A recent story in the New York Times (1) about the evolution of GE from a manufacturing company to a digital one describes IoT as "the next battlefield" for companies and cites and projects the possibility of a hundredfold growth in the data flowing from machines by 2020. In a similar vein, Michael Porter wrote recently in the Harvard Business Review (2) about "smart, connected products"—made possible by vast improvements in processing power and device miniaturization and by the network benefits of ubiquitous wireless connectivity that have unleashed a new era of competition.

> *"I see the Internet of Things as a huge transformative development, a way of boosting productivity, of keeping us healthier, making transport more efficient, reducing energy needs, tackling climate change.* ***We are on the brink of a new industrial revolution*** *and I want us... to lead it."*
> — David Cameron, former prime minister of U.K. (116)

Governments have been slower than the private sector to respond to the IoT phenomenon. Policy makers must, however, contend with growing pressure to become more innovative, open, collaborative, evidence based, and participatory (3) as the expectations of business and society change, technology becomes more pervasive, the old policy regime starts to show cracks, and efficiency and

AT A GLANCE

Still early days for IoT in government

Underdeveloped policy and regulatory frameworks

Unclear business models, despite strong value proposition

Clear institutional and capacity gap in government AND the private sector

Inconsistent data valuation and management

Infrastructure a major barrier

Government as an enabler

Most successful pilots share common characteristics (public-private partnership, local, leadership) optimization become ever more necessary. In regulatory enforcement, for example, where factors such as inconsistencies, variability, and poor interoperability across government departments have a clearly detrimental impact on business, there is growing, though by no means uniform, recognition that **IoT can help reap significant public benefits such as convenience, safety, and efficiency**. In sectors such as transport, environment, water, and energy there are numerous examples of applications and programs where IoT serves as a central stitching element for government and business. Sensors mounted on lampposts that measure and share environmental or pollution data (4) (Chicago and Barcelona, for example), GPS devices that track and provide real-time updates on transit (5) (Mississauga in Canada), smart meters that monitor energy consumption (6) (Amsterdam, Seoul), and sensors that detect volumes in garbage bins (7) (Milton Keynes in the United Kingdom) are now fairly mainstream in many city governments, with others planning similar pilots (for example, smart street lighting in Astana, Kazakhstan).

Many governments accept that they have a role to play in establishing and supporting an environment in which new technologies such as IoT can emerge, flourish, and grow. Initiatives such as Plattform Industrie 4.0 (8) in Germany, the Digital Single Market Strategy of Europe (9), the U.K. Digital Strategy (10), the Smart Nation initiative of Singapore (11), the Digital India (12) program, and so on explicitly describe government commitment to helping make firms more competitive through better use of IoT technologies. Much of this effort has, however, been geared toward using IoT within business operations (within manufacturing operations, for example, or embedding sensors within products to make them more appealing and useful for consumers).

What has been relatively less explored is how governments and businesses can collaborate to mutually reap the potential benefits of IoT while grappling with the numerous challenges that new technologies inevitably pose. **Governments are keen to learn how IoT may make their economies more competitive or make it easier to manage businesses within their jurisdiction**. Businesses, too, need government support to test new technologies within "living" conditions—and for which the policy, capacity, financing, and the business model environment are still unclear.

Implementing IoT within government settings is easier said than done, however; there are many unanswered questions for both governments and businesses. **Can IoT make it easier to do business** in a jurisdiction by reducing the cost of regulatory compliance while simultaneously providing assurance to government that regulation is having its intended effect? How can the government offer a platform for the private sector to test new application of IoT in "living labs" or "sandboxes" within urban environments while letting government assess its own policy

Figure 1. Jurisdictional Ranking on IoT Government – Business Systems

Jurisdiction	Policy	Capacity	Data	Tech	Top Support	Public-Private Partnership	Business Models	Pilot Space
Bristol	Green	Green	Green	Green	Green	Red	Red	Green
Milton Keynes	Green	Green	Green	Green	Green	Green	Red	Green
Reutlingen	Green	Grey	Grey	Grey	Green	Green	Red	Green
Hamburg	Green	Yellow	Yellow	Green	Green	Green	Yellow	Grey
Ludwigsburg	Green	Green	Red	Yellow	Green	Green	Red	Green
Mannheim	Green	Green	Grey	Grey	Green	Grey	Grey	Grey
Astana	Yellow	Red	Red	Yellow	Green	Yellow	Red	Green
Estonia	Green	Green	Green	Yellow	Green	Yellow	Red	Yellow
Mississauga	Green	Green	Green	Green	Green	Yellow	Yellow	Yellow
Kobe City	Grey	Grey	Red	Green	Yellow	Green	Yellow	Green
Dubai	Green	Grey	Yellow	Yellow	Yellow	Red	Grey	Green
Rajkot	Green	Grey	Red	Red	Green	Green	Red	Yellow

Note: **Green** = available and functional; **yellow** = partially available; **red** = not available; **grey** = not known.

preparedness to deal with the technical and nontechnical implications of the introduction of new digital technologies? What are the risks for everybody involved? How might such initiatives align with other related programs?

In this study, we try to answer these questions by examining the evidence in several cities around the world. The report draws on lessons learned during the actual implementation of IoT-oriented projects (countries covered include Canada, Estonia, Finland, Germany, India, Japan, Kazakhstan, Luxembourg, the United Arab Emirates, the United Kingdom, and the United States); it also draws on several secondary sources, plus a review of the current IoT marketplace.

IoT in Action (Main Findings)

IoT discussions often get mired in mind-boggling numbers about the sheer growth in the number of IoT devices and their potentially transformative impact. However, how do these numbers correspond to the reality on the ground? We sought to understand the experience of several cities and jurisdictions around the world to see how the reality stacked up against a range of parameters.

Here are a few observations from our study.

It is still early days for IoT in government and most initiatives are in the pilot or proof of concept stage. While we observed notable exceptions (the integrated port management systems in Hamburg, Germany; smart energy monitoring systems in Canada, Estonia, and the United Kingdom; remote rail inspection and monitoring in Kazakhstan), almost all of the initiatives we assessed were either in early stages of implementation (garbage collection in Milton Keynes, United Kingdom, for example) or still on the drawing board (remote monitoring of elevators for compliance in Ontario, Canada). Most pilots tend to cluster around similar ideas, such as smart street lighting, traffic/transit management, solid waste management, public safety involving security monitoring, and smart energy systems. The reality of IoT implementation has not yet caught up with the hype around it.

The value proposition of IoT for government to business services is evident, but the business model is unclear. The business models for IoT within the government to business space aren't fully established. We observed two primary models:

- IoT as a competitiveness differentiator (the City of Ludwigsburg's (13) view of a smart city is to create an attractive and competitive economy through technologies such as IoT)
- IoT as a means to improve regulatory compliance while reducing burden on businesses (the Cambridge City Council, for instance, hopes to accept a cloud-based food safety management system (14) using IoT sensor data as an acceptable means of fulfilling legal requirements)

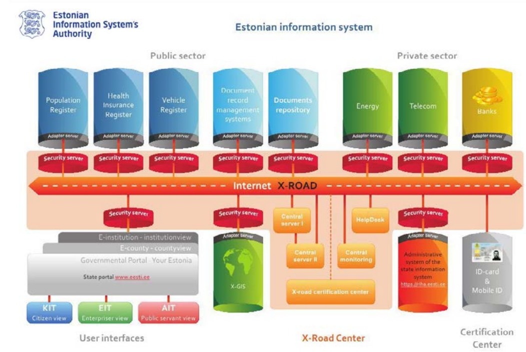
There are few clear and enabling IoT-related policies and regulatory frameworks in place yet. A few governments, such as the United Kingdom (10), India (12), and Singapore (11), have established broad-based strategic IoT policies as enablers for digital development. These policies cover issues such as the establishment of government working groups to develop IoT-specific capabilities within government; spaces for collaboration between academia, businesses, and the public sector on IoT-based innovation; or broad strategic direction for the creation of IoT-based industry. In most cases, however, IoT-specific policy remains underdeveloped both in the area of IoT technology itself (such as data, security, interoperability, and availability of radio frequencies) and with regard to IoT-enabling issues (such as the prescriptive requirements like physical inspections, and so on).

Institutional capacity, competency, and education need upgrades. The IoT phenomenon remains poorly understood by both businesses and government agencies. The term IoT is only beginning to seep into government consciousness in almost every city we studied, and there seems to be a limited understanding of the phenomenon among businesses as well (15). In both the public and private sectors, entities that were not "born digital" continue to struggle to create digital/data competency within management and leadership layers, and much of the current training favors technical rather than executive skills. To tackle this, Estonia has made digital courses in secondary education mandatory. In the United Kingdom, the government provides funding and infrastructure to support government-business-academic partnerships through "Digital Catapults."

Data are central to IoT, but there is inconsistent understanding of data's value and management. Cities such as Bristol (16) and Milton Keynes (17) in the United Kingdom are embracing and further enhancing their open data initiatives by making data generated by IoT sensors available. Data hubs such as that of Milton Keynes accept data from a wide variety of sources (including sensors owned by nongovernmental entities) and let businesses and civil society use the data to perform analytics and develop software applications. Bristol's Data Dome lets users create IoT data-driven experiments. In addition, data from IoT can be an economic asset for both government and business. For example, in Astana, Kazakhstan, implementing fuel control sensors on garbage hauling trucks has both triggered significant cost savings for the city and allowed the trucking company to control the theft of fuel. However, this is an area of study that needs further exploration.

Figure 2. Bristol Data Dome, the United Kingdom's Only 3-D 4K Immersive Data Visualization Space (left); Estonia's X-Road

Source: Bristol is Open



Source: Siim Sikkut, Government of Estonia

IoT-specific infrastructure remains a barrier even in advanced economies. Lack of advanced broadband technologies seems to be a concern even in major economies such as Germany. The lack of consistent standards governing IoT networks such as low-power wide-area networks can discourage large-scale investments. Cities such as Bristol and Mississauga are trying to overcome such challenges by constructing their own infrastructure and offering them to businesses for use.

The government often plays a crucial role as an IoT enabler. Most successful IoT projects operate under public-partnership models. City governments act either (a) as enablers by creating independent innovation teams designed to bring relevant stakeholders and businesses together and facilitate active partnerships, offering innovation infrastructure such as "living labs" to private sector providers; or (b) as "business partners" by helping develop business models, commercializing research, creating technology infrastructure and/or "relaxing" regulatory frameworks for testing and experimentation (for example, the Morgenstadt experiment in Reutlingen).

Successful IoT pilots share several characteristics. We studied a range of cities as part of our study but observed a few common characteristics that distinguished most successful pilots:

1. **Inspirational leadership is key to kick-start projects, accelerate progress, and sustain momentum.** The mayors of Ludwigsburg, Bristol, and Astana, for instance, have taken a keen and personal interest in IoT-based applications to address their vision and the expectations of their citizens. In almost all cities we studied, the mayors' individual motivation, commitment, and inspiration were essential to catalyze IoT projects. In some cases, the mayors were tech-savvy and very familiar with IoT-based solutions, but not always.
2. **Most IoT engagements are led by municipal/city/subnational governments, not their federal counterparts.** With a few exceptions, while national and subnational governments support initiatives such as smart city projects, they are not directly involved in IoT-based projects, especially those that focus on business services (for example, inspections). In Canada, for example, the federal government has only recently referenced their intent to support IoT-based technological innovations in the 2017 budget. However, Mississauga has pursued investments and implementation in IoT infrastructure for several years.
3. **The "smart city" tag is a major driver for IoT initiatives.** Cities with an interest in smart city recognition are pursuing several initiatives that involve the use of IoT-based technology solutions. In most cases, these projects focus on citizen service delivery, but many of them also have a government to business (G2B) focus, either directly or indirectly. Stuttgart and Mannheim in Germany, Milton Keynes and Bristol in the United Kingdom, Mississauga in Canada, Chicago in the United States, and Dubai in the United Arab Emirates are making significant strides in this direction. National governments such as those in Germany, India, Kazakhstan, and the United Kingdom are actively supporting such initiatives through direct funding, competitions, and/or creation of innovation hubs.
4. **Independent, third-party "coordinators" play a key implementation role.** Digital Catapult in the United Kingdom, Fraunhofer Institute in Germany, and Astana Innovations in Kazakhstan are examples of coordinating bodies that bring together different stakeholders, including governments, academia, and industry, to undertake proof of concept studies and establish strategies for implementation. Government typically funds these facilitators.

5. **Focus on the local.** Identifying local problems to solve, generating local solutions and content, and promoting local businesses help create more viable IoT-based solutions. Bristol, for example, has been able to successfully link its IoT projects to its vision and periodically engages its local community in generating ideas and developing solutions.
6. **Public-private partnerships can provide a sustainable model.** Initial funding and support from governments supplemented by contributions from the private sector is the model favored by several jurisdictions. Milton Keynes, Mannheim, and Kobe City use a public-private model that supports greater initial involvement by the private sector with a view toward a "build to own" model, whereas Estonia and the city of Mississauga are exploring a joint or independent ownership approach.

The IoT Toolkit – What Governments Can Do

IoT, both as a technology and as a governance practice, is still in its infancy, and while there is tangible excitement about it within both government and the private sector, the evidence of success is still patchy. Governments have a vital role in catalyzing the space and contributing as partners/leaders in the long term.

Based on the findings and the characteristics of successful pilots, we present a conceptual toolkit containing ideas and resources for government agencies that want to implement IoT-based initiatives within their jurisdictions. The toolkit has three pillars:

- Leadership/policy
- Strategy and implementation
- Capacity and engagement

Here are a few highlights from the toolkit for potential government action.

Leadership/Policy

Proactively and iteratively engage in policy development with an eye toward regulatory balance. Given the pace of disruption, the wide diversity of stakeholders, the cross-boundary nature of the digital economy, and the scale of new digital services, it is important for policy makers to look beyond policy models that served the public sector well before the advent of the digital economy. Within the IoT policy environment, policy makers must consider trade-offs between increased efficiency, reduced privacy, equality, and security. They must also engage more closely with innovators, as Ludwigsburg has done, to define regulatory frameworks that are iterative rather than definitive. The EU Data Protection Regulation, for exam-

THE IOT TOOLKIT

Leadership/Policy

Proactive policy development

Align strategic objectives

Strategy and Implementation

Establish sandboxes to develop pilots (test value proposition, technology, policies, infrastructure, security)

Establish a coordination agency to manage and run pilots

Develop public-private partnerships and platforms

Research and develop "localized" business models

Develop IoT infrastructure

Capacity and Engagement

Engage local stakeholders through education and outreach

Develop IoT capacity within and outside the government

Encourage standardization

ple, is designed to foster the market and ensure a balance between overregulating and underregulating. Also, while national governments have a significant role to play in creating a level playing field with respect to allocation of spectrum, pricing, and policy reforms, the dynamic between them and subnational and municipal governments is key, as illustrated in the case of Canada.

Ensure alignment with a larger vision and strategic objectives (IoT should support existing vision, not vice versa). Clear and direct synergies should exist between proposed IoT applications and the strategic objectives of jurisdictions that implement IoT-based solutions. The most effective and organic institutionalization of IoT-based initiatives are possible when they tie directly to strategic initiatives envisioned by mayors or leaders of jurisdictions wherein real problems and challenges faced by citizens and businesses are tackled using such solutions. The cities of Bristol (18) and Mississauga (19) have integrated and entrenched their digital/IoT priorities as enablers for achieving specific strategic initiatives identified by the mayor and city councils.

Strategy and Implementation

Establish sandboxes for pilots and proofs of concept to test policies and solutions. Sandboxes, facilitated directly or indirectly by government, in the form of physical spaces, clusters, and/or environments for running pilots and proofs of concept, were the one constant in all the cases we observed. Sometimes referred to as living labs or model cities, these physical spaces provide facilities for setting up start-ups and building "models" ranging from simple IoT applications to even "model" cities. The Bristol Living Lab is a place where citizens, artists, technologists, businesses, and public sector organizations come together to co-create ideas and to understand how digital technologies can be used to meet local needs. Similarly, Mannheim's Benjamin Franklin Village, once an old U.S. military base, has been converted into a sandbox district designed to test ideas for energy efficiency, smart grids, and electro-mobility. These sandboxes are designed to test more than technology; they serve as test beds for governments to test policy alternatives to accommodate and promote the use of IoT by businesses. The Benjamin Franklin Village is helping develop ideas for procurement requirements that incentivize IoT-based solutions, relaxation or exemption of regulatory barriers such as licensing or inspections, and gathering stakeholder views on data privacy/ownership. Other ideas being tested in similar sandboxes include public perception and awareness, data stewardship, financial models, business value propositions, competency, and skill requirements.

Identify and appoint "coordinators" to lead and facilitate implementation (Digital Catapult, Astana Innovations, Fraunhofer Institute). The successful implementation of IoT-based solutions requires a phased approach and the involvement of multiple stakeholders. The appointment of independent third-party bodies as facilitators and caretakers of IoT projects during the pilot and proof of concept stages appears to be an effective model based on the experience of the studied jurisdictions. These bodies, typically funded either directly by governments or through public-private partnerships, act as coordinators between academia, government, industry, civil society, and other stakeholders. They play the role of project manager and are responsible for the design, planning, and execution of pilots and proofs of concept and for scaled implementation. The U.K. government has created Digital Catapult and IoTUK for this specific purpose. Fraunhofer Institute in Germany has proactively taken this role and has been building such partnerships. The mayor of Astana established Astana Innovations to play a similar role.

Build public-private-academic partnerships and platforms. The development of public-private-academic partnerships appears to be a critical success factor. Agencies in Finland and Canada are looking to partner with academia and businesses to evaluate IoT solutions for remote monitoring and inspections of technologies such as elevators, fire protection systems, and building management systems. Kobe City in Japan has worked with a telecom provider to use a Bluetooth low energy (BLE) tag to track the movement of elementary school children and ensure their safety. Dubai is working with a variety of service providers, including hospitals, auto manufacturers, and parking companies, to implement a child immunization program. In each case, success hinges on the participation of numerous stakeholders with different priorities, finances, capacity, infrastructure, and constraints. A partnership, sometimes via the coordinator office described above, is usually the only way to bring these players together.

Research and develop "local" business models. The study threw up several examples of incipient local business models for IoT. Estonia is considering "Data Corporations" with shared ownership across the value chain. The city of Mississauga estimates that it saves Can$2 million annually (20) through its own fiber-optic network. Astana Tazartu, a solid waste management company established as a public-private partnership, has installed fuel control sensors in its vehicles that have helped reduce both its fleet size and associated fuel costs. Bristol is evaluating and testing a range of sustainable business models over the next two years and eventually hopes to develop a suite of models that can be applied effectively in different contexts. Other jurisdictions are pinning their hope on the monetization of IoT data.

Develop own technology infrastructure (fiber optics, LoRaWAN, and so on) or establish "productive" partnerships with telecom providers. Stable and reliable network infrastructure is a prerequisite for IoT applications. Cities like Mississauga have developed their own fiber-optic infrastructure and/or low-power wide area networks (LPWAN) that support IoT devices. Others like Kobe have entered partnerships with telecom providers. Kobe is also building an IoT infrastructure using LoRaWAN technology, taking advantage of its geography (the surrounding mountains help extend coverage as far as 15 kilometers).

Capacity and Engagement

Engage and partner with local communities through education and outreach. Community groups and citizens can play an early and proactive role in generating ideas, providing feedback and input for tackling sensitive and difficult issues such as data privacy and data ownership, and ensuring the long-term sustainability of such projects. The Knowle West Media Centre, an arts center and charity based in Bristol, is a good example of using outreach and education to develop trust and partnership with local communities.

Develop IoT capacity within and outside government (work with academic and educational institutions to develop curriculum for current and future capacity development). IoT-based applications and processes require a very different skill set and competency from the people managing them. For example, remote regulatory inspections may not require physical observations but may call for strong analytical skills and capabilities. Several governments are already starting to engage and partner with universities and academic institutions to develop appropriate curriculum, starting from early education all the way through college/university studies. In the United Kingdom, the Open University's FutureLearn program has created a free online module on smart cities that provides foundational and high-level education and understanding of smart city applications including IoT-based solutions. Estonia's e-school program ensures mandatory education in digital technology for all students from an early age.

Participate in and support international standardization initiatives. IoT and its associated technological innovations is still an evolving field. While numerous exciting and innovative devices, technological systems, and infrastructure have been developed recently, their dependability (reliability, availability, resilience, maintainability, and use) is often questionable in the absence of uniform standards. It is important that governments, especially in developing countries, actively participate in the development of such standards to ensure that their needs and constraints are expressed and addressed by the standards that do eventually emerge. Examples of standardization initiatives include RAMI 4.0 (Germany); IIC (Industrial IOT Consortium) (21); OCF (Open Connectivity Foundation), which deals with Interoperability (22); and Project Haystack (23), which is a data consortium establishing data standards for data models for hierarchical representation of devices.

A Note on the Methodology

The information in this report is drawn from the following:

- Field visits, phone calls, and email exchanges with city representatives and other stakeholders in government, industry, nongovernmental organizations, and academia across Europe, Asia, the Americas, and Africa
- A literature review of the state of IoT technology and applications covering a range of public sources
- A brief survey of the IoT marketplace
- Discussions during an IoT workshop organized in partnership with Astana Innovations in Astana, Kazakhstan

We recognize that our geographic coverage was limited (Asia, Africa, and Australia are blind spots, for instance). Our choice of cities was influenced by the responsiveness of city officials and by their current exposure in the existing research (we were keen to go beyond the "usual suspects" to see how deeply IoT may have penetrated into cities that weren't necessarily the most visible early adopters). That said, we would like eventually to validate the findings/recommendations in this report with a larger group of cities. In a future study, we would also like to engage more substantially with the private sector.

An IoT questionnaire developed for this report is included as appendix A.

INTRODUCTION & METHODOLOGY

Introduction & Methodology

Background

The public sector is under pressure to become more innovative, open, collaborative, evidence based, and participatory (3) as the expectations of business and society change; technology becomes more pervasive, bringing a new set of policy challenges; and efficiency and optimization become ever more necessary. Government directives such as the United Kingdom's Growth Duty (24)—which mandates its departments to reduce administrative burden and unnecessary regulations while promoting innovation, creating prosperity and opportunity for all—and the World Trade Organization's Trade Facilitation Agreement (25)—which sets out expectations among signatory nations to reduce bureaucratic delays and red tape' and create a simplified, modernized, and harmonized process of trade to create competitiveness and growth—are among the reasons driving the shift from "regulating innovation" to "innovating regulation."

The emergence and application of advanced digital and smart technologies are key drivers of innovation in government. The United Kingdom's Growth Duty requires regulators to "consider how legislation and enforcement frameworks could adapt to emerging technologies and innovative business models." Similarly, the EU's Digital Single Market (26) strategy and supporting documents and policy papers (27) advocate the use of smart technology for the reduction of barriers to make the EU competitive in the global market, including regulatory and administrative burdens. A recent story in the New York Times (1) about the evolution of GE from a manufacturing company to a digital one describes IoT as "the next battlefield" for companies and cites the possibility of a hundredfold growth in the data flowing from machines by 2020. In a similar vein, Michael Porter wrote in the Harvard Business Review recently (2) about "smart, connected products"—made possible by vast improvements in processing power and device miniaturization and by the network benefits of ubiquitous wireless connectivity that have unleashed a new era of competition.

- Significant potential benefits of IoT, yet limited adoption within governments
- Policy response poorly understood
- Regulatory systems not up to speed
- Business models underdeveloped
- Limited understanding of the IoT marketplace

The Organisation for Economic Co-operation and Development (OECD) suggests, in the paper "The Internet of Things – Seizing the Benefits and Addressing the Challenges" (28), that the potential benefits of IoT depend on the capacity of innovators to conceive and implement novel IoT approaches and on the capacity of governments to create policy and regulatory frameworks in key policy areas. The report identifies the role that IoT can play in making public infrastructure such as roads and public spaces, emergency services, and safety and security more efficient, and how IoT can help governments better achieve their objectives and measure the effectiveness of their policies and implementation.

For businesses, the value proposition of IoT lies in the development of new products/services, new business models enabled by IoT data, new and more efficient business processes, easier regulatory compliance, development of new markets, commercialization of research, the creation of entrepreneurial opportunities, and ultimately the growth of sustainable revenue models.

While the potential for IoT in the public sector (29) appears to be significant, the IoT phenomenon is still poorly understood by both businesses and government agencies. There are very few examples of large-scale IoT implementation in the government to business domain, and there aren't any established business and partnership models for governments and businesses to collaboratively develop strategies to either increase regional competitiveness or reduce the regulatory burden on business using better IoT technology. The policy options for government remain unclear; the IoT marketplace remains abstract as well, with little public information yet on cheap, effective, and reliable technology options to collect/use/share IoT data or on the infrastructure requirements for evidence and real-time data-based decision making and capabilities. Governments need to bring their regulatory systems up to speed to meet the demands of the marketplace and create the enabling environment for businesses. This includes not merely streamlining individual regulatory processes but also the enactment of new regulations, improvements in regulatory governance and delivery, and the creation of platforms and environments for innovation and research.

The private sector has its own set of challenges. Despite many evident benefits (reduced costs for maintenance, increased reliability and extension of lives of technologies, new products/services), commercial models for many IoT applications are still unclear, many technologies require living test beds, and entrepreneurs need support engaging the large number of stakeholders many IoT services inevitably require.

This report aims to fill this knowledge gap and to create greater awareness about the IoT phenomenon within governments. It captures the findings from the first phase of the study based on a jurisdictional scan of a select list of countries in Europe, North America, and Asia.

We hope that this report will help governments better assess the potential/challenges of IoT and help them develop pragmatic digital strategies that drive the use of real-time data to monitor, manage, and proactively respond to infrastructure challenges; raise stakeholder (including investors') confidence; and protect public interest.

Study Approach

The information in this report is drawn from the following:

- Field visits, phone calls, and email exchanges with city representatives and other stakeholders in government, industry, nongovernmental organizations, and academia across Europe, Asia, the Americas, and Africa
- A literature review of the state of IoT technology and applications covering a range of public sources
- A brief survey of the IoT marketplace
- Discussions during an IoT workshop organized in partnership with Astana Innovations in Astana, Kazakhstan

We recognize that our geographic coverage was limited (Asia, Africa, and Australia are blind spots, for instance). Our choice of cities was influenced by the responsiveness of city officials and by their current exposure in the existing research (we were keen to go beyond the "usual suspects" to see how deeply IoT may have penetrated into cities that weren't necessarily the most visible early adopters). That said, we would like eventually to validate the findings/recommendations in this report with a larger group of cities. In a future study, we would also like to engage more substantially with the private sector.

Jurisdictional Scan

We conducted interviews with experts and key stakeholders in government representing national, subnational, and local interests, academia, industry and industry associations, and nongovernmental agencies. The interviewees were either directly or indirectly involved in IoT-related strategies or applications in Canada, Estonia, Finland, Germany, India, Japan, Kazakhstan, Luxembourg, the United Arab Emirates, the United Kingdom, and the United States. Their responsibilities covered policy research and policy making, economic development, information management, inspections and enforcement, technology, law, communication, and social media in a variety of areas:

- City infrastructure
- Building Infrastructure
- Energy systems, including power generation, transmission, heating, ventilation and air conditioning equipment, boilers and pressure systems
- Ports and port logistics, including transportation
- Utility infrastructure, including water supply, water/wastewater treatment
- Public health and health care
- Environment, including solid waste management, air pollution, climate change, and so on
- Agriculture
- Rail and airport infrastructure
- Public and commercial transportation

The interviews were conducted using a standard interview protocol and covered a wide range of topics:

- Legal and regulatory framework
- Institutional capacity and governance
- Technology framework
- Data ownership, privacy, security, and other governance issues
- Value propositions and benefits for businesses and governance
- Financing and revenue models
- Performance measurements

Please refer to appendix A for the detailed questionnaire.

Literature Survey

The objective of this part of the report is to provide a literature survey outlining applications, regulatory implications, and challenges in current IoT deployments and future applications that can provide guidelines for government authorities, policy makers, and business groups. There is a wide range of regulatory standards for wireless and security considerations of wireless devices used to connect sensors. The developers of IoT platforms, therefore, should be aware of licensing and spectrum management restrictions of such wireless devices. The report provides some important information and future directions for government authorities, business groups, investors, and start-ups to collaborate and complement each other integrating smart digital technologies with emerging IoT into public infrastructure. This report contains some social media activities involving discussions, announcements of IoT products, and applications. Such social groups have been the key platform for some IoT technology developments, generating business and providing benefits through discussions and regular meetings, with a wide range of community feedback.

Marketplace Survey

We conducted a review of the marketplace to examine the potential of IoT for the public sector, to highlight examples of practical implementation, and to identify successful architectures for IoT based on experience in real-world settings, with an emphasis on developing countries. The intent of the review was also to prepare a compendium of IoT systems available in the marketplace applicable to the built infrastructure environments, including costs (where readily available), limitations, and advantages. An assessment of costs was not possible within the scope of this project, in large part because IoT systems, especially in government settings, are not widely deployed—nor are they well understood. With the exception of highly aggregated data on total cost of ownership in some instances, no general information on costs was ascertained.

WHAT IS INTERNET OF THINGS

What Is Internet of Things?

The terms Internet of things and its sibling, Internet of everything, are still relatively poorly understood or defined. The authors of a recent green paper on IoT gathered multiple definitions of IoT (30), which ranged from "there is no universally agreed-on definition of IoT, just as there is not universal agreement that the phenomenon itself is named IoT" (Microsoft) to "a precise, exclusive definition of IoT is not necessary at this point" (U.S. Council for International Business) and "any definition should be flexible enough to adapt as IoT further develops" (Trans-Atlantic Business Council). Other definitions of IoT focused on the attributes of devices and networks. These included "as the growing range of Internet-connected devices that capture or generate an enormous amount of data every day along with the applications and services used to interpret, analyze, predict and take actions based on the information received" (IBM) and "term used to describe the set of physical objects embedded with sensors or actuators and connected to a network" (Center for Data Innovation). Other definitions focused on the "smartness of things" (Center for the Development and Application of Internet of Things Technologies at Georgia Tech) and the ability to "sense, log, interpret, communicate, process, and act on a variety of information or control devices in the physical world" (National Security Telecommunications Advisory Committee).

In this report, we use the term IoT to refer to a system involving **connected devices that gather data, connect with the Internet or local networks, generate analytics, and (in some cases) adapt behavior/responses based on the data/analytics in the network**.

Elements of an IoT System

There are three primary technologies behind IoT:

- Sensors
- Networks
- Analytics

The diagram below shows the connectivity structure of a typical IoT system with the three elements. Sensors collect data from physical or mechanical systems and transfer all data to a central cloud system using networks and connected technologies. Intelligent analytics are then applied to extract meaningful information. Wireless connections from sensors to a gateway are established using short-range wireless technologies such as wireless personal area network (WPAN) and wide area network (WAN) radio. Fixed-line telecommunications or Wi-Fi are generally used to connect gateways to the cloud. Connections in IoT may also be based on mobile technology, using a SIM to connect a device to a mobile network.

Figure 3. IoT Connectivity with Three Main Technological Components

The hardware part of an IoT system can consist of simple devices with sensors that just transmit the data via the network to the storage/processing infrastructure, or they can be smarter high-powered devices and processes.

Sensors

Sensors are electronic devices that sense the physical/mechanical world to generate useful data that is transferred to the Internet through network technologies. A sensor "acquires a physical quantity and converts it into a signal suitable for processing (for example, optical, electrical, mechanical)." Sensor devices can be embedded in everyday physical objects, public infrastructures, transportation structures, and machines used in industrial buildings and factories. See appendix B for examples of sensor types.

Networks (or Connection Technologies)

It is important to note that embedding a sensor in a physical object is not sufficient to form an IoT platform. As described earlier, an IoT sensor device should be able to transmit data over a network. Existing networks are categorized in terms of the range, coverage, and distance that the communication devices can communicate with each other. Digital infrastructure relevant to IoT also includes the following:

- Data centers
- Security and other services layers
- High-capacity computers

Investments in these areas are enablers of IoT growth. Common network technologies are described in appendix B.

Analytics

The billions of sensor devices connected through the Internet generate a huge amount of digital data (so-called big data) that are generally stored in the digital domain using cloud computing services via the Internet. Advanced analytics helps generate meaningful information and actionable intelligence from these huge streams of data. This is an exciting opportunity for policy makers, governments, and industrial business owners to utilize analytics to predict, optimize, and improve business and operations of public infrastructure.

Several big data processing tools, efficient databases, streaming analytics engines, and platforms have been developed to support IoT deployments in real-world applications. Popular analytic approaches include deep learning, crowd analytics, anomaly detection engines, tracking algorithms, and pattern recognition and detection techniques. In addition, artificial intelligence models have been developed for the public or users to interact with IoT technologies. Augmented reality and virtual reality are other techniques that can be considered for human IoT interactions. Edge computing is an emerging data analytic approach that helps with localized decision making, reducing latency/increasing responsiveness, resiliency to network failures, and so on. Despite these developments, it is safe to say that much of IoT data remains underused.

The Analog Components of IoT

Technology by itself does not necessarily lead to growth and prosperity, and this is especially true for digital technologies such as IoT. The 2016 World Bank *World Development Report* on digital dividends notes that digital economy initiatives require a strong foundation, consisting of *regulations* that create a vibrant business climate and let firms leverage digital technologies to compete and innovate; *skills* that allow workers, entrepreneurs, and public servants to seize opportunities in the digital world; and *accountable institutions* that use the Internet to empower citizens.

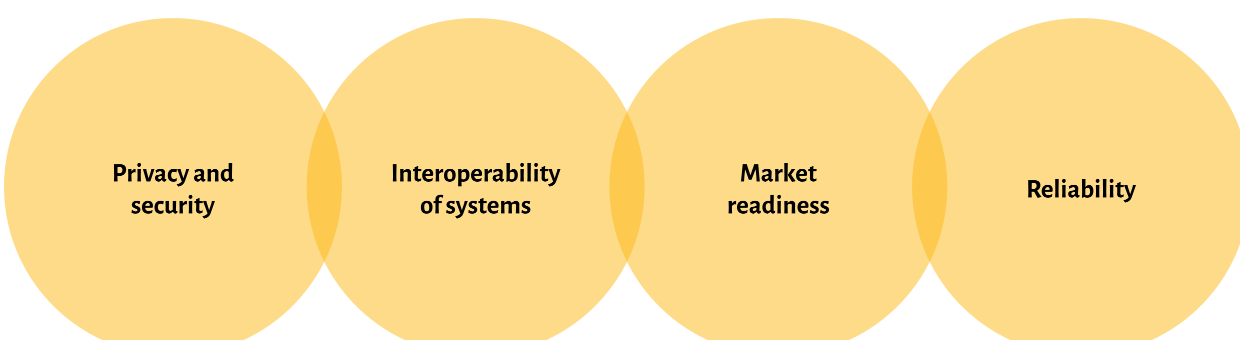
IoT Challenges

For all its promises, IoT implementation still faces a host of technical and nontechnical challenges. In this section, we briefly summarize a few of these.

Technology

IoT tools and technologies are now cheaper, faster, and more easily available than ever before. However, there are still very few examples of large-scale IoT implementations in government. There are many technical challenges:

- **Network coverage:** The required mobile and wireless networks should provide continuous coverage, stable, and reliable connectivity despite the huge demand coming from increased device connections. Limited coverage is often the cause for reduced benefits from IoT applications.
- **Power consumption:** IoT applications depend on devices that operate using electrical energy. Low power consumption is therefore very important to facilitate continuous operation of these devices. Newer IoT devices and applications have begun to explore and exploit energy harvesting techniques to achieve long-term operation of battery-powered IoT devices.
- **Privacy and security:** IoT devices may suffer from privacy and security vulnerabilities. Existing solutions often are not sufficient to address these challenges.
- **Interoperability/standards:** Different IoT systems should coexist without affecting each other. There are, however, only limited wireless standards available to address the connectivity and interoperability of the huge amount of different IoT devices being deployed.
- **Analytics:** As described above, IoT technologies produce a massive data volume that is diverse, random, unprocessed, and unorganized. This presents new challenges and opportunities, and existing analytic techniques often are not able to process, aggregate, and analyze this volume of diverse data.



Privacy and Security

Privacy and security are fundamental IoT challenges, and data protection and cybersecurity are essential components of any IoT strategy. Many IoT devices still suffer from security vulnerabilities and aren't necessarily designed to protect the privacy or integrity of business networks. The Mirai bot that took advantage of vulnerable devices such as digital cameras and DVR players (31) and led to one of the largest denial of service attacks ever is one example of the many existing IoT devices that still suffer from one or more fundamental weaknesses:

- The inability to update the firmware remotely
- Generic passwords that can be easily guessed
- No user nudges to manage their devices for security

It is important to establish forward-looking regulatory standards to guard the security and privacy of data. Most of the current solutions to these issues rely on higher-level computational and memory-intensive processes that tend to be limited in IoT devices. Significant hardware support, such as encryption, authentication, and attestation, and software support, such as run-time self-healing architecture, are required for future IoT devices. It is critical to ensure that only authorized users are allowed to access the data and that the systems are developed with processes and standards and monitored to ensure bad actors cannot exploit the system to access the data or damage the systems, particularly when the IoT systems feed back into the physical world.

Interoperability of IoT Systems

As IoT technologies continue to develop, it is crucial to enable seamless interoperability between IoT systems. Lack of interoperability can lead to disruptions in the network, poor data exchange, and suboptimal performance. Currently, the interoperability of existing standards is still unproven, or still being formulated, making it extremely difficult for IoT devices to function across ecosystems. Several industry consortia, such as Wi-SUN, the Industrial Internet Consortium (32), Open Interconnect Consortium (22), and the Thread Group, have been formed to address existing interoperability issues in IoT systems.

Market Readiness

The lack of market readiness may be one of the biggest barriers in commercializing IoT products and services. Applications that do not require or expect government intervention, such as in Industry 4.0, have been widely adopted. By contrast, despite the innovative IoT technologies being produced, the IoT market remains underdeveloped and unready at scale when government partnership or action is needed or inevitable. An uncertain business environment is the most likely culprit for this. The lack of regulations, policies, or other government indications have left entrepreneurs and businesses unsure of how potential business could be affected in the future by later government action.

An analogy can be drawn with the consumer IoT market. There are multiple brands of personal activity monitors and there is an active market. There are no regulations beyond the traditional electronic safety certifications that are required, so the consumer is creating the market through the demand for these products. Because the government is involved with the G2B or B2G IoT space, the government needs to define the market through regulations and policies. Since those are not defined yet, the risk is not sufficiently reduced or defined for businesses to act (28).

Reliability

The typical consumer electronics life cycle of 2-4 years is not feasible for large-scale IoT. The costs and logistics of updating/redeploying any pieces of an IoT system every 2-4 years can potentially outweigh the value for all stakeholders. Any IoT solution should have a clear annual maintenance contract (AMC) in place to support the devices and services over the lifetime of the system. An AMC will incentivize the system provider to provide devices that will be able to withstand external conditions, their sensors remaining calibrated to ensure proper measurements.

However, given the rapid development/iteration/continued growth of IoT technology, a strategy can be developed that will support the updating/redeployment of the system as new technologies and new approaches are developed to ensure the system is not obsolete and the value from the application is not lost.

IOT ON THE GROUND

IoT on the Ground

What does IoT on the ground look like, especially when it comes to government to business services? What are the goals of different agencies trying to implement IoT-based solutions? What is working and what isn't? How close is reality to the hype? How does the private sector contribute to these initiatives? Or does it? Which technologies have been harder to adopt than others? How are governments grappling with policy implications? And many more questions like these.

In this section, we describe the experience of several cities and jurisdictions around the world. The "cases" aren't comprehensive, but we have tried to convey a reasonably complete picture based on field visits and interviews with a variety of stakeholders in each city. In each locale, we examine the business case for IoT implementation and the government's preparedness for it, look at the actual solutions that different agencies tried to implement, and, finally, try to identify possible lessons learned and results/next steps.

Our choice of cities was influenced by the responsiveness of city officials and by their current exposure in the existing research (we were keen to go beyond the usual suspects to see how deeply IoT may have penetrated into cities that weren't necessarily the most visible early adopters). Eventually, we would like to validate the findings/recommendations in this report with a larger group of cities.

United Kingdom
Milton Keynes
Bristol

Germany
Hamburg Port Authority
Ludwigsburg
Mannheim
Reutlingen

Estonia

Kazakhstan
Astana

Canada
Mississauga
Technical Standards and Safety Authority, Toronto
Ontario Tire Stewardship

United States

Japan
Kobe City

United Arab Emirates
Dubai

India
Rajkot

United Kingdom

The Business Case

"A world-leading digital economy that works for everyone" is the stated goal of the U.K. Digital Strategy (33), which "sets a path to make Britain the best place to start and grow a digital business, trial a new technology, or undertake advanced research." The strategy commits Britain to "work closely with businesses and others to make sure the benefits and opportunities are spread across the country." IoT is an important part of this approach. As the government's chief scientific advisor Sir Mark Walport noted in a 2015 GO-Science report (34), "*We will only get the best from these technologies if researchers, business leaders and government work together, to ensure they deliver the greatest possible benefit to the public.*"

> *"The opportunity to develop new technologies for smart cities in the UK is massive. We want to make sure that we are at the forefront of this digital revolution ..."*
> —Rt. Hon. David Willetts, Minister of State for Universities and Science *(117)*

IoT in Action

Innovate UK is an executive nondepartmental public body sponsored by the U.K. Department for Business, Energy, and Industrial Strategy (35). Innovate UK (36) has set up and now oversees 11 catapults. Catapults (37) are not-for-profit, independent technology and innovation centers that connect businesses of all sizes with the United Kingdom's research and academic communities.

Each catapult specializes in a different area of technology. All offer specialized facilities to help businesses and researchers solve specific problems. This can help them develop new products and services on a commercial scale. Both the Digital Catapult (38) and Future Cities Catapult (39) focus on supporting businesses and cities through digital innovation.

Digital Catapult launched Things Connected (40) in September 2016, an innovation support program targeting U.K. businesses that wish to leverage the capabilities of LPWAN technologies. Things Connected provides start-

AT A GLANCE

Policy references
U.K. Digital Strategy
Technology and Innovation Futures 2017

Implementing agencies/programs
IoTUK
Innovate UK
Catapults

Focus areas
Future cities
Health

Data
IoTUK Nation Database

Technology
Supporting low-power networks

Financing
Department of Business, Industry and Sport (U.K. government), academic institutions, and industry

Capacity development
Best Practice Guides

Related intiatives
Multiple ongoing projects

Jobs
Not known

ups, small businesses, and developers improved access to LPWAN networks that cover London. It supports the deployment of sensors, applications, and services and enables businesses to develop IoT products and services. The initial London-based network will use 50 LoRaWAN base stations scattered across the city to provide a LPWAN test bed. Things Connected also aims to include other evolving LPWAN technologies in its rollout. Areas of potential application include infrastructure provision, traffic and transport services, energy management, and environmental sensing. To deliver Things Connected in the capital, Digital Catapult funds the project in collaboration with industry partners and academia.

In 2014/15, the Digital Economy Unit (then under the Department of Business, Industry and Skills), Innovate UK, the Engineering and Physical Sciences Research Council, and other partners, in informal consultation with industry and the research community, developed a business case for research and innovation projects using IoT, focusing on the public sector (health and cities). The March budget of 2015 set aside £40 million for such IoT projects, of which £32 million was allocated to the Department of Business, Industry and Sport and the remaining to the Department of Health as sponsors for projects in health and social care. The £32 million (41) helped establish the IoTUK (41) program.

"We will only get the best from these technologies if researchers, business leaders and government work together."

Powered by the Digital Catapult and the Future Cities Catapult, IoTUK (41) is a national program of activities that seeks to advance the United Kingdom's work in the IoT space and increase the adoption of IoT technologies and services throughout businesses and the public sector. It was launched as part of the government's above-described investment in IoT.

The IoTUK program has the following aims:

- U.K. academic research excellence in IoT
- More U.K. research and development (R&D) in IoT applications
- U.K. business competitiveness in international IoT markets
- Adoption of IoT applications by the U.K. public sector and industry

For this report, we examined the following programs supported by IoTUK:

- City of Milton Keynes
- Bristol City Council
- Digital Catapult
- Future Cities Catapult
- Bristol Is Open
- University of Bristol

In addition to the programs supported by IoTUK, and to get some perspectives directly from industry and businesses, we also reviewed the IoT experience of Gas Tag Limited (42) and CogDEM (43). Gas Tag is a start-up company experimenting with an RFID tag-based technology that helps validate the credentials of engineers and then prompts them to record data and photos relating to all gas works they undertake, including installations and maintenance. CogDEM, the Council of Gas Detection and Monitoring, represents the gas detection, gas analysis, and environmental monitoring industry.

Challenges/Lessons Learned

According to the report *Mapping the IoT Nation*, published by IoTUK (44), the IoT marketplace is currently dominated by large, multinational businesses with deep pockets, assertive marketing messages, and incumbent market share to protect. There is an overreliance on scale economics as a success factor in selecting IoT partners, which keeps costs of entry unreasonably high for small players. A lack of standards and interoperability further restricts market activity to players with scale big enough to set their own standards. Thus, the organizations proving successful are those for whom there is a structural disincentive to disrupt—and consequently the development of cross-cutting technology, platform, and infrastructure plays is held back.

Several examples of good practices were noted in the examined programs (more details in the individual case studies that follow):

- The creation of individual catapults and independent facilitation bodies such as IoTUK have helped bring academia, industry, community, and government together.
- Establishing data hubs such as the one in Milton Keynes (that is like X-Road in Estonia) are intended to create an efficient flow of data.
- Bristol's early investment in building its own fiber-optic infrastructure resonates with an identical strategy for the city of Mississauga in Canada.
- Visualizing and prioritizing the use of IoT solutions to address immediate needs of the city, including creating growth using a top-down approach, demonstrate the importance of vision and leadership as a key element for success.
- A grassroots-driven agenda in Bristol appears to be a critical success factor for that city, which has a particularly evolved citizenry. The lack of adequate pilots and case studies appears to inhibit any significant progress with key policy topics such as regulatory implications on data privacy, ownership, and sharing.
- No concrete examples were observed that indicated evidence of reduced burden reduction on businesses by government agencies, nor were there examples wherein regulators used IoT solutions as tools for alternate compliance verification. The Cambridge City Council, a local authority responsible for food safety inspections, has approved the use (14) of an IoT-enabled monitoring process as an acceptable food safety management system for compliance purposes; however, the widespread acceptance of this process across the country is not evident.

Results/Next Steps

The government has taken a long-term view of the IoTUK program and acknowledges that some of its impacts might not be realized until beyond the lifetime of the public investment. Nevertheless, the Department for Digital, Culture, Media and Sport (DCMS), which is now coordinating the program, is planning an evaluation of the program and has commissioned a scoping study and baseline. This will help clarify program aims and develop metrics.

Milton Keynes

Policy	Capacity	Data	Tech	Top Support	PPP	Business Models	Pilot Space

The Business Case

Milton Keynes is one of the fastest growing cities in the United Kingdom and is recognized as an economic success story (45). The city has identified the challenge of supporting sustainable growth without exceeding the capacity of the infrastructure while meeting key carbon reduction targets as a key issue. MK:Smart was established in 2014 as a large collaborative initiative, partly funded by HEFCE (Higher Education Funding Council for England) and led by the Open University, with the aim to develop innovative solutions and to support sustainable economic growth in Milton Keynes. MK:Smart has a core steering group and is supported by academia, business partners, and the Digital and Future Cities catapult programs.

IoT in Action

Central to the project is the creation of the MK Data Hub (17), which supports the acquisition and management of vast amounts of data relevant to city systems from a variety of sources. According to Geoff Snelson, director of strategy and futures at the city of Milton Keynes, "understanding data is at the heart of all that the city is doing." The MK:Smart collaboration partners have invested in building the physical installation for the data hardware and built the software as part of the data hub, with a considerable amount of computing power based in Milton Keynes itself.

> *"Understanding data is at the heart of all that the city is doing."*

MK:Smart was among the first city-based projects (46) that tried to understand data at the heart of a smart city. The data hub receives static open city data together with dynamic data from sensors owned by individuals, government, and private firms: data about energy and water consumption, transport data, data acquired through satellites, social and economic data sets, and crowdsourced data from social media or specialized apps. Building on the capability provided by the MK Data Hub, the project is innovating in the areas of transport, energy, and water management, tackling key demand issues. Anyone can establish an account and access the data for use, though some data are restricted to specified users. Examples of current applications of IoT are shown in figure 4, panel A.

AT A GLANCE

Policy references
U.K. Digital Strategy
MK Vision 2050

Implementing agencies/programs
MK:Smart

Focus areas
Transport, energy, water management

Data
MK Data Hub

Technology
Public and private sensors
Weather, traffic, pollution, water, temperature, humidity, soil sensors

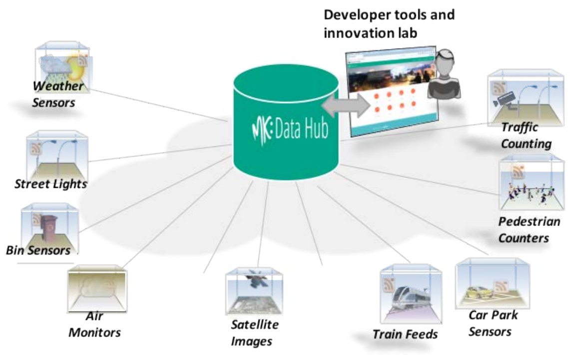
Financing
Public-private partnership

Capacity development
Open University/massive open online courses; enterprise training

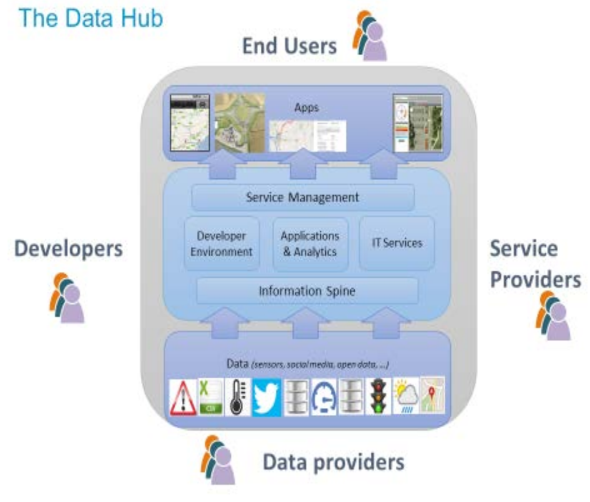
Related initiatives
Smart garbage bins, water monitors, electric vehicles, motion maps for public transit

Jobs
Not known

Figure 4. MK Data Hub



A: Current Applications



B: Data Policies, Quality, and Trading

Source: Geoff Snelson, "Creating a Smart City Innovation Eco-System in Milton Keynes."

The scope of the MK:Smart programs exceeds purely technical solutions and incorporates a number of educational, business, and community engagement activities. Through its Apex Suite (47), a business engagement platform that includes both physical facilities (based at University Campus Milton Keynes (48)) as well as remote facilities allowing access to the MK Data Hub, the city has engaged with over 90 small and medium enterprises (SMEs) to help them

- develop case studies involving smart city solutions;
- understand how connected projects can help them;
- understand how complex and big data can be of use to them; and
- build a service management platform allowing commercial activities (for example, buying and selling data sets) to be integrated into MK:Smart's MK Data Hub, organizing hackathons, presenting short courses (for example, the Postgraduate Certificate in New Enterprise Creation (48)), and working with students who are looking to transform their ideas and concepts into working solutions.

In addition, MK:Smart has teamed up with industry to deliver the Urban Startup Lab (49), a course that will bring entrepreneurs together to create new products and services in a smart cities context.

Through a citizen innovation (50) platform, there is an ongoing citizen engagement drive toward looking at IoT-based innovations to making Milton Keynes and smarter city.

Challenges/Lessons Learned

Data are at the heart of the MK:Smart program, and there is still considerable ongoing discussion about the most appropriate policies to manage the access and use of data. Currently, the data providers are setting the data policies and the users sign up to the terms and conditions attached to the individual data sets. The data hub creates a platform for integration. Some data sets may be for "closed" collaborations. While a flexible data-trading model exists, it is not currently being used. Service level agreements are being established for IoT to ensure data quality. A technical management forum deals with issues and concerns regarding interoperability. Data-related issues, including privacy and security, are currently being handled using a permissions and restrictions–based approach.

Results/Next Steps

The city is committed to providing funds for MK Data Hub for the next two years. Technology partners currently match this funding through in-kind contributions. Major corporations, including those in the auto sector, have made long-term commitments as well. Developing investable business models, delivering benefits at scale, and expanding use cases across more services are important ongoing priorities. A major deployment of 2,500 traffic movement and parking video sensors to provide full coverage of the city is now funded and under way. This will be one source of data for an integration platform at the heart of a new mobility as a service test bed project. At the moment, the more engaged and interested departments in government are those with focuses on environment, transport, health, and social care services. This study did not make a formal assessment of the results of the work that has been carried out, but we do see the opportunity for a follow-up exercise of consultation with all the target stakeholders in the future.

Bristol

Policy	Capacity	Data	Tech	Top Support	PPP	Business Models	Pilot Space

The Business Case

Bristol, home to almost 450,000 city residents and more than a million people across the broader metropolitan region, was recently voted the best place to live in the United Kingdom (51). It has the most skilled workforce of any English city, and it boasts two world-class universities. The Bristol region has the largest cluster for tech and digital employment in the United Kingdom outside of London. The area is favored by start-up businesses and has particular strengths in software development, data management, and analytics.

According to Kevin O'Malley, Bristol's city innovation team manager, "Bristol is a smart, inclusive and playable city that is organically advancing as opposed to having the smart city agenda dictated from the top down." The mayor's vision is linked to the city's corporate strategy, which in turn is supported by the City Innovation strategy.

> *"A smart, inclusive and playable city that is organically advancing as opposed to having the smart city agenda dictated from the top down."*

The city recognizes a resilience value in the "smart" offering and is guided by the principle that every resident should have access to technologies that are essential for their productivity, well-being, and enjoyment. The city believes this proposition empowers residents, communities, and businesses to innovate and develop new smart capabilities to better serve their social and economic needs, ultimately enabling new approaches that will help the city to prosper.

IoT in Action

Bristol is developing an open programmable city through Bristol Is Open, a joint venture between Bristol University and the City Council. Bristol Is Open works with the technology, media, and telecommunications industries; universities; local communities; and local and national governments to develop and pilot IoT research projects. Long-term partners can be invited to join an advisory panel that guides the joint venture on the evolution of the

AT A GLANCE

Policy references
U.K. Digital Strategy
Bristol Resilience Strategy
Bristol Corporate Strategy

Implementing agencies/programs
Bristol Is Open
Connecting Bristol

Focus areas
Connected homes
Public health
Community-based resilience projects

Data
Data Dome

Technology
Own fiber-optic network for experimentation; working on 5G wireless technologies

Financing
Bristol City Council
European Network of Active Living Labs
Knowle West Media Centre
Industry

Capacity development
Knowle West Media Centre
Open University

Related initiatives
Citizen Sensing
Damp Busters Project
Girls Making History

Jobs
Not known

network, the creation of multipartner experiments, the services that underpin the infrastructure, and the publicity and events surrounding the project.

This digital infrastructure is the foundation for its IoT initiatives. The infrastructure includes fiber in the ground, a mesh bouncing from lamppost to lamppost across the city, and a mile of experimental wireless connectivity.

The Internet of things mesh network (52) is a "canopy of connectivity" across most of the city, created from access points mounted on 1,500 street lampposts. It uses a range of self-regulating advanced wireless technologies for extending connectivity, connected to a core fiber ring. It is designed for low-bandwidth applications, but it can accommodate a large number of sensors spread around the city. Small sensors, including smartphones and GPS devices, supply the three new fast networks in the center of Bristol with information about many aspects of city life, including energy, air quality, and traffic flow.

The mesh is designed to enable IoT devices to be implemented at scale, offering test facilities to network operators, application developers, and manufacturers of IoT devices. A city operating system dynamically hosts this machine-to-machine communication, allowing the development of a wide range of applications. Once the new networks are fully functional in the city center, they will be extended to other regions, over the next three years. These networks are for research and development projects; they will not provide free or commercial broadband or Wi-Fi. However, there will be opportunities for people to join one of the experimental projects if they want to.
The active, wireless, and mesh network is technology agnostic; it was built on open network principles, using software-defined network technologies that enable network function virtualization.

Source: Kevin O'Malley: "Bristol: Smart and Inclusive City"

The City Council's City Innovation Team looks to pilot the potential of the latest smart technologies to ensure that Bristol becomes a resilient, sustainable, prosperous, inclusive, and livable place, using the Bristol Is Open test bed to rapidly deploy experiments at city scale. Their work is delivered in partnership with other public sector agencies, the private sector, and the community and their representatives.

Living Lab

Bristol is one three European cities to receive support from the European Commission as part of **REPLICATE**—**Re**naissance of **Pl**aces with **I**nnovative **C**itizenship **A**nd **Te**chnologies—which is a research and development project that aims to deploy integrated energy (53), mobility (54), and information and communication technology (ICT) solutions (55) in city districts.

The project, led by the City Council employs the principles of the Living Lab to engage and include the broadest range of perspectives and inputs. Bristol's Living Lab is managed by the Knowle West Media Centre as a place where citizens, artists, technologists, businesses, and public sector organizations can come together to co-create ideas and to understand how digital technologies can be used to meet local needs.

One of the successful projects deployed using the Living Lab approach has been the Damp Busters pilot, a damp-monitoring initiative in rental accommodations (56) to address potential mold-related health issues. The project has co-designed and developed a frog-shaped sensor detecting moisture and temperature in the environment.

The Bristol Living Lab is also part of SPHERE (Sensor Platform for Healthcare in a Residential Environment). SPHERE is a community of nearly 100 researchers who have developed a number of sensors that help track the risks of obesity, depression, diabetes, stroke, falls, respiratory conditions, and cardiovascular and musculoskeletal diseases by monitoring behavior in homes.

Source: Bristol is Open

Data Dome

Housed in At-Bristol's Planetarium, the Bristol Data Dome connects to a high-performance computer at the University of Bristol via a 30Gb/s fiber link. The combination of display, on-demand network capacity, and computing power provides an opportunity to visualize IoT-generated data experiments, creating interactive virtual reality environments and providing individual audience members with the ability to make their own assessments.

In addition to public visualization and demonstration of city data, the City Council has made a host of data publicly available through an open data portal.

Challenges/Lessons Learned

IoT-based initiatives in Bristol appear to be influenced largely through a combination of visionary leadership and grassroots-based collaborative partnerships, and supported by early investments in infrastructure (including its own fiber-optic network). This top-down/bottom-up integrated approach is helping the city organically evolve into a smart city. IoT initiatives are largely citizen-centric with an active participation of start-ups in a variety of projects.

Results/Next Steps

As with most other similar initiatives, clarity around sustainable business models for smart city interventions remains a work in progress. However, through the REPLICATE project Bristol plans to evaluate and test a range of sustainable smart city business models over the next two years with the aim of developing a suite of models that can be applied effectively in different contexts.

The smart city infrastructure in Bristol may continue to grow and develop while being used by research institutions, businesses, and the public sector. As the impact of this investment is realized for Bristol, the research and development network will be extended to the wider city region—to Bath and parts of North Somerset and South Gloucestershire—over the next three years, creating a diverse city-regional test bed.

Germany

The Business Case

In 2014, Germany released its *Digitale* *Agenda* (57) (referred to as the Agenda), which documents three primary objectives using technology:

- Growth and employment
- Access and participation
- Confidence and security

The Agenda includes a number of measures to guide the government, reflected in laws like the General Data Protection Regulation (58) and initiatives like the Plattform Industrie 4.0. (59). The Agenda clearly states that the digitization of innovative public services and processes facilitates the further opening up of state geodata, statistics, and other data (open data).

Plattform Industrie 4.0 (8) maps out how IoT projects can advance industrial technology and capacity, creating a new competitive advantage for Germany.

IoT in Action

Led by the federal Ministries of Economic Affairs and Energy and of Education and Research, and with stakeholders from every market, Plattform Industrie 4.0 has developed standards and services to help any German company enhance their Industry 4.0 capabilities. This includes a compendium of services as well as a growing map that currently shows over 500 projects of how companies are using Industry 4.0 technology. But perhaps the most impactful piece to come from the platform is RAMI 4.0 (Reference Architectural Model Industry 4.0) (60).

RAMI 4.0 addresses the need for interoperability. A working group—consisting of key stakeholders from automation, manufacturing, government, and academia—developed RAMI 4.0 as a representative guideline for how developers should build their product to be ready for the interconnected reality of German production. RAMI 4.0 is not law, but rather a reference meant to promote harmonized technology that can readily work together (61).

AT A GLANCE

Policy references
Digitale Agenda
Regierungsprogramm Digitale Verwaltung 2020

Implementing agencies/programs
Digital Government (Summary)
National Action Plan for the Implementation of Open Data
Internet of Things/Industrie 4.0
Plattform Industrie 4.0

Focus areas
Open data
Data protection regulation
Interoperability of devices

Data
Open data

Technology
Focus of broadband connectivity

Financing
Public-private partnerships

Capacity development
Fraunhofer Fokus

Related initiatives
Industry 4.0
Living Labs

Jobs
9 jobs added for every 10 ICT jobs created

Challenges/Lessons Learned

The German experience has produced numerous lessons:

- **The pros and cons of consensus.** Germany's decision to create a working group to create standards allows for consensus-based decisions across all stakeholders. For example, RAMI 4.0 does not force companies to change by law. There is no dictate for future production, nor is there any favored solution. The result is an ideal that anyone could implement. On the downside, however, consensus solutions and architecture design can take considerable time to develop.

A consensus-based, research-accompanying standardization process is essential for the rapid realization of more highly digitized industrial manufacturing processes.

A cooperative approach to infrastructure development. Forty-six percent of the German economy (SMEs) still does not see the impact of digitization. This is largely because broadband connectivity is an infrastructure issue: Germany is one of the world's top five economies, but it ranks 28th for broadband connectivity. With respect to digital technology and IoT, the federal government is focused on its own infrastructure and internal development. There is a conscious effort to overcome the boundaries that currently exist between federal states and central government. While the states/local authorities have built their own digital technologies, they require the federal government to remove regulatory barriers.

- **Focus on digital literacy.** The lack of a proper curriculum for public sector education involving digital transformation (except with regards to privacy and security) is a barrier. Groups like Fraunhofer Fokus focus on communication and education, including explaining technologies for government, reviewing frameworks/regulations, and explaining implications to governments.

- **Data challenges remain.** Data ownership is currently very fragmented and no business models have yet emerged with respect to monetization of data. Smart city applications currently focus on open data and transparency. A study (62) indicates that half of the IoT companies are in Berlin (most of them are not more than five years old), but their focus is on application software development for international clients.

Results/Next Steps

The federal government has created intelligent networks to help industry, as they need some room for experiments. Special regions or Living Labs are being built for experiments in IoT projects. Special clauses, including exemptions in regulations, are being introduced for experiments. Within this framework, Industry 4.0 partners are working to establish standards, help develop regulations, conduct research to address barriers between federal states and the central government, and develop proofs of concept driven by the market and representative of a bottom-up approach.

In addition, through its Digitale Agenda directive, the German government aims to strike a balance between relaxing and increasing regulations to meet the three broad objectives of growth and employment, access and participation, and confidence and security. On one hand, it is keen to create a regulatory framework that supports investment with reforms like the relaxation of government procurement requirements. On the other hand, the federal government seeks strict data privacy and ownership regulations for both individuals and industry, including net neutrality, IP laws, and a harmonized European data protection law,[1] which goes into effect May 2018.[2]

[1] *Digitale Agenda 2014-2017*, Federal Government of Germany, August 2014.

[2] GDPR Portal: Site Overview, EUGDPR, www.eugdpr.org

Hamburg Port

Policy	Capacity	Data	Tech	Top Support	PPP	Business Models	Pilot Space

The Business Case

The Hamburg port (63) occupies about one-tenth of the total area of Hamburg and is the backbone of business in the city. An institution under public law, the Hamburg Port Authority (HPA) is in charge of infrastructure management in the port.

HPA has set the goal of developing the port of Hamburg as a **smartPORT** (64) with a focus on logistics and energy. The introduction of innovative mobility concepts, renewable energy sources, and the interlinking of energy-generating plants and industrial plants to promote the efficient use of resources are at the forefront of HPA's approach. The approach calls for the development of an intelligent infrastructure using technologies such as IoT to collect, analyze, and process data, to ensure transparency at all stages of the supply chain and enable early intervention for traffic management.

IoT in Action

HPA began upgrading its core information technology infrastructure in 2009 (65), developing sensor-based applications to monitor land- and water-based traffic, including sensors in roadways and bridges.

The road sensors are connected to determine traffic speed, congestion, and significant issues. The system (65) also monitors vehicle weight—which helps determine how much traffic has crossed a bridge, informing bridge design, maintenance, and renovation schedules—and communicates with drivers about delays and traffic patterns. Sensors also provide parking information to drivers via mobile applications that take advantage of GPS-enabled location data. This system has reduced the time drivers spend looking for parking.

The Vessel Traffic Service Center manages data collection for waterways, which includes radar and AIS (Automatic Identification System) to monitor incoming ship traffic. HPA is currently piloting a solution that would integrate with roadway traffic data to help manage traffic disruptions that may occur when ship traffic requires bridge closures around the port area.

HPA is also now piloting a number of IoT projects for rail monitoring and inspections, environmental and flood monitoring, road/rail/bridge maintenance, and traffic and parking management.

AT A GLANCE

Policy references
Digitale Agenda
HPA Environmental Policy

Implementing agencies/programs
Hamburg Port Authority (HPA)

Focus areas
Logistics
Energy

Data
Vision for a central management hub

Technology
CISCO, Kiwi Security, T-Systems International, Swarco, Philips, WPS Solutions, AGT International, IBM, and many more

Financing
Self-funded

Capacity development
8,9 Mio. TEU https://www.hafen-hamburg.de/de/statistiken/containerumschlag

Related initiatives
Several

Jobs
261,000 jobs dependent on Port

Challenges/Lessons Learned

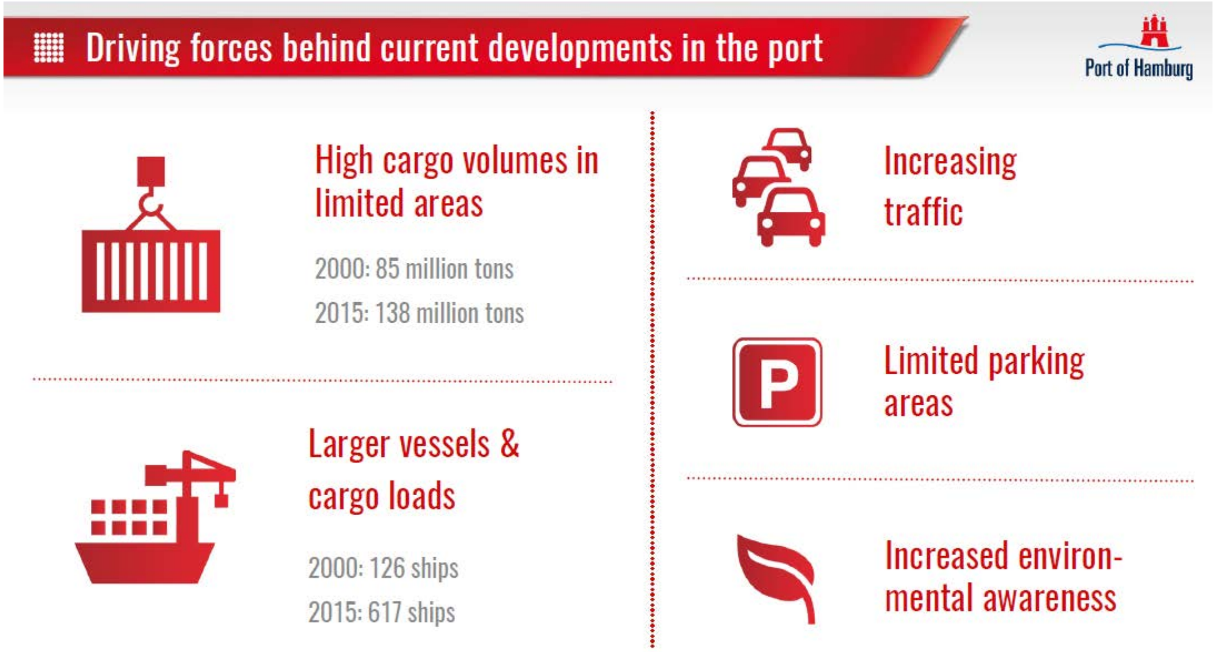
According to Cisco, which looked at HPA as part of a wide analysis on the economic benefits of IoT for the public sector (65), one of the biggest challenges has been demonstrating tangible results of technology, and communicating them in terms the general public will understand. One strategy to address this has been to build small prototypes to show incremental benefits. This allows HPA to highlight project results to generate momentum and support larger implementations.

Another challenge has been integrating various technologies and initiatives. Different systems, if kept separate, provide a fragmented picture. Pulling the systems together is crucial to building an overall perspective on port operations. Finding heterogeneous technologies, and integrating technologies into the overall plan, has been more difficult than originally anticipated.

Results/Next Steps

HPA is attempting to integrate additional sensors into its systems, based on initial findings. It wants to place additional and more capable sensors in key hot spots to gain a deeper understanding of what is taking place. HPA also wants to learn more about who is moving where, and when they are moving. In order to bring HPA into the real of big data, HPA is currently looking at auto registrations using sensors and images. These sorts of higher-level intelligent applications appear to be the future for HPA and are already in the planning phases. Lastly, among various pilots and test cases that are ongoing, the environment is an area that HPA is beginning to explore, including a smart street-lighting program. HPA views this as another infrastructure building block necessary before moving into higher-level intelligent systems.

In the future, HPA plans to expand and upgrade the system so that all the information—sensor data, video, photos, and other pieces of data—feeds into a central management hub, to help build an intelligent system that can quantify and manage the different systems of transport.



Source: Port of Hamburg

Ludwigsburg

Policy	Capacity	Data	Tech	Top Support	PPP	Business Models	Pilot Space

The Business Case

Ludwigsburg faces challenges common to several other cities in Germany. These include local ones like demographic change and pollution caused by high levels of particulate matter emissions as well as large-scale issues such as climate change. The city also seeks to offer an attractive environment for inhabitants and a competitive business environment.

Ludwigsburg has responded by establishing an innovation network called Living LaB Ludwigsburg, made up of partners from the city administration, industry, and research institutions that work together in a cooperative manner. The aim of this cooperation is to develop innovative solutions to improve the quality of life. To do so, the city focuses on user-centered, digital transformation and provides an urban test ground.

To support the innovation process, the Living LaB (13) was set up in March 2016. This unit is distinctive because of (1) its makeup, with representatives from the municipality, industry, and academia; and (2) its integration directly into the municipal apparatus. In conjunction with other municipal departments, the Living LaB identifies needs, conceptualizes innovative solutions with the network and municipality, and supports the pilot implementation. All Living LaB activities foster the city's strategy for a sustainable urban development. The underlying development plan was developed in a participative process with citizens of the city.

IoT in Action

A key element of the digital transformation and the Living LaB activities in Ludwigsburg is the **Smart City Cloud** and **Smart City Dashboard**. The cloud aggregates and interfaces data that is (1) already available within the municipal apparatus (open data); (2) generated through Living LaB and other municipal projects (for example, measuring of indoor air quality in public buildings, environmental air quality, smart lighting, river and flood monitoring, waste bin filling levels); (3) from local businesses (for example, opening hours, portfolio, special offers) and tourism (for example, events); and (4) of general interest (for example, weather). The Smart City Dashboard offers user-specific access to provided information and data sets. The city's IT community is encouraged—for example, through active

AT A GLANCE

Policy references
Digitale Agenda

Implementing agencies/programs
City of Ludwigsburg

Focus areas
Energy
Mobility
Architecture/construction
IT
Public participation

Data, e.g.
Parking space
Air quality
Road quality
River water levels
Waste bin filling levels
Energy grid

Technology
Different

Capacity development
Co-creation makathons

Jobs
Not known

participation in hackathons and makathons—to elaborate with this data (for example, develop apps) and initiate projects that further create data (for example, create an own sensor network to measure air quality or bicycle routes).

Ludwigsburg tests sensors to **identify the availability of free parking spaces** in the city via smartphone or a navigation device. At Groenerstraße, the company Bosch has installed test sensors in the ground. Their data will be sent via app to car drivers. Related projects are currently under way testing **seamless parking** (for example, reservation and payment).

The **intelligent lighting solutions** (23 installed LED street lanterns) will automatically dim and only light up when someone approaches. These intelligent street lamps are projected to save 60 percent on energy costs. Optionally, the lights can serve as a WLAN point, as a charging station for electric vehicles, or as an emergency call facility.

A **smart grid system** is being tested to optimally coordinate consumption and supply. The prerequisite for this is that the energy from the various sources can be collected in a single place and distributed smartly from there. Per the planned design, software will tell how the weather will be—and thus the expected energy consumption. It will also know where to get the energy from: photovoltaic sources, wind power plants, or combined heat and power plant.

Furthermore, a number of makathons, in which participants can share their expertise to create innovative solutions for and with the city of Ludwigsburg, are planned in 2017 and 2018 to spur **co-creation in the context of the digitalization of urban spaces**. This can be understood as capacity development for inter- and transdisciplinary groups with an interest in local urban development. Future scenarios will be made partly visible through augmented reality and include IoT-based solutions.

Challenges/Lessons Learned

Many IoT technologies and concepts have been tested or are under preparation to be tested and further improved in a real-life environment in Ludwigsburg. In this context, a mind-set that welcomes being part of innovation processes is central to the projects' success. Challenges occur, for example, in the matching of actual current city demands and solutions that fulfill the criteria to be tested under the given conditions in an urban environment as well as the commitment to cooperatively finance the test scenarios.

Results/Next Steps

To develop and deploy the digital transformation in conjunction with the sustainable development concept of Ludwigsburg, the municipality has set up a Digitale Agenda. The city administration of Ludwigsburg believes that to achieve its objectives, a sophisticated **digitalization strategy** is a prerequisite. How this can be integrated with the sustainable development plan consisting of 11 master plans, which form the strategic foundation and the frame of reference, is not yet decided.

Mannheim

Policy	Capacity	Data	Tech	Top Support	PPP	Business Models	Pilot Space

The Business Case

Mannheim—where Carl Benz invented the automobile in 1885—is active in all areas of urban sustainability and is consistently bringing relevant processes into the economic, ecological, and social activity of a smart city. Like many other cities, Mannheim faces several challenges, including climate change, pollution, demographic shifts, migration, lack of qualified professionals, and area shortages (availability of military conversion areas).

The city's excellent infrastructure is a crucial factor for the companies' investments, and the city's continued focus on energy efficiency, smart grids, and climate change initiatives using smart technologies such as IoT is seen as critical to maintaining its status as a smart city.

IoT in Action

IoT-based developments/pilot projects in the dynamic smart city of Mannheim include:

Climate Protection

Under the heading Blue City Mannheim, a modern district for energy efficiency, smart grids, and electro-mobility is being developed in the former U.S. military installation **Benjamin Franklin Village (BFV)**, with living space for up to 10,000 people. Plans call for jobs to be created near the residential zone, which is close to a large wooded area yet still well connected to the city thanks to public transport.

The vision is to create an integrated, energy-efficient neighborhood development with new public and private transport options, greater use of renewable energy managed using intelligent systems, architectural innovation, and new business models to support implementation.

Energy Technology

MVV Energie, a company based in Mannheim, is working on Modellstadt Mannheim (Model City Mannheim, also known as moma), developing an "Internet of energy" that will allow consumers to adapt their energy requirements automatically across different renewable sources, such as wind or solar.

AT A GLANCE

Policy references
Digitale Agenda
List

Implementing agencies/programs
Blue City Mannheim

Focus areas
Mobility
Energy efficiency
Smart grids

Data
Not known

Technology
Not known

Financing
Public-private partnerships

Capacity development
Not known

Related initiatives
Modellstadt Mannheim

Jobs
Not known

moma was one of six projects chosen to participate in Germany's E-Energy program in 2006. The program was established to meet the need for new ICT technologies in the energy industry. moma is designed to increase energy efficiency and integrate renewable energy supplies through a combination of real-time energy pricing and smart home automation.

Transport Technology

Leading this sector on Mannheim's streets is the PRIMOVE bus. Since June 2015, two electric buses from Swiss manufacturer Hess have been undergoing tests in real street t raffic. They are equipped with wireless charging technology and a compact and fully integrated propulsion system. Bombardier Transportation, together with local partners, developed the contactless charging technology wherein electricity is transmitted via charging stations that are located at several selected stops. This pilot project is also gathering data from sensors that will further research in the field of sustainable urban mobility, including enhancing the passenger experience.

Framework Franklin
including Masterplan blue_village_franklin

- Definition of „blue_village" as one of five brands in the commercialization strategy
- Determination of ambitious objectives (e.g. energy efficiency, decentralized energy management)

	Minimum value	Target value
Housing (new buildings)	EffH 55	EffH 40 / Passive House Standard
Housing (existing buildings)	EnEV for new buildings	EnerPHit

- Definition of measures fostering e-mobility (including Smart Grid Integration)
- 11 Lighthouse Projects for energy and e-mobility

Source: Stadt Mannheim: Rahmenplan: Benjamin Franklin village

Reutlingen

Policy	Capacity	Data	Tech	Top Support	PPP	Business Models	Pilot Space

The Business Case

Eleven different Fraunhofer institutes, 14 cities of varying sizes (including Reutlingen), and 22 companies engaged in activities from automotive development to urban planning have come together to create the innovation network **Morgenstadt: City Insights** to collaboratively conceptualize and realize the future of an integrated, sustainable, livable, and resilient city of tomorrow. The objective of Morgenstadt is to help cities best utilize and help define this transformation process, with the aim of creating more sustainable, livable cities.

IoT in Action

The project "Smart Urban Services: Data-driven Service Development for Urban Value Creation Systems" connects different city subsystems currently regarded separately—for example, mobility, logistics, health, environment, commerce, and citizen services—to exploit the emerging potential for service innovation by designing a more integrative and collaborative urban value creation system. To set up the smart services, a sensor-based platform is being designed to link the various subsystems and the urban authorities that operate them, which then will be implemented as a prototype.

In Reutlingen, one of the project's two partner cities, the project proposes to distribute sensor networks in the city that will be able to closely follow urban life (66). Their "insights" could enable a wide range of improvements for citizens, from the local shopping app and mobility tips to road cleaning and the elimination of public waste containers "on demand."

AT A GLANCE

Policy references
Digitale Agenda
Morgenstadt

Implementing agencies/programs
Fraunhofer Institute
City of Reutlingen

Focus areas
Retail sector
Climate change and supply chains
Traffic management

Data
Not known

Technology
Not known

Financing
Federal Ministry of Education and Research

Capacity development
Not known

Related initiatives
Morgenstadt Initiative

Jobs
Not known

Within Reutlingen, the following potential application areas have been identified as the project focus:

	Goals	Solution
Retail services and tourism	‣ Improvement of the competitiveness of downtown retail ‣ Adjustment of the framework (dynamic retail) ‣ Integration of retail services with tourism, etc. (shopping day trips)	‣ smaRT city App ‣ Individualized and data-based provision of information ‣ Personalized products and services based on sensory data
Optimizing the attractiveness of the city	‣ Increasing the attractiveness of the cityscape ‣ Road maintenance, disposal, noise mapping ‣ Efficient organization through integration: improving interfaces between stakeholders ‣ Event management: targeted information provision	‣ Planning routes for garbage disposal according to need, based on level and movement data as well as predicted filling speed ‣ Distinguishing between full and blocked (underfloor) waste containers
Traffic and environment	‣ Handling of increased traffic ‣ Reduction of pollutant and noise pollution ‣ Improved traffic flow	‣ Traffic programs of the light signal systems ‣ Evaluation of the transport programs with regard to environmental pollution ‣ Integrated parking and traffic management

Challenges/Lessons Learned

System solutions are facing major challenges in the field of technological implementation, especially in the urban environment:

- Challenges to integrate and harmonize different subsystems involved in system logics
- Technical challenges due to different basic technologies and nonstandardized device components or interfaces
- Legal framework in the public space
- Guarantees of a working and appropriate data protection concept

Results/Next Steps

Currently, solutions for the areas of actions are in the phase of implementation and testing.

Estonia

Policy	Capacity	Data	Tech	Top Support	PPP	Business Models	Pilot Space

The Business Case

In the early 1990s, Estonia, a small country with a small population and few resources, made a conscious decision (67) to use the Internet to build an open e-society. A co-operative project between the government, business, and citizens started in 1996, called Tiger Leap (67). It helped prioritize the development of an information technology infrastructure and initially provided educational institutes and public agencies access to computers and the Internet.

Around the same time, Estonia passed legislation that allowed the creation of infrastructure such as the national digital identity (ID Card) program (68) and the data exchange platform X-Road (69), both critical for developing the digital society systems that were to come. In the private sector, the nation's banks and telecoms introduced online services and innovations like M Parking, which signaled the growing digital capacity in the country. With a fully established and functional digital infrastructure (67) in terms of technology, capacity, and regulatory frameworks, Estonia prepared to move into its next phase of digital revolution in the form of Industry 4.0 and real-time economy, with an emphasis on IoT.

Source: E-Estonia

In its Digital 2020 (70) agenda, Estonia sees the need to monitor current technology trends and carry out pilot projects to keep its information system and services up to date and constantly evolving. These include IoT, advanced analytics, big data, linked open data, and augmented reality and privacy enhancing technologies. Highlighted in the Digital 2020 agenda is the belief that IoT can enable priority areas, such as the remote diagnostics of its infrastructure, energy consumption, and safer traffic and transport management.

AT A GLANCE

Policy references
Digital 2020
Digital Signatures Act
Digital Transactions Act
National ID Card

Implementing agencies/programs
Government CIO Office, Ministry of Economic Affairs and Communications
Estonian IT and Telecom Association (ITL)

Focus areas
Energy
Transportation
Wooden houses clusters

Data
X-Road

Technology
Fiber-optic infrastructure
LoRaWAN networks

Financing
Public-private partnership

Capacity development
Digital education

Related initiatives
Industry 4.0

Jobs
E-Residency

IoT in Action

Estonia has established a regulatory, competency, and technical infrastructure that supports IoT implementation. Some early examples of IoT-based applications (though these are not necessarily G2B-oriented solutions) include smart city lighting systems, a smart grid for energy management, smart wooden houses, public transit systems, and a smart harbor for transportation and logistics purposes.

Smart Transportation, Borders, and Ports

Estonia's National Road Administration (71) has implemented a system that uses sensors and GPS-based monitoring to provide real-time information about road conditions—including air and road temperatures, wind speeds, and visibility—to help users, particularly during harsh winters.

In partnership with a private sector firm, GoSwift (72), a system has been designed and implemented to create a real-time border queuing reservation system, eliminating a long-time problem for cargo vehicles, which have had to wait for lengthy periods of time before crossing the country's eastern border. A similar pilot project that also includes commuter traffic planning has been under way between Estonia and Finland since 2016.

Estonia's Smart Grid

Estonia's Electricity Market Act (73) requires all electricity meters to be replaced by smart meters, incentivizing Estonian entrepreneurs and software developers to develop smart-metering (74) and billing management software for use by utility providers. These systems allow end users to monitor their energy consumption in real time, select appropriate options and packages, and evaluate renewable energy sources.

Facility energy management solutions (for ports, airports, universities, and so on) are also being developed to manage their energy consumption from an efficiency standpoint. These systems can predict when an area's electricity supply is likely to be strained, and automatically forward customers instant bonus offers to reduce their consumption during those times, thereby smoothing peaks and troughs in the local grid. Customer billing is integrated into the same system, which results in an enormous cost savings for the distributor.

Local innovators have also taken a new approach to smart homes, developing systems that integrate electrical, heating, and security systems. These systems are designed to maximize energy efficiency, which saves the homeowner money and is much friendlier on the environment than older methods of home management.

Challenges/Lessons Learned

Estonia has established the foundation necessary to implement IoT-based initiatives and strategies. The following areas were tackled early on:

- Policy/regulatory framework
- Institutionalization and governance
- Technical infrastructure, especially for interoperability
- Public-private partnerships, including promoting businesses and start-ups
- Competencies and education
- Data

Source: E-Estonia

Regulation

The government has established **regulatory policies and regulatory frameworks without being technology specific**. The Electronic Communications Act (75), for example, states that "*the purpose of this Act is to create the necessary conditions for the development of electronic communications to promote the development of electronic communications networks and electronic communications services without giving preference to specific technologies and to ensure the protection of the interests of users of electronic communications services by promoting free competition and the purposeful and just planning, allocation and use of radio frequencies and numbering*." In a similar vein, the Spatial Data Act (76), Electronic Identification and Trust Services for Electronic Transactions Act (77), Digital Signatures Act (78), the Once Only Principle, and so on provide the platform for digital transformation.

Governance

The e-Estonia digital society evolution started with a reconsideration of the state, its services, and its legal framework from scratch. Instead of developing a single, all-encompassing, central system, Estonia has created an open, decentralized, and distributed system that links different services and databases effectively and securely. The flexibility provided by this open setup has allowed new components of the digital society to be developed and added over the years, yet the system remains resilient to cyber risks.

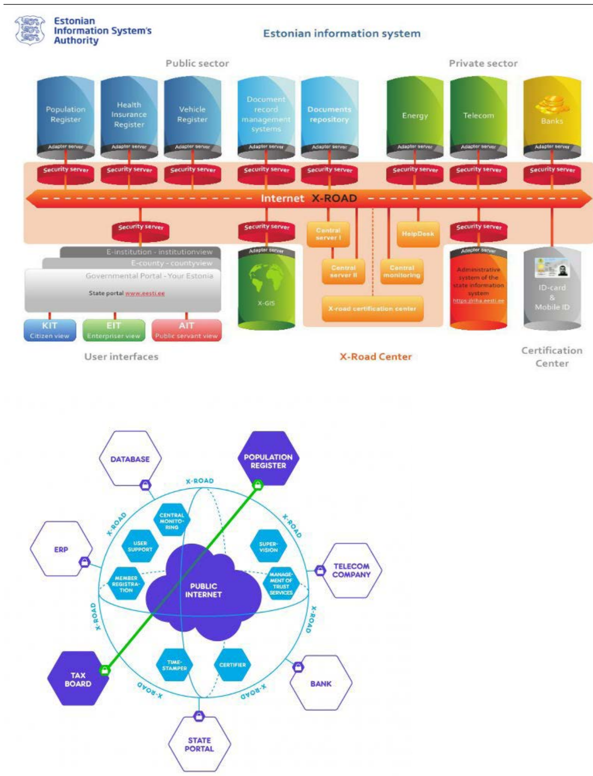
Estonia has established the role of a government chief information officer (CIO) (79), who reports (80) to the minister of economic affairs and communication (and effectively also the prime minister, through the e-Estonia Council), to help oversee the coordination of digital projects including IoT across government while maintaining the independence and uniqueness of each department's digital needs. The CIO is the gatekeeper of finances and is therefore in a strong position to influence agencies and other sectors to identify and establish digital strategies, including the use of IoT-based service delivery to businesses and citizens. The office of the CIO can identify and coordinate pilot studies for departments and also beyond government.

Change management is identified as a key limitation, and many agencies do not yet see technology and associated regulation as priorities.

Infrastructure

Estonia has established X-Road, which provides a shared platform in the form of a uniform protocol for data exchange between government bodies, and also with G2B and B2G. X-Road serves as the backbone for more than 2,000 (nearly 99 percent) online state services. It connects 1,000 organizations and databases and supports nearly 500 million transactions per year. Figure 5 depicts the X-Road data exchange layer in information systems that allows the databases and registers across the different services to communicate securely via the Internet. Currently, an adapter server/security server is being set up to increase access to X-Road for a larger stakeholder base; some thought is also being given to devising an economy-wide data exchange platform (also for B2B interoperability) based on X-Road ("Business X-Road").

Figure 5. Estonia's X-Road



Source: Siim Sikkut, Government of Estonia

Public–Private Partnerships

Estonia has actively engaged the private sector under the coordination of the government CIO to set goals for the Estonian ICT policy (81) and to prepare the Digital Agenda 2020. One of the key areas of public-private partnerships is competency and ICT skills in schools to address skill/labor shortage issues. Other opportunities being explored include broadband network development in rural areas of the country, participation in maintaining and upgrading X-Road, and IoT-based applications including big data and data analytics.

Competencies and Education

Estonia has placed significant emphasis on digital literacy at all levels. Within the government, there's strong emphasis on digital leadership and skills as part of competence models. The government offers training/stipends for administrators to obtain training. Focus area workshops/training are also provided on an agency-by-agency basis, as well as thematic training and awareness programs horizontally (for example, to enhance data analytics capacity throughout government). In addition, private sector partners such as telecoms and banks (82) provide free education services on their digital applications to employees and citizens. Robotics and programming are initiated in the school curriculum starting in the first grade. Eighty-five percent of schools are e-schools and higher education is free.

Data

Issues related to data retention and data ownership still remain outstanding. Because Estonia is an EU member, it is awaiting EU legislation on these two topics, as this is a domain in EU (not national) competence. Estonia has made the issue a priority during its EU Presidency in the second half of 2017, stating that such a framework is necessary for an EU data economy to go forward. The lack of a sufficient number of proven cases is seen as a weak link in establishing appropriate practices with respect to data ownership and retention.

Results/Next Steps

The results in Estonia show significant strengths at the organizational/strategic level, but success in the field has been mixed. The adoption of digital solutions including IoT-based solutions within the private sector continues to be low. Issues such as lack of knowledge and awareness, inadequate government support and incentives, and infrastructure availability despite the presence of new solutions (for example, LPWANs) are seen as barriers for industry participation. The value chain of IoT provisioning is also seen as very complicated, with very few clear business models around them. The part of the value chain that has the highest entry barrier is network availability. Estonian telecom operators currently seem to favor closed value chains.

Estonia is considering the idea of a Business X-Road (83) to promote the use of technology-based solutions within small and medium enterprises. This platform will be designed to provide secure unified data exchange between businesses. As part of the vision for 2020, the government of Estonia plans to furnish the initial funding for it, with subsequent support coming from the industry.

On the government side, the results have been much more positive. Estonia is now the training ground for countries that want to introduce solutions such as i-Voting, e-Cabinet, e-Health systems, and more. Over 70 countries around the world are using e-solutions and know-how from Estonia and by its experts and companies. And new systems are constantly in development.

With respect to data ownership, ideas including the creation of "data corporations" with shared ownership across the value chain are being contemplated. Together, the Ministry of Economic Affairs and Communication and the Estonian Association of Information Technology and Telecommunications commissioned a study called "Linked Estonia," which envisages a growing role for linked data, particularly using technologies such as IoT. The report urges the government to prepare for changes in the Estonian legal system and recommends policy measures necessary for the development and use of linked data.

Kazakhstan (Astana)

Policy	Capacity	Data	Tech	Top Support	PPP	Business Models	Pilot Space

The Business Case

In his January 2017 national address, President Nursultan Nazarbayev (84) firmly put IoT on the agenda when he said, *"[T]he 4th industrial revolution is currently underway in the world. Universal digitization of the economy will result in the disappearance of whole sectors and the creation of conceptually new ones. The great changes we are witnessing today are the historical challenge and a chance for the nation at the same time."*

The president instructed the government to develop and adopt a separate Digital Kazakhstan program, including several other such directions in the form of "100 concrete steps to institutional reforms (84)" that captured the need for the country to accelerate its digital economic growth.

Astana aspires to be one of the 50 smartest cities of the world; it created JSC Astana Innovations in 2011 with this objective. The establishment of a separate entity dedicated to building innovation capacities was seen to have several advantages, including the separation of regulatory powers and business development agenda, better flexibility in staffing and reporting procedures, as well as in development of the private sector.

Under the Smart Astana agenda, Astana Innovations has three broad immediate priorities:

- Smart energy
- Smart transportation
- Smart ecology and environment

Astana Innovations works with the different city departments to determine the need for innovative digital strategies and offers its support in designing and coordinating related projects. Astana Innovations may fund some of these projects, while others are funded directly by the departments.

IoT in Action

Astana Innovations has initiated several pilot projects in the digital space, including the use of IoT-related technologies. It is important to note, however, that most of these pilots cannot strictly be categorized as government to business services. They typically focus on providing services directly to citizens.

AT A GLANCE

Policy references
Digital Kazakhstan
Presidential Address

Implementing agencies/programs
Astana Innovations

Focus areas
Smart energy
Smart transportation
Smart ecology and environment

Data
None

Technology
Fiber-optic networks run by national telecom
Supporting low-power networks

Financing
Zerde
Public-private partnerships

Capacity development
None

Related initiatives
Smart city initiatives

Jobs
Not known

Smart Schools

The Smart Schools program integrates several systems, including an e-canteen, an e-library, and a security system that is used to control access to school buildings and to monitor the safety of students in real-time, using a video surveillance system and sending SMS notifications to parents' phones about student attendance.

Public Transit Management System Through a Common Control Center

The city's public transit involves nine fleet companies, eight of which are private and the other run by the municipality. There are currently 83 routes served by 750 buses. Each bus has a GPS and each fleet company operates its own control center. All information, including that of the private companies, is available to the city's control center. Displayed arrival times at bus stops are in real time, integrated with traffic systems and IoT based. An e-ticketing system currently under implementation will collect more information on load, capacity on routes, and will be integrated with passenger count sensors placed on the doors of all vehicles.

Additionally, the city's transport department is considering the possibility of using IoT sensors to monitor the condition of buses. Currently, inspectors and the traffic police physically check the buses; the use of IoT sensors would reduce the number of physical inspections.

While the data collected by the city from the IoT sensors are not available to the public, the department is open to sharing the data publicly for use by businesses and start-ups to create applications.

Smart Street Lighting

The goal of this project is to reduce energy consumption and street lighting operating expenses. The pilot study involves a system of street lighting that provides a flexible configuration of operating modes. Managers on duty can set the schedule of turning on/off lighting and choose an automatic mode based on the amount of natural light. Data on the status of lamps and operating mode as well as system management tools are displayed on a dashboard. Dimming function provides control over the load on lighting equipment. The software provides the opportunity to dim individual lamps as well as a selected group of lamps.

Communication is provided by means of both wireless (radio, GSM) and wired technologies (PLC). Astana Innovations projects the energy savings could reach up to 48 percent if the pilot is successful and the project is scaled. Astana Innovations expects to involve private sector companies, especially start-ups, to participate in the project when ready for implementation. This project is seen as a potential case for a public-private partnership.

Smart Polyclinics

The goal of "smart polyclinics" is to improve the operation of the health care industry by automating internal and external processes. They are designed to provide timely, relevant, and reliable medical information to doctors and patients. Services include linking individual IDs for patients with the nearest polyclinics, providing doctors with real-time schedules and patient information, and the tracking and dispensing of drugs. Much of this information is delivered through a single instrument to doctors. The project is expected to increase the productivity of labs and create an integrated database of research results drawn from data in laboratory informational systems and medical information systems. The project does not currently use any IoT-based applications, but future initiatives include integrating and updating patient conditions with IoT-based health-monitoring devices.

Solid Waste Management

The natural resources and wildlife management department is responsible for overseeing solid waste management, including collection, transportation, and disposal of household and construction waste. Under its smart program, GPS trackers are placed on trucks and can be monitored by any device. Container areas (about 1,800) are identified on the map by personnel also equipped with GPS trackers.

Astana Tazartu, a company established in public-private partnership, is responsible for 23 sections in the city. Its vehicles are equipped with cameras that help determine other information and assist the drivers in maneuvering vehicles. Additionally, fuel control sensors on the vehicles monitor fueling at gas stations, which has resulted in significant savings and helped reduce the fleet size from 100 to 77. The quality of bin dumping has also improved. Technical sensors to check the status of the vehicles are being investigated. The weather is key issue when trying to place sensors on bins to help better optimization of dispatch: many of the cheaper sensors failed under extreme cold weather conditions.

Fuel Management on Rail Locomotives

JSC TransTeleCom, an operator of a nationwide fiber-optic backbone network laid along railways, has introduced an automated management system for railway engines. The system is based on 15 types of sensors in each engine that measure the level of fuel, rpm of engine, location, and more and send it to a central system. The purpose of the system is to control the consumption of diesel fuel by the engine. Plans include collection of data to optimize the speed of trains and reduce or eliminate driver intervention except in emergency situations. This has legislative implications because current legislation mandates driver operation.

Challenges/Lessons Learned

As a general assessment, Astana's intentions, motivations, challenges, and current practices align with current practices across other jurisdictions in the developed world. **This positions Astana very well to establish its own course of action, creating opportunities for benchmarking and collaboration with other jurisdictions** without necessarily having to worry about "catching up" with them.

Astana, like many other jurisdictions, is proceeding with IoT initiatives largely under a smart city agenda. In that context, as seen with cities such as Bristol, Ludwigsburg, and Mississauga, the leadership shown by the mayor of Astana has been a key influencing factor. **The creation of and the mandate for Astana Innovations as a coordinator IoT initiatives under the smart city directive is well aligned with current practices,** as seen in Germany, the United Kingdom, and parts of the United States. As is the case with other studied jurisdictions, IoT initiatives in Astana are very much in the pilot/proof of concept or aspirational stages.

Since all IoT initiatives in Astana are very much in their nascence, it is **too early for the city to make any assessments or observations on the potential business models and value propositions** for itself and/or for businesses. However, pilot applications such as the fuel control sensors, transit management, and garbage truck scheduling have demonstrated early evidence of creating efficiencies and reducing costs to the city and businesses.

Issues regarding data ownership, data sharing, data privacy and security, and any policies concerning them have not been raised or discussed within any levels of government. The city should consider developing policies in this regard and using some of the proof of concept studies as opportunities to try and evaluate them. The steps undertaken in Germany, Estonia, the European Union, and the United Kingdom, detailed in this report, can be considered as good practices.

Infrastructure, both in terms of network availability and IOT devices such as sensors, has been identified as a challenge for implementation. Kazakhtelecom, the largest telecommunication company in the country, is in the early stages of implementing an IoT infrastructure in the country. Per the company, the country's current infrastructure is limited compared to that in world digitalization leaders: Kazakhstan has 65,000 kilometers of optical fiber in place; the Republic of Korea, in contrast, despite being 30 times smaller in size, has 650,000 kilometers of fiber-optic networks. Other approaches, including the use of LoRa networks, are being envisioned once standards are in place for such technologies. Advice is being sought from Korea Telecom, including undertaking pilot studies on the use of copper cables in the absence of fiber to save costs. On the devices front, specific constraints have included the **reliability and dependability of sensors in localized and extreme environments,** such as cold temperatures, high snow conditions, and so on. The lack of a local presence of sensor manufacturers and IoT companies further hampers the cost and reliability of implementation.

While there is **a strong aspirational commitment to create public-private partnerships for initiating and implementing IoT strategies, the process is slow and seemingly bureaucratic**. This is a barrier for start-up companies. For example, Smart Shelf Solutions is a start-up founded in the city of Almaty originally for retail monitoring of inventory. Their technology included end-to-end solutions using IoT sensors. They are currently undertaking several projects with oil companies and have a contract to undertake a pilot study using LPWAN- and LoRaWAN-based systems for the railways to monitor tracks. The company identifies itself as an IoT integrator and believes it does not have adequate opportunities to participate in public-private partnerships on IoT pilot projects.

Similarly, Korkem Telecom is the first and only producer of traffic cameras and is involved in video surveillance and road traffic project trials. They have invested in and maintain a large Wi-Fi network with over 10,000 daily users and have created an app for users of local public buses with over 200,000 subscribed users. They obtain the data from the transport authority. Korkem Telecom believes the lack of competent talent within the country has inhibited the growth of IT companies.

The **lack of clarity around laws governing public-private partnerships is seen as a major barrier**. However, the company feels that the current Mayor's Office is very open to suggestions. The first IT public-private partnership project in Astana involving the traffic system is being implemented in good faith and has been entirely financed by investors. According to Korkem, private companies could succeed if the government provided support in legal ways to prove to other investors and eased restrictions on the fiber channel market, which currently requires permission from 14 entities.

The Kazakhstan Association of Automation and Robotics has members involved in IoT, including TransTeleCom and TNS Intec. TNS Intec was engaged with the smart lighting project (pilot); TransTeleCom operates the railway network. The association's membership is very limited, indicating a lack of adequate IoT-based companies.

Kazakhstan generally, and Astana specifically, is facing **challenges with scarce availability of locally competent professionals in the field of IoT technologies**. Nazarbayev University in Astana and other universities offer courses and options in the digital technology field including IoT, but the field is still very much nascent. Most city department officials expressed a lack of awareness of IoT-based technology solutions and the absence of competent professionals in their agencies. However, some agencies, such as those involved in building inspections, solid waste management, health care, transit, and energy systems, expressed an eagerness to understand and test some of these applications for their purposes, seeing value in making their processes more efficient and allowing businesses they regulate to become more compliant and competitive.

Results/Next Steps

Astana Innovations (AI) was established to help coordinate innovative strategies toward achieving Astana's smart city objectives.

AI is willing to adopt best practices identified through this study to achieve these objectives. Specifically, with respect to IoT implementation in areas where it can provide better "services" and encourage businesses, it is interested in undertaking proof of concept studies. Officials from some departments have expressed a keenness and readiness to undertake these studies. Based on their interest, capacity, and currently available solutions, the studies would focus on the following areas:

- Building inspections
- Solid waste management
- Polyclinics
- Other city services

Apart from the specific pilots identified above, Astana Innovations is also interested in simultaneously tackling broader strategic and policy-based issues and has requested recommendations.

Canada

The Business Case

In 2016, Canada declared Internet access with high-speed broadband download speeds of up to 50Mb/s a "basic telecommunications service" (85) that every citizen should be able to access. According to the Canadian government's Telecom Regulatory Policy issued in December 2016, access with these broadband speeds "*would enable Canadians to take full advantage of the applications available today and to use future applications as they become available (e.g. the IoT)*."

In Budget 2017 (86), the government of Canada introduced its Innovation and Skills Plan, which focuses on people and addresses the changing nature of the economy to ensure it works for all Canadians. The plan aims to develop Canada as a world-leading innovation economy to create jobs and grow the middle class.

Specifically, the government's budget supports innovation in key growth industries—including digital—with new measures that will improve access to financing, encourage investment, support the demonstration of technologies, and build the capacity necessary for Canadians to take advantage of growth opportunities and create good, well-paying jobs.

IoT in Action

The International Data Corporation (IDC) has predicted that in Canada, the number "of installed autonomous intelligent and embedded systems" will rise from 23 million in 2013 to 114 million in 2018 (87). To encourage cities to adopt new and innovative approaches to city building, the Canadian government has proposed to provide Infrastructure Canada, a federal agency investing in the building of public infrastructure, with Can$300 million over 11 years to launch a Smart Cities Challenge Fund (88). The challenge would invite cities across Canada to develop smart city plans, together with local government, citizens, businesses, and civil society, and help improve the quality of life for urban residents through better city planning and implementation of clean, digitally connected technology, including greener buildings, smart roads and energy systems, and advanced digital connections for homes and businesses. Winning cities will be selected through a nationwide, merit-based competition, facilitated by the government's new Impact Canada Fund.

AT A GLANCE

Policy references
Telecom Regulatory Policy
Innovation Agenda

Implementing agencies/programs
Infrastructure Canada

Focus areas
Smart cities

Data
None

Technology
Fiber-optic networks currently held by large telecom providers

Financing
Impact Canada Fund

Capacity development
Canada's Innovation and Skills Plan

Related initiatives
Not known

Jobs
Not known

Finance Minister Bill Morneau, announcing this challenge, envisaged IoT as an essential part of this landscape. He described a future where "*Internet-connected devices help to shape our daily commutes, with 'smart' traffic lights that measure and adapt timing to improve traffic flows. In connected cities, electricity is now distributed across dispersed energy storage systems, sending energy derived from remote solar, wind and geothermal generating stations to wherever power is needed. Underground, connected sewer systems will detect leaks and monitor real-time water flow, and on our roads and highways, our transportation systems will show real-time information on rail traffic, transport capacity and port loading times, making supply chains faster and more reliable.*"

Challenges/Lessons Learned/ Results/Next Steps

A study conducted by the Public Policy Forum of Canada (89) has identified several challenges Canada must overcome before it can become an IoT leader:

- Executive understanding and acceptance of IoT solutions
- Availability of skilled labor
- Privacy and security issues
- Build-out of the connectivity infrastructure

While the study captures several innovative leadership examples of IoT-based applications in the private sector in Canada and sees the potential for the country to be an early mover in the IoT space, it identifies the need for a concentrated and collaborative effort to achieve success.

Unlike Germany and the United Kingdom, Canada does not have a national initiative that is exclusively focused on the promotion of IoT as innovative digital solutions to increase the competitiveness and growth of its industry and businesses. However, Canada's innovation agenda (90) intends to step up Canada's role in this sector.

Mississauga

Policy	Capacity	Data	Tech	Top Support	PPP	Business Models	Pilot Space

The Business Case

Mississauga is the sixth largest city in Canada, with a population of more than 700,000, and nearly 60 of the country's Fortune 500 companies have their global or national head offices here.

In 2009, Mississauga embarked on an ambitious journey: the launch of a Strategic Plan (91) and a 40-year vision for the city. More than 100,000 residents were engaged in the development of the plan. The pillars of the plan are to help Mississauga "Move, Belong, Connect, Prosper, and Green." The city develops and uses IT strategic plans (92) to delivery its objectives.

"Connectivity is city-building. In Mississauga, this idea guides Council and staff's efforts to better use technology to shape policy, make informed decisions and deliver quality public services."
—Mayor Bonnie Crombie

In October 2015, the city approved an IT Master Plan (92) with the following objectives:

- Fostering open and transparent government
- Enabling decisions through research analytics (big data, IoT)
- Creating a connected and engaged workplace
- Improving innovation through partnerships

IoT in Action

The city has been an active partner in a public sector network (PSN) (93) since 2001 alongside the Region of Peel, city of Brampton, and town of Caledon. The PSN is a fiber-optic network privately owned and operated by the PSN; it carries voice and data communications for all PSN members as well as for some other agencies that have been provided access. The PSN is registered with the Canadian regulator as a nondominant (meaning the PSN does not have any significant commercial impact in the marketplace in providing such access) telecommunications network carrier and is permitted to provide access to other agencies for a fee within the guidelines of maintaining

AT A GLANCE

Policy references
Strategic Plan
IT Master Plan

Implementing agencies/programs
City of Mississauga
Private sector

Focus areas
Transit
Environment
Open data
Local business growth

Data
Mississauga Data

Technology
Own fiber-optic infrastructure

Financing
City of Mississauga
Region of Peel
Federal and provincial governments

Capacity development
Chief Information Officer
Win the Human Race
Eduroam

Related initiatives
Not Known

Jobs
Not known

nondominant carrier status. The PSN helps connect city services such as traffic, transit, digital signs, and the city's fleet of vehicles, and the mobile workforce.

Mississauga owns about 19,185 fiber strand kilometers of the PSN fiber network. In the city, the network currently connects 152 sites and 700 intersections with connectivity to traffic sensors, cameras, and localized computing. Estimates suggest that the PSN has led to savings of Can$2 million annually (94). The infrastructure continues to be expanded to other public facilities, such as hospitals and educational institutions, wherein the incremental costs are relatively less and shared among different stakeholders.

Over the last two years, with a base of over 6,000 employees in 50 buildings and in the field, the city has deployed more than 2,000 mobile devices in the field to collect data across a range of services provided by the city, including transit, fire, and so on. For example, the building automation systems across the buildings are integrated and IoT-based sensors assist in managing energy systems (95). They also help with monitoring and optimizing maintenance of engineering and other services at these locations, including heating and ventilation systems such as boilers and refrigeration units. Per Shawn Slack, chief information officer for the city of Mississauga, *"Just about every piece of equipment the city buys has the ability to connect to a wireless network. Snowplows, buses, fire trucks, HVAC units, and traffic lights are all capable of transmitting real-time data. Collecting and using that data to make better decisions will enable more responsive and efficient operations."*

Figure 6. Mississauga Connectivity

Source: City of Mississauga.

The city's Advanced Transportation Management System (96) has been implemented across more than 120 intersections, and the remaining 90 percent (nearly 700) of its traffic intersections will be completed by 2018. Traffic, water, rain gauge, and camera-based sensors have been installed at these and other locations (97). The system currently helps the city manage its fleet management system, public transit, and snowplow monitoring, but the data have also been made available through its open data initiatives to citizens and businesses. The next phase involves the city placing additional environmental sensors (for example, for air pollution monitoring) at these intersections, using the basic infrastructure and access points that are already in place.

Challenges/Lessons Learned

The creation and establishment of a public sector network in partnership with other cities in the region is an important best practice. The PSN works like a separate "company" (93); it is governed by the PSN Steering Committee, with representatives from each organization, typically the chief information officer, and has an annual budget that is managed by the Region of Peel. The city of Mississauga is registered as a noncommercial network provider. Federal regulations prevent the city from offering its fiber-optic infrastructure to businesses, thus limiting economic competitiveness.

Results/Next Steps

With strong mayoral commitment and visibility at the senior management level, the strategic/business plan drives the smart city agenda for Mississauga. Over 75 of the city's strategic initiatives are directly linked to technology road maps, and IoT is a component in each of those initiatives. The city provides data gathered from its sensors using an open data platform. In addition it can provide the access points at traffic intersections to the private sector to place additional sensors.

The city continues to seek out innovation and proof of concept opportunities to create synergies between the city government, the community, educational institutions, local industry, small businesses, and other idea or innovation incubators. The city's continued partnership with the technology sector is intended to drive innovation and provide opportunity and access to technology in the community.

Ontario Tire Stewardship (OTS)

The Business Case

The Used Tires Program in Ontario was established in accordance with the Waste Diversion Act, 2002 and is now overseen by the Resource Productivity and Recovery Authority (RPRA). RPRA is responsible for developing, implementing, and operating diversion programs for designated wastes and monitoring their effectiveness and efficiency. The Used Tires Program is funded by brand owners and first importers of tires, called stewards, who must remit a Tire Stewardship Fee (TSF) to Ontario Tire Stewardship (OTS) for every tire they supply into the Ontario market. The TSFs are used exclusively to fund all aspects of the program related to the management of used tires. Collection, storage, transportation, reuse and recycling, processing, research and development, and consumer education are key elements.

OTS is the service provider for those such as retailers and manufacturers that deliver used tires to markets for recycling. Ontario legislation requires that the documentation of the diversion of tires through its life cycle be demonstrable. OTS was established as the overseer of this market to ensure a level of professionalism, standard of compliance, consistency, and the growth of the recycling industry.

The stewards of the system include tire manufacturers, vehicle manufacturers (brand owners, original equipment manufacturers, first importers [for example, tire dealer brings in imported tires]), collectors (retails, auto recycling [accumulators]), haulers, recyclers (processors), and recycled product manufacturers.

IoT in action

OTS has developed a mobile manifest system in partnership with IBM that eliminates paper-based forms, reduces administration, and makes it easier for program participants to submit information to OTS. Called TreadMarks Mobile (98), it uses mobile devices such as iPads, QR codes that track businesses, integrated weight measurement systems, GPS on vehicles, and a privately owned cloud-based platform. OTS is able to oversee the movement of tires, verify and validate locations and tonnage hauled, and automatically pay the stewards upon successful completion of activities. The system can track individual components of a tire, including rubber, steel, and fiber, based on initial information loaded by the manufacturers.

AT A GLANCE

Policy references
Ontario Waste Diversion Act
Used Tire Regulation

Implementing agencies/programs
Ontario Tire Stewardship Program
Resource Productivity and Recovery Authority

Focus areas
Recycling and recovery of tires

Data
Proprietary

Technology
GPS system
Cloud-based management

Financing
Tire stewards

Capacity development
Not relevant

Related initiatives
None

Jobs
At risk

Stewards pay the fee for OTS and the system itself operates on an incentive-based model. Incentives are paid through the chain on a tonnage basis. Currently, 80 percent of OTS's budget goes to these incentives.

Challenges/Lessons Learned

The creation of an independent centralized body (OTS) combined with legal requirements (a law necessitating documentation of the diversion of tires) allowed for the development of an innovative solution. In addition, tying invoice payments and incentives to the adoption of the mobile technology solutions is a good example of a business model that provides value proposition to businesses.

To make the process paperless, OTS needed to retrain their staff, moving them from traditional clerical roles to that of analysts monitoring and evaluating transactions on a real-time basis. While the solution does not use sensors (it relies on QR codes), opportunities exist not only to integrate sensors on tires but also to expand the solution to other recycling sectors such as electronics.

Results/Next Steps

The Waste Diversion Act and Used Tire Regulation have been revoked in Ontario and have been replaced with a new piece of legislation called the Resource Recovery and Circular Economy Act. New regulations on used tires have yet to be developed under this act. In addition, the revocation of the Waste Diversion Act has effectively shut down the operations of Ontario Tire Stewardship. OTS is moving toward winding down in 2018 and possibly ending the application of TreadMarks despite its success.

Ontario – Technical Standards and Safety Authority

The Business Case

The Technical Standards and Safety Authority (TSSA) is Ontario's regulator of technical devices and equipment such as elevators, escalators, boilers, and pressure vessels, and of fuel burning appliances such as furnaces and water heaters. Public safety issues (for example, incidents involving injuries and fatalities and high levels of noncompliance) have spurred the organization to explore innovative options like the use of real-time monitoring sensors (99) that can potentially increase performance compliance while not creating an unnecessary burden on businesses. TSSA believes that in addition to reducing risks, such applications provide other ancillary benefits, including the reduction of regulatory burden (for example, smarter allocation of resources for inspections).

"We are supportive of businesses' use of innovative IoT based solutions for demonstrating compliance so long as they are proven, reliable and meet and exceed Ontario's public safety expectations."
—Roger Neate, Statutory Director for Elevating Devices, TSSA

In partnership with Intel Corporation, TSSA is examining the use of IoT-based technologies for monitoring the performance of elevators, including observing its accuracy when level with floors, patterns of user behavior as they approach closing elevator doors, and other related parameters. TSSA envisions the pilot studies will help them and the owners of the devices better understand factors influencing past failures, informing design solutions that can provide real-time warnings to users, schedule maintenance, and reduce public safety risk. TSSA will consider incentivizing building owners implementing such technologies if the solutions are proven. TSSA is also participating in the development of international standards that would permit the use of such applications.

TSSA is also considering undertaking pilot studies that use IoT-enabled gas sensors to monitor for carbon monoxide (CO) levels associated with heating equipment such as boilers in buildings, including schools. TSSA has identified

AT A GLANCE

Policy references
Technical Standards and Safety Act
Annual State of Safety Report

Implementing agencies/programs
Technical Standards and Safety Authority

Focus areas
Technology inspections

Data
None

Technology
Intel

Financing
Not known

Capacity development
Not known

Related initiatives
Elevating devices
Heating appliances

Jobs
Not known

CO as a major public safety risk and poor maintenance of appliances is one of the primary causes that allow CO to build to dangerous levels. IoT-enabled solutions will better assist institutions to plan their maintenance schedules and associated budget allocations. TSSA may consider reduced regulatory inspections to incentivize owners of this equipment.

United States of America

Over the past few decades, the U.S. government has created an environment that allows technology to grow and thrive within its borders. Encouraging private sector leadership in technology and standards development and using a multistakeholder approach to policy making have been integral elements of the government's approach to technology development and growth.

In a January 2017 green paper titled "Fostering the Advanced of the Internet of Things," the U.S. Department of Commerce (30) suggested that the challenges and opportunities presented by IoT require a reaffirmation rather than a re-evaluation of this well-established U.S. government policy approach: the federal government's role is to encourage IoT growth and innovation by helping to expand markets and reduce barriers to entry. The department can also help convene stakeholders to address public policy challenges, and it is exploring cross-cutting issues like cybersecurity and privacy, innovation and intellectual property, data sovereignty, standards development, public-private partnerships, procurement, and more with stakeholders at the local, tribal, state, federal, and international levels.

The President's Council of Advisors on Science and Technology report *Technology and the Future of Cities* (100), released in February 2016, suggests that the proliferation of sensors through IoT and converging data standards are combining to provide new possibilities for the physical management and socioeconomic development of cities. Local governments are looking to data and analytics technologies for insight and are creating pilot projects to test ways to improve their services. According to the report, large U.S. cities, through their chief technology officers and related staff, are using technology and data analytics to solve specific problems in areas such as health, transportation, sanitation, public safety, economic development, sustainability, street maintenance, and resilience. The report makes recommendations similar to the Department of Commerce findings on the role of the federal government in supporting city-based initiatives.

AT A GLANCE

Policy references
Department of Commerce IoT Green Paper
President's Council of Advisors on Science and Technology

Implementing agencies/programs
U.S. Ignite

Focus areas
Agriculture
Community Safety
Health care
Transit

Data
None

Technology
Intel

Financing
Federal government and county funding
Public-private partnerships

Capacity development
Not known

Related initiatives
Smart agriculture
SCALE

Jobs
Not known

Japan (Kobe City)

Policy	Capacity	Data	Tech	Top Support	PPP	Business Models	Pilot Space

The Business Case

Kobe City sits almost at the center of the Japanese archipelago, on the Seto Inland Sea, with a population of 1.5 million. In 1995, the Great Hanshin-Awaji earthquake struck Kobe and the surrounding area, causing 4,751 deaths within the city and destroying or damaging much of the city's infrastructure. In the years since, and with considerable help and support from people throughout Japan and the world, the citizens of Kobe have rebuilt the city into a thriving hub and have almost completely recovered from the damage of 20 years ago. The city is now embarking on a journey to become a smart city, with the intention of tackling some of its historic challenges and risks (such as floods, earthquakes, public safety) using technologies such as IoT.

IoT in Action

Kobe City is piloting several experiments with IoT, including one spurred by a child abduction and murder incident near a school in Kobe. In September 2016, in a joint effort with NTT DOCOMO—the largest telecom provider in Japan—Kobe initiated the Kobe City-DOCOMO urban monitoring service (verification trial) (101), using Bluetooth low energy (BLE) tags for monitoring children's safety in collaboration with 48 companies, including railway and taxi operators.

This initiative is considered an example of a business collaboration agreement in the use of data generated through mobile applications that would be used for the primary purpose of solving various social issues in communities. The project involves the placement of BLE tags in school bags/pockets of children, signals from which can be picked up by sensors in town and transmitted to parents via the NTT DOCOMO network. These signals can be transmitted up to a maximum distance of 30 meters. In addition to strategically placed sensors, volunteers such as shopping malls, taxi drivers, individuals, and others can also install applications on their mobile phones that can relay the signals from the BLE tags to the NTT network.

AT A GLANCE

Policy references
Not known

Implementing agencies/programs
Kobe City

Focus areas
Smart city
Children's safety
Public security

Data
Open source
Sentilo Network

Technology
Fiber optic/LPWA
BLE tags
Sensors

Financing
Kobe City/private sector

Capacity development
Kobe University

Related initiatives
Kobe Marathon
Kobe City–DOCOMO trial

Jobs
Not known

Challenges/Lessons Learned

Several positive aspects came out of the Kobe-DOCOMO trial. Data privacy concerns raised by parents were managed through a series of ongoing consultations and workshops. The number of participating schools (and parents) rose from two to five, suggesting the success of the approach. The number of volunteers signing up for the program has also apparently increased.

Kobe City is no longer in a position to install more sensors and pay the telecommunication fees to the provider. To ensure continuity of the program, Kobe is looking at different business propositions, including a fee for service model for parents, and hopes to arrive at a solution soon.

Results/Next Steps

Kobe City plans to install tidal sensors, land flood sensors in mountainsides, traffic sensors, human tracking sensors, and security sensors. Using the open source Sentilo Network System (102), Kobe intends to collect data on one system/dashboard. It has also entered into a partnership with Barcelona as part of its smart city initiative.

The mountains surrounding Kobe provide an ideal topography for setting up LPWA IoT networks to complement the existing fiber-optic networks. The setting is improved by the fact that Kobe University sits halfway up the mountain and a cable car runs to the top of the mountain. Private service providers can use these resources to install additional sensors that can access the LPWA network to support the children's safety project, and also consider them when installing other sensors as part of the smart city initiative.

United Arab Emirates (Dubai)

Policy	Capacity	Data	Tech	Top Support	PPP	Business Models	Pilot Space

The Business Case

Inspired by the prime minister of the United Arab Emirates, His Highness Sheikh Mohammed bin Rashid Al Maktoum, the Smart Dubai (103) program seeks to make Dubai the happiest city on Earth. Building on innovation programs developed earlier to drive competitiveness, Dubai aims to create an efficient, seamless, safe, and impactful city experience for residents and visitors through strategic initiatives and partnerships. It has established different focus areas within its smart city dimensions, including smart economy, smart living, smart governance, smart environment, smart people, and smart ICT infrastructure. The underlying layers (104) for delivering the focus areas include its connectivity or IoT infrastructure, data, and analytics.

IoT in Action

Several proofs of concept (POC) currently under way in the city largely focus on delivering better services to citizens in partnership with the private sector. One involves a citywide parking management system that is integrated with personal requirements. The system allows a Dubai resident to reserve a parking slot based on real-time information provided by sensors. This POC is currently being tested as part of a child immunization management program wherein an integrated process of notifying parents, scheduling appointments with doctors, traffic routing through GPS sensors, and parking reservation at hospitals are being set up and piloted. The objective is to ensure that appointments for child immunization are set up, notified, and the optimal mechanisms for arriving at the hospital are all coordinated. Currently, the focus is primarily on the public sector service delivery to citizens. As part of the next phase, other aspects, including involving businesses, will be considered.

AT A GLANCE

Policy references
Smart Dubai

Implementing agencies/programs
Smart Dubai

Focus areas
Smart homes
Education
Connected hospitals
Mobility

Data
Dubai Data

Technology
Not known

Financing
Not known

Capacity development
Not known

Related initiatives
Integrated parking management

Jobs
Not known

India (Rajkot)

Policy	Capacity	Data	Tech	Top Support	PPP	Business Models	Pilot Space

The Business Case

The government of India has established a national digitization plan called Digital India (105). The plan focuses on key priority areas: Broadband Highways, Universal Access to Mobile Connectivity, Public Internet Access Program, e-Governance, Electronic Delivery of Services, Information for All, Electronics Manufacturing, IT for Jobs, and Early Harvest Programs.

The first three pillars—Broadband Highways, Universal Access to Mobile Connectivity, and the Public Internet Access Program—address the need for new Internet and cellular service, with emphasis on rural access. The new infrastructure lays the foundation for all other pillars and forthcoming projects, including the Center of Excellence for IoT in India (CoE IoT) (106).

A government-run incubator for IoT products, CoE IoT "aim[s] to build a Startup Ecosystem for the Nation." Its objective is, with support from the private sector and academia, to create innovative applications and gain domain capability in the IoT sector by harnessing the start-up community. The support for IOT development comes in the form of funding and equipment from companies like Cisco, TI, and Qualcomm, plus matched mentorship, lab space, and research support from institutions such as Indian Institute of Technology. The incubator can house up to 40 start-ups and 10 emerging companies and specializes in robotics, agritech, healthtech, and smart city and Industry 4.0 products. The incubator only recently opened (July 2016) and there are no specific success stories to report yet.

The government of India has established a draft policy on IoT (107). The approach comprises five vertical pillars (Demonstration Centers, Capacity Building and Incubation, R&D and Innovation, Incentives and Engagements, Human Resource Development) and two horizontal supports (Standards and Governance Structure).

A report released by India's IT industry association, NASSCOM, projects India's IoT market will reach $15 billion by 2020, with nearly 120 firms currently offering solutions. It identifies smart cities, industrial IoT, and health care as key growth opportunities involving a government to business partnership.

AT A GLANCE

Policy references
Digital India
Smart City Mission Guidelines
IoT Policy

Implementing agencies/programs
CoE IoT
City of Rajkot

Focus areas
Water supply
Solid waste management
Environment and energy
Transportation

Data
Not known

Technology
Not known

Financing
Public-private partnership

Capacity development
CoE IoT

Related initiatives
Smart metering
Transit
Water supply

Jobs
Not known

IoT in Action

India's Ministry of Urban Development (MoUD) selected Rajkot (108), in the state of Gujarat, as one of the 100 cities participating in its smart cities initiative. Rajkot has implemented smart initiatives (109) in areas ranging from transit and e-governance to solid waste management and water supply. The city's vision under its smart city proposal includes several pan-city and area-based development initiatives, with a focus on both infrastructure and ICT advancements in the city and at strategic locations. Objectives of the proposed ICT initiatives include public safety improvement and surveillance, traffic management, quality of public services, and real-time tracking of services. Several of these initiatives include IoT components. The city's municipal corporation is currently reviewing proposals from the private sector to establish a 200-kilometer-long fiber-optic network, CCTV network, environmental and other related IoT sensors, and several Wi-Fi access points. The city envisions providing the infrastructure to businesses for them to use and benefit from. A variety of IoT-based projects (110) on water conservation, solar-based heating, and climate change–related initiatives are being planned in partnership with the private sector.

THE IOT TOOLKIT

Recommendations and Toolkit for Governments

IoT, both as a technology and as a governance practice, is still in its infancy, and while there is tangible excitement about it within both government and the private sector, evidence of success remains patchy. Governments have a vital role in catalyzing the space and contributing as partners/leaders in the long term.

Based on the findings and the characteristics of successful pilots, we present a conceptual toolkit containing ideas and resources for government agencies that want to implement IoT-based initiatives within their jurisdictions. The toolkit is structured using three pillars:

- Leadership/policy
- Strategy and implementation
- Capacity and engagement

Leadership/Policy

Proactive Policy

One objective of this study has been to understand how/if government policy and regulation has kept up with the fundamentally different demands of the digital economy in which the pace of disruption and innovation is significantly more rapid, consumer protection throws up qualitatively different challenges, and business regulation requires a nuanced balance between promoting competitiveness and correcting market failures. Based on the cases studied, we have identified an initial list for action (this will be supplemented in the future by a detailed policy note focused on IoT policy).

Governments need to **proactively engage in policy development** and administration that supports regulatory balance. Broadly speaking, there are two sets of policies—regulations and standards—that are crucial to support IoT implementation. **One set of policies deals with the technology system itself.** Issues include the availability and equity of network infrastructure; data challenges including privacy, security, ownership, and sharing; interoperability of technologies; access to the private sector; and costs. The EU digital protection legislation, Canada's telecom policy, and Estonia's X-Road standards are examples of policy interventions aimed at IoT as a technology.

THE IOT TOOLKIT

Leadership/Policy

Proactive policy development

Align strategic objectives

Strategy and Implementation

Establish sandboxes to develop pilots (test value proposition, technology, policies, infrastructure, security)

Establish a coordination agency to manage and run pilots

Develop public-private partnerships and platforms

Research and develop 'localized' business models

Develop IoT infrastructure

Capacity and Engagement

Engage local stakeholders through education and outreach

Develop IoT capacity within and outside the government

Encourage standardization

The **other set of regulations and policies enable IoT applications** by businesses either for compliance or for meeting the needs of the marketplace. Many jurisdictions currently have regulations that may constrain or may not support the use of IoT for compliance. For example, regulations may require physical inspections of premises and may not allow remote monitoring and reporting by businesses. Risk and performance-based regulations provide the foundation for fostering innovation. The United Kingdom's Growth Duty directive is an example of a policy that is intended to support the amendments to regulation to allow for such technologies. Several jurisdictions, including national and subnational governments in Canada, Estonia, and Finland, are exploring significant changes to regulations to reduce burden on businesses, catalyze growth in sectors such as agriculture and infrastructure, and allow for innovative compliance demonstration methods by businesses. Slow regulatory modernization cycles pose a major constraint to eager and forward-looking agencies. However, these agencies require support, capacity, and directives to move in that direction.

Governments may stifle innovation in the use of IoT for problem solving by not providing **incentives such as funding for pilots and exemptions from regulatory requirements during experimentation and pilot studies.** Governments could consider incentivizing businesses that use IoT applications to generate and share real-time data demonstrating compliances. Incentives may include reduced inspections, fees, or recognition. Examples in the United Kingdom and Canada, as discussed earlier, are emerging as good practices.

As governments grapple with such challenges, a set of new methods loosely called anticipatory regulation has emerged (111) as one possible response. The goal of such proactive policy making is to seek optimum balance between technology development, market regulation, and policy administration. Open dialogues with innovators, iterative and performance-based rules, the creation of sandboxes and test beds, risk management approaches, and innovative regulatory delivery through the use of smart technologies like IoT are example components of this set of methods.

A few policy references that may be useful to policy makers:

City/Regional Policies

- Bristol Resilience and Corporate Strategies
- Mississauga Strategic and IT Plans
- MK Vision 2050
- HPA Environmental Policy
- Smart Dubai

National Digital Strategies and Policies

- U.K. Digital Strategy
- Technology and Innovation Futures 2017 - U.K.
- Data Protection Regulation - EU
- Digitale Agenda - Germany
- Regierungsprogramm Digitale Verwaltung 2020 - Germany
- Digital 2020 - Estonia
- Digital Signatures Act - Estonia
- Digital Transactions Act - Estonia
- National ID Card - Estonia
- Digital Kazakhstan
- Telecom Regulatory Policy - Canada
- Innovation Agenda - Canada
- IoT Policy - India

Vision/Strategy Alignment

It is important to **ensure alignment with a larger vision and strategic objectives (IoT should support existing vision and not vice versa)**. Clear and direct synergies should exist between proposed IoT applications and the strategic objectives of jurisdictions that implement IoT-based solutions. The most effective and organic institutionalization of IoT-based initiatives are possible when they tie directly to strategic initiatives envisioned by mayors or leaders of jurisdictions wherein real problems and challenges faced by citizens and businesses are tackled using such solutions. The cities of Bristol (18) and Mississauga (19) have integrated and entrenched their digital/IoT priorities as enablers for achieving specific strategic initiatives identified by their mayors and city councils.

Strategy and Implementation

Sandboxes to Test Policy/ Technology

We recommend establishing **sandboxes to test policy and technical issues**. In fact, sandboxes, facilitated directly or indirectly by government, in the form of physical spaces, clusters, and/or environments for running pilots and proofs of concept, were the one constant in all the cases studied. Sometimes referred to as living labs or model cities, these physical spaces provide facilities for setting up start-ups, building "models" ranging from simple IoT applications to even "model" cities. The Bristol Living Lab, for example, is a place where citizens, artists, technologists, businesses, and public sector organizations come together to co-create ideas and to understand how digital technologies can be used to meet local needs. Similarly, the Benjamin Franklin Village in Mannheim, which was part of an old U.S. military base, has been converted into a sandbox district designed to test ideas for energy efficiency, smart grids, and electro-mobility.

These sandboxes are designed to test more than technology, however; they also serve as test beds for governments to test policy alternatives to accommodate and promote the use of IoT by businesses. Procurement policies, for instance, may be caught between opposing bureaucratic procedures (113), stimulating competition and promoting innovation (112), and thereby they discourage active participation by innovative firms, especially during pilot or proof of concept stages. The Benjamin Franklin Village is helping develop ideas for procurement requirements that incentivize IoT-based solutions, the relaxation or exemption of regulatory barriers such as licensing or inspections, and gathering stakeholder views on data privacy/ownership. Other ideas being tested in similar sandboxes include public perception and awareness, data stewardship, financial models, business value propositions, and competency and skill requirements.

The following are examples of sandboxes:

- Blue City Mannheim
- Bristol Living Lab
- Benjamin Franklin Village - Mannheim

Public-Private Partnerships and Platforms

The development of **public-private-academic partnerships and platforms** appears to be a critical success factor. Agencies in Finland and Canada are looking to partner with academia and businesses to evaluate IoT solutions for remote monitoring and inspections of technologies such as elevators, fire protection systems, and building management systems. Kobe City in Japan has worked with a telecom provider to use a BLE tag to track the movement of elementary school children and ensure their safety. Dubai is working with a variety of service providers, including hospitals, auto manufacturers, and parking companies, to implement a child immunization program. In each case, success hinges on the participation of numerous stakeholders with different priorities, finances, capacity, infrastructure, and constraints. A partnership, sometimes via a “coordinator” office (described below), is usually the only way to bring these players together.

Public-private-academic partnerships cover both infrastructure and nontechnical aspects, including policy assessments and implications, public perception and awareness, data stewardship, financial models, business value propositions, competency and skill requirements, and so on. Examples of such partnerships include the following:

- India’s Centre for Excellence in IoT
- Milton Keynes’ MK:Smart
- Bristol Is Open
- Connecting Bristol

Independent Coordinators

We recommend that governments **identify and appoint “coordinators” to lead and facilitate implementation** (along the lines of Digital Catapult, Astana Innovations, and Fraunhofer Institute). The successful implementation of IoT-based solutions requires a phased approach and the involvement of multiple stakeholders. The appointment of independent third-party bodies as facilitators and caretakers of IoT projects during the pilot and proof of concept stages appears to be an effective model based on the experience of the jurisdictions we studied. These bodies, typically funded either directly by governments or through public-private partnerships, act as coordinators between academia, government, industry, civil society, and other stakeholders. They play the role of project managers and are responsible for the design, planning, and execution of pilots and proofs of concept, and for scaled implementation. The U.K. government has created Digital Catapult and IoTUK for this specific purpose. Fraunhofer Institute in Germany has proactively taken on this role and has been building such partnerships. The mayor of Astana established Astana Innovations to play a similar role.

The following are examples of independent third-party bodies as facilitators and caretakers of IoT, coordinating academia, governments, industry and other stakeholders:

- Digital Catapult - U.K.
- IoTUK
- Innovate UK
- Catapults - U.K.
- MK:Smart - Milton Keynes
- Fraunhofer Institute - Germany
- Astana Innovations - Kazakhstan
- CoE IoT - India

It is also important to point out that agencies and departments with advanced understanding, interest, and need for IoT-based solutions may not always have adequate decision-making authority to implement IoT-based services. For example, many cities do not have the policy-making authority to support smart city initiatives that involve IoT-based applications. Such authority may lie with national and subnational governments. This issue was observed not only in developing countries such as Kazakhstan but also in advanced economies, including Canada and the United Kingdom.

Creative, risk-taking jurisdictions such as Milton Keynes are proceeding with their proofs of concept, particularly in currently "unregulated" domains, and preparing to handle regulatory issues and challenges as they arise. More conservative jurisdictions, such as those in Germany, are working with their national partners to undertake "controlled" experiments. Traditional methods such as municipal bylaws also provide flexibility to cities to exploit opportunities for testing IoT technologies. One example of such a practice is in the United Kingdom: the Cambridge City Council has approved remote food safety inspections.

Local Business Models

The study has thrown up several examples of **incipient local business models for IoT**. Estonia is considering "Data Corporations," with shared ownership across the value chain. The city of Mississauga estimates that it saves Can$2 million annually (20) through its own fiber-optic network. Astana Tazartu, a solid waste management company established as a public-private partnership, installed fuel control sensors in its vehicles that have helped reduce both its fleet size and associated fuel costs. Bristol is evaluating and testing a range of sustainable business models over the next two years and eventually hopes to develop a suite of models that can be applied effectively in different contexts. Other jurisdictions are pinning their hope on the monetization of IoT data.

Business models to sustain IoT initiatives are still evolving, with very few clear "winners":

- IoTUK business models
- Bristol REPLICATE project

Develop Infrastructure for IoT

Many jurisdictions have begun to **develop their own technology infrastructure (fiber optics, LoRaWAN, and so on)** or to establish "productive" partnerships with telecom providers to develop data platforms. Stable and reliable network infrastructure is a prerequisite for IoT applications. Cities like Mississauga have developed their own fiber-optic infrastructure and/or LPWANs that support IoT devices. Others like Kobe have entered partnerships with telecom providers. Kobe is also building an IoT infrastructure using LoRaWAN technology, taking advantage of its geography (the surrounding mountains help extend coverage as far as 15 kilometers).

Many cities have opted to develop their own IoT infrastructure, while others rely on local telecom providers. Here are examples of a few approaches:

- Bristol fiber-optic network
- Mississauga fiber-optic network
- Kobe LoRaWAN

Many cities have developed platforms to collect and share IoT-generated data. Access and reuse policies are still very inconsistent.

- IoTUK Nation Database
- MK Data Hub - Milton Keynes
- Data Dome - Bristol
- X-Road - Estonia
- Mississauga Data
- Dubai Data

Capacity and Engagement

Engagement, Awareness, and Trust-Building

Governments must **engage and partner with local communities through education and outreach.** Governments need to be able to educate, build awareness, and engage all stakeholders (115), identifying their individual roles and responsibilities in the overall management of risks from IoT deployments, while clearly communicating the broad ranging benefits of the technology. Community groups and citizens can play an early and proactive role in generating ideas, providing feedback and input tackling sensitive and difficult issues such as data privacy and data ownership, and ensuring the long-term sustainability of such projects. The Knowle West Media Centre, an arts center and charity based in Bristol, is a good example of using outreach and education to develop trust and partnership with local communities.

Businesses and the public look to governments to **proactively understand and manage potential privacy and security issues related to data** generated through the use of IoT. Security incidents (28) expose technical limitations of the technology and tend to make governments risk averse and react in a manner (114) that may not be in the best long-term interest of innovation. Building trust and credibility with its citizens is key in the deployment of technology solutions such as IoT, considering the variety of risks and challenges identified above.

Useful references include the following:

- Knowle West Media Centre (Bristol)
- Best Practice Guides - U.K.

Develop IoT Capacity Within and Outside Government

It is essential to **develop IoT capacity within and outside government.** IoT-based applications and processes require a very different skill set and competency from the people managing them. For example, remote regulatory inspections may not require physical observations but may call for strong analytical skills and capabilities. Several governments are already beginning to engage and partner with universities and academic institutions to develop appropriate curricula, starting from early education all the way through college/university studies. In the United Kingdom, the Open University's FutureLearn program has created a free online module on smart cities that provides foundational and high-level education and understanding of smart city applications, including IoT-based solutions. Estonia's e-School program ensures mandatory education in digital technology for all students from an early age.

The following resources describe ways to engage communities and develop IoT-related capacity:

- Open University/Massive Open Online Courses - UK
- Enterprise Training - Milton Keynes
- Hamburg Port Authority - Germany
- Canada's Innovation and Skills Plan
- Win the Human Race - Canada
- Eduroam - Canada
- e-School program (Estonia)
- Open University's FutureLearn - U.K.
- NTIA green paper on IoT

Standardization

Government agencies must **participate in and support international standardization initiatives.** IoT and its associated technological innovations is still an evolving field. While numerous exciting and innovative devices, technological systems, and infrastructure have been developed recently, their dependability (reliability, availability, resilience, maintainability, and use) is often questionable in the absence of uniform standards. It is important that governments, especially in developing countries, actively participate in the development of such standards to ensure that their needs and constraints are expressed and addressed by the standards that do eventually emerge.

Examples of standards development currently under way:

- RAMI 4.0 - Germany
- IIC (Industrial IoT Consortium)
- OCF (Open Connectivity Foundation), which deals with interoperability
- Project Haystack - a data consortium establishing data standards for data models for hierarchical representation of devices

LOOKING AHEAD

Looking Ahead

This study is an initial exploration of IoT in the field in which we try to understand whether the reality of IoT for government to business services matches implementation realities, beyond the small group of 3-5 cities that are routinely heralded as champions in the space. The cities we studied are technically progressive; their leaderships understand and champion digital initiatives, and have put in place specific governance, financial, and technical infrastructure to implement IoT-driven solutions. Our initial findings suggest the following:

- It's still early days for IoT in government and much work remains to be done.
- The value-proposition of IoT for government to business services continues to become clearer.
- Business models remain unclear, but the promise is too stark to ignore.
- Several cities have begun to establish models for "best practice" implementation.
- Data management is key—as in all digital initiatives.
- Government has a strong role to play, but it must do so in the spirit/act of partnership with the private sector and the academia.
- IoT literacy remains a barrier.

We recognize that these are initial findings and that a more rigorous and wide-ranging analysis of IoT use/implementation around the world needs to occur. Future work should include the following:

Research

- Wider geographic coverage (and analysis of factors such as income, size, digital maturity, and others that might influence differing levels of IoT adoption in different situations/sectors)
- Deeper research into data- and property ownership–related issues in the IoT world, plus a comprehensive analysis of data/digital policies for IoT
- Greater research on issues surrounding IoT infrastructure (technical issues, plus emerging business models)
- Examination of the role of IoT in the global value chain and its impact on entrepreneurship and financial inclusion
- A separate analysis of business models for IoT within government and the private sector
- More formal IoT-related data collection (more rigorous data on IoT devices within cities, usage patterns, connectivity trends, infrastructure choices, services delivered, and so on)

Implementation

- Further development of the IoT toolkit which is still very rudimentary
- IoT as a component in World Bank and other development projects, ideally in multiple sectors and geographies (these can serve as further 'learning by doing' opportunities that help move the discussion beyond the hype and potential of IoT)
- Further development of standards
- More rigorous M&E frameworks

Diffusion

- There is still considerable need to develop awareness around both the potential and practical aspects of IoT within governments, businesses, and civil society
- We have identified several organizations, partnerships, and networks working on IoT related issues. International organizations such as the World Bank are still peripheral participants at best. There is no need to do more and engage more purposefully
- IoT is part of a larger digital ecosystem and it is important to include it in all initiatives related to the digital economy. And vice versa.

Bibliography

1. Lohr, S. G. E., "The 124-Year-Old Software Start-Up." *New York Times.* August 27, 2016.

2. Porter, M. E., and Heppelmann, J. E. "How Smart, Connected Products Are Transforming Competition." *Harvard Business Review.* November 2014.

3. OECD (Organisation for Economic Co-operation and Development). *The Innovative Imperative in the Public Sector.* s.l.: OECD.

4. Bousquet, C. "How Cities Are Using the Internet of Things to Map Air Quality." *Data - Smart City Solutions.* Harvard University. April 19, 2017.

5. www.transit55.ca. [Online]

6. Talari, S. et al. "A Review of Smart Cities Based on Internet of Things Concept." *Energies* 10 (March 23, 2017): 421.

7. MK:Smart. *Helping to Delivery the Internet of Things in Milton Keynes.* [prod.] MK:Smart. Milton Keynes, UK: s.n., May 23, 2014.

8. *www.plattform-i40.de/I40/Navigation/En/Home/home.html.* [Online]

9. European Commission. *Internet of Things in Digital Single Market.* [prod.] European Commission. October 1, 2013.

10. Bradley, K. "UK Digital Strategy." Policy Paper. UK Department for Digital, Culture, Media and Sport, March 1, 2017.

11. Government of Singapore. *Formation of the Smart Nation and Digital Government Group in the Prime Minister's Office.* March 20, 2017.

12. India, Ministry of Electronics and Information Technology. *Internet of Things.* s.l.: Government of India, July 22, 2016.

13. Living Lab. Living Lab. [Online] https://www.ludwigsburg.de/,Lde/start/stadt_buerger/living+l_a_b.html.

14. Checkit. "Checkit and Cambridge City Council Partner to Transform UK Food Safety." [Blog] April 6, 2016.

15. World Economic Forum. *Industrial Internet of Things: Unleashing the Potential of Connected Products and Services.* Industry Agenda. January 2015.

16. Bristol Is Open. Open Programmable City. *Bristol Is Open.* [Online] www.bristolisopen.com.

17. MK:Smart. MK Data Hub. *www.mksmart.org/data.* [Online]

18. Bristol City Council. Corporate Strategy 2017-2022 Consultation. *City of Bristol.* [Online] www.bristol.gov.uk/council-spending-performance/corporate-strategy-2017-2022-consultation.

19. City of Mississauga. Strategic Plan. [Online] www.mississauga.ca/portal/strategicplan/plan.

20. ———. Information Technology, 2015-2018 Business Plan and 2015 Budget. [Online] www.mississauga.ca.

21. [Online] http://www.iiconsortium.org.

22. Open Connectivity Foundation. Unlocking the Massive Opportunity in the Internet of Things. [Online] www.openconnectivity.org.

23. *Project Haystack.* [Online] http://project-haystack.org.

24. United Kingdom, Department for Business, Energy and Industrial Strategy. *Growth Duty: Statutory Guidance.* s.l.: U.K. Government, March 2017.

25. World Trade Organization. *Trade Facilitation.* s.l.: WTO.

26. European Commission. *Digital Single Market.* s.l.: European Commission.

27. Directorate-General of Internal Policies. *Reducing Costs and Barriers for Businesses in the Single Market.* s.l.: European Parliament, 2016.

28. Working Party on Communication Infrastructures and Services Policy. "The Internet of Things: Seizing the Benefits and Addressing the Challenges." Background Report for Ministerial Panel 2.2. JT 03396520. Directorate for Science, Technology, and Innovation Committee on Digital Economy Policy, OECD, 2016.

29. Cisco. Potential for IoT in the Public Sector. *Internet of Everything.* [Online] internetofeverything.cisco.com.

30. United States, Department of Commerce. "Fostering the Advancement of the Internet of Things." Green Paper. Department of Commerce, 2017.

31. Woolf, N. “DDoS Attack That Disrupted Internet Was Largest of Its Kind in History, Experts Say.” *The Guardian*. October 26, 2016.

32. Quatromoni, K. “The Industrial Internet Consortium Announces the Industrial Vocabulary Technical Report V. 2.0.” [Press Release] Industrial Internet Consortium. July 24, 2017.

33. Government of United Kingdom. “Digital Strategy to Make Britain the Best Place in the World to Start and Grow and Digital Business.” [Press Release] gov.uk. March 1, 2017.

34. United Kingdom, Government Office of Science. *Annual Report 2015-2016*. s.l.: U.K. Government, 2016.

35. United Kingdom, Department for Business, Energy and Industrial Strategy. “Upgrading Our Energy System.” Policy Paper. Department for Business, Energy and Industrial Strategy, July 24, 2017.

36. Innovate UK. [Online] www.gov.uk/government/organisations/innovate-uk.

37. Catapults. [Online] www.catapult.org.uk.

38. Digital Catapult. [Online] www.digitalcatapultcentre.org.uk.

39. Future Cities Catapult. [Online] www.futurecities.catapult.org.uk.

40. Digital Catapult. [Online] www.digitalcatapultcentre.org.uk/project/things-connected.

41. IoTUk. About Us. [Online] www.iotuk.org.uk/about-us.

42. Gas Tag. [Online] www.gastag.co.uk.

43. Council of Gas Detection and Environmental Monitoring. [Online] www.cogdem.org.uk.

44. IoTUK. *Mapping the IoT Nation*. s.l.: IoTUK, August 2016.

45. Chan, S. P. “Cambridge and Milton Keynes to Lead UK Growth in 2016.” *The Telegraph*. January 5, 2016.

46. Cooter, M. “Taking a Closer Look at the Milton Keynes Smart City Project.” *Computer Weekly*. January 11, 2016.

47. MK:Smart. [Online] www.apexsuite.mksmart.org.

48. University of Bedfordshire. [Online] www.beds.ac.uk/about-us/campuses/milton-keynes.

49. MK:Smart. “Urban Startup Lab from Fronesys Promotes Critical Entrepreneurship Skills in Milton Keynes.” [Online]

50. MK:Smart. “Supporting Citizens to Shape the Future of Milton Keynes.” [Online] www.mksmart.org/citizens/.

51. BBC News. “Bristol Named Best Place to live in Britain in 2017.” British Broadcasting Corporation, March 19, 2017.

52. Bristol Is Open. Bio Application IoT Mesh. [Online] www.bristolisopen.com/wp-content/uploads/2016/01/BIO-Application-IoT-Mesh.pef.

53. REPLICATE. Excellence in Integrated Energy. [Online] http://replicate-project.eu/energy-efficiency/.

54. ———. San Sebastian Mobility Action. [Online] http://replicate-project.eu/mobility.

55. ———. Excellence in ICT and Infrastructure. [Online] http://replicate-project.eu/ict/.

56. Knowle West Media Centre. “The Bristol Approach.” [Online] www.kwmc.org.uk/projects/bristolapproach/.

57. Die Bundesregierung. *Digitale Agenda*.

58. Wybitul, T., and Bohm, W.-T. “German Parliament Passes New Federal Data Protection Act.” [Online] Hogan Lovells. May 2, 2017.

59. Plattform Industrie 4.0. [Online] www.plattform-i40.de.

60. ———. [Online] http://www.plattform-i40.de/I40/Redaktion/DE/Downloads/Publikation/interaktionsmodell-i40-komponenten-it-gipfel.html.

61. Adolphs, P. “RAMI 4.0: An Architectural Model for Industrie 4.0.” www.omg.org. Presentation, June 2015.

62. Seibel, B. *Open Data in der Praxis*. s.l.: Technologiestiftung Berlin, January 2016.

63. Hamburg Port Authority. [Online] http://www.hamburg-port-authority.de/en/Seiten/Startseite.aspx.

64. ———. [Online] http://www.hamburg-port-authority.de/en/smartport/Seiten/Unterbereich.aspx.

65. Cisco. [Online] http://internetofeverything.cisco.com/sites/default/files/pdfs/Hamburg_Jurisdiction_Profile_final.pdf.

66. Woyke, I. *New Senses for the city (he) live*. [prod.] Innovisions. s.l.: Fraunhofer IUK Technologie, July 23, 2015.

67. e-Estonia. We Have Built a Digital Society and So Can You. [Online] www.e-estonia.com.

68. ———. e-Identity. [Online] www.e-estonia.com/solutions/e-identify/id-card/.

69. ———. Interoperability Services. [Online] www.e-estonia.com/solutions/interoperability-services/x-road.

70. Estonia, Ministry of Economic Affairs and Communication. *Digital Agenda 2020 for Estonia*.

71. Tootsi, T. "Utilisation of Road, Traffic, and Weather Information in Effective Maintenance." [Presentation].

72. GoSwift. Estonia Borders Queue Management Service. [Online]

73. Riigi Teataja. Electricity Market Act. July 2014.

74. My Smart Energy. Find Out What Is Happening in Your Country. [Online] www.my-smart-energy-eu/my-copuntry/estonia.

75. Riigi Teataja. Electronics Communications Act. January 1, 2016.

76. ———. Spatial Data Act. January 17, 2016.

77. ———. Electronic Identification and Trust Services for Electronic Transactions Act. October 26, 2016.

78. ———. Digital Signature Act. June 30, 2014.

79. OECD Digital Government Studies. *Benchmarking Digital Government Strategies in MENA Countries.* Paris: OECD, 2017.

80. OECD. *Estonia and Finland: Summary of Key Findings: Fostering Strategic Capacity across Governments and Digital Services across Borders.* Paris: OECD, 2015.

81. Rahe, A. "Overview of Estonian ICT Policy Coordination: How to Keep Costs Under Control and Still Achieve the Results?" [Presentation].

82. e-Skills Monitor EU. *e-Skills in Europe: Estonia Country Report*. 2014.

83. Soe, R.-M. "Real-Time Economy Applications." [Presentation] Norway_Estonia_Cooperation Seminar, ICT WEEK, 2015.

84. Embassy of the Republic of Kazakhstan. 100 Concrete Steps to Implement the 5 Institutional Reforms. [online] www.Kazakhembus.com.

85. Canadian Radio-Television and Telecommunications Commission. Telecom Regulatory Policy CRTC 2016-496. s.l.: Government of Canada, December 21, 2016.

86. Government of Canada. Budget in Brief. [Online] www.budget.gc.ca/2017/docs/.

87. Telus/IDC. *Internet of Things Study.* 2014.

88. Infrastructure Canada. Welcome to Canada's Smart Cities Challenge. [Online] www.infrastructure.gc.ca.

89. Public Policy Forum of Canada. *The Promise and Pitfalls of Internet of Things in Canada*. Public Policy Forum. 2017.

90. Government of Canada. Strategic Innovation Fund. [Online] https://www.canada.ca/en/innovation-science-economic-development/programs/strategic-innovation-fund.html.

91. City of Mississauga. *Our Future Mississauga: Strategic Plan*. City of Mississauga. 2009.

92. ———. *Inspiring Possibilities - IT Master Plan*. City of Mississauga. 2015.

93. ———. General Committee Minutes. May 18, 2016.

94. ———. *2015-2018 IT Business Plan and 2015 Budget.* 2016.

95. ———. *5-year Energy Conservation Plan*. 2014.

96. ———. *Advanced Transportation Management System*. February 7, 2017.

97. Cisco. Transforming to an Engaged and Connected City. [Online] http://www.cisco.com/c/dam/m/en_ca/innovationcenter/toronto/pdf/city-of-mississauga-case-study.pdf.

98. Ontario Tire Stewardship. TreadMarks Mobile. [Online] http://rethinktires.ca/wp-content/uploads/Premiere-Hauler-and-Processor.pdf.

99. Technical Standards and Safety Authority. *Annual Public Safety Performance Report*. 2016.

100. U.S. White House. *Technology and the Future of Cities.* Washington, DC: White House, 2016.

101. NTT DOCOMO. *Earnings Release FY 2016*. 2016.

102. Sentilo. [Online] http://www.sentilo.io/xwiki/bin/view/Sentilo.About.Product/Whatis.

103. City of Dubai. [Online] http://www.smartdubai.ae/about.php.

104. Smart Dubai. Smart Services and Initiatives Spanning all City Layers. [Online] www.smartdubai.ae/foundation_layers.php.

105. Government of India. [Online] www.digitalindia.gov.in.

106. ———. [Online] http://coe-iot.com.

107. India, Ministry of Electronics and Information Technology. *IoT Policy Document.* Ministry of Electronics and Information Technology.

108. Rajkot Municipal Corporation. RITE Governance.

109. ———. Smart City Proposals. [Online] www.rmc.gov.in.

110. ICLEI. The Urban Climate Project: Building Clean and Efficient Cities, Initiatives in Rajkot. [Online] http://urbanclimateproject.iclei.org/rajkot.html.

111. Nesta. "Anticipatory Regulation: 10 Ways Governments Can Better Keep Up with Fast-Changing Industries." [blog] http://www.nesta.org.uk/blog/anticipatory-regulation-10-ways-governments-can-better-keep-fast-changing-industries. May 2017.

112. Georghiou, L. et al. "Policy Instruments for Public Procurement of Innovation: Choice, Design and Assessment." *Technological Forecasting and Social Change* 86 (July 2014): 1-12.

113. GovLoop. *The Internet of Things: Challenges and Opportunities for Government.* s.l.: GovLoop, 2017.

114. Future of Privacy Forum. *The Benefits, Challenges and Potential Roles for the Advancement of Internet of Things.* 2016. Docket No: 160331306-6306-01.

115. Simpson, A. "Increasing the Potential of IoT Through Security and Transparency." [Blog] U.S. National Telecommunications and Information Administration. August 2016.

116. Cameron, D. "Prime Minister Cameron's Speech to the CeBIT Trade Fair." Hanover, Germany, January 9, 2014.

117. Willetts, D. "New Initiative to Support $40 Billion Smart Cities in the UK." [Press Release] gov.uk. October 9, 2013.

APPENDICES

APPENDIX A. IoT Questionnaire

IOT Study – Interview Protocol (Government/Regulatory Agencies)

Category I: Organizational Information

1. Country/City Name:
2. Name of Organization:
3. Person(s) Name:
4. Persons(s) Title:
5. Person(s) Roles and Responsibilities:

Category II: Legal/Regulatory Framework

1. Is there a formal digital policy from the government?
2. Does the digital policy recognize the use of IoT-based applications for government service delivery?
3. Is the current policy designed to foster or inhibit the growth of IoT in society?
4. Is the policy aimed at specific uses of IoT or is it more general than that?
5. Are there existing laws or policies on freedom/right/access to information or privacy laws that either facilitate or hinder/pose a barrier to the use of IoT-based applications?
6. Does the policy cover IP?
7. Are there any specific laws that regulate the collection and use of data produced by IoT applications?
    a. Who owns the data? (The device provider or the buyer? The government? Or another?)
    b. Are there any limitations on the sharing and use of this data?
8. Does the policy contain any cybersecurity provisions?
9. Does the policy specify any technical standards for IoT; is interoperability a policy goal?
10. Is there a formal stakeholder consultation/citizen engagement process? Were businesses consulted?
11. Were the stakeholders consulted prior to formalizing the use of IoT-based applications?
12. What was the mechanism for consultation and what was the feedback and response from the consultation process?
13. Are there any outstanding/residual concerns from stakeholders?
14. What is the authorizing framework/environment for the use of IoT-based applications within the agency (e.g., mandate letter, policy direction, etc.)?
15. Are there policy guidelines/standards informing the IoT implementation, and if so, what are they?
16. Are any measurement/evaluation standards incorporated in the policy

Category III: Areas of Public Infrastructure

- What are the areas of public infrastructure services and what type of IoT applications are being considered?

1. Built Environments/Buildings, including institutions such as hospitals, schools, social housing, seniors' homes, etc.
    a. Smart systems such as lighting, elevators, face recognition–based security systems, etc.
    b. Predictive maintenance of engineering systems such as elevators/escalators using real-time monitoring
    c. Real-time monitoring of operation and maintenance of emergency management systems such as fire protection, backup generators, etc.
    d. Performance-based licensing and inspections by regulatory agencies
    e. Sensor-based integrated building management systems (e.g., supported LEED buildings)
2. Energy Systems, including power generation, heating, ventilation and air conditioning equipment, boilers and pressure systems
    a. Remote monitoring and operation of energy systems
    b. Sensor-based detection, response, and management of equipment failures such as corrosion, leaks, and environmental releases
    c. Drone-based monitoring of pipelines
    d. Indoor air pollution monitoring and response systems
    e. Remote monitoring and verification of certified contractors
3. Transportation
    a. Real-time GPS-based scheduling and routing
    b. Real-time monitoring and management of fleet, such as school buses
    c. Remote vehicular inspections

    d. Tracking and compliance at ports/border crossings
4. Environmental Infrastructure, including water supply, water/wastewater treatment, waste management
    a. Remote monitoring of water leaks
    b. Flood detection and warning systems
    c. Remote and real-time monitoring for contaminants at wastewater treatment plants
    d. Sensor based real-time garbage/waste pickup, disposal, and tracking systems
5. Food, Consumer Products, and Public Health
    a. RFID tags on food/meat products for monitoring of conditions, expiry dates, etc.
    b. Remote monitoring and inspections of restaurants and food service locations
    c. Protection and supply of vaccines
6. Other Applications

- What specific types of services are being delivered (or being contemplated) with IoT applications?

1. Are these services delivered by the agency or by businesses? (e.g., regulatory inspections are serviced delivered by the agency, preventive maintenance services are delivered by businesses but accepted/ overseen by the agencies)
2. Is the scope of the IOT application limited to certain aspects of the service or across the entire sector (e.g., are the services limited to certain geographic regions, specific types of technologies etc.)?
3. Is the use of IoT-based applications mandatory or voluntary?

Category IV: Institutional Framework

1. What is the overall agency governance structure for IoT-based policy making and delivery (roles and responsibilities, organizational chart, job descriptions, etc.)?
2. Are decisions on IoT-based applications made at the strategic (senior management) level or viewed as operational?
3. Do the decision makers have adequate statutory/ regulatory authority to recommend/implement IoT-based applications?
4. How are businesses engaged in the process (voluntary choices, mandated/regulatory requirements, incentives, etc.)?
5. What is the level of awareness of IoT-based applications within the agency and among businesses?
6. Are there formal training/communication programs for building awareness and educating internal and external stakeholders?
7. Do the services provided overlap with other agencies, and if so, what is the process for reducing conflict and addressing consistency?
8. Does the agency have formal institutional arrangements with other agencies in facilitating an efficient/ effective implementation of IoT-based solutions?
9. Are there performance management processes/ programs in place to measure the effectiveness and impact of IoT-based solutions?
10. Are the results from performance measurement available to the public from the businesses and the agency?

Category V: Technology Framework

1. What was the specific role of the agency in determining the technology solution/architecture?
2. What is the technology architecture that is being used?
3. What are the specific components of the IOT system (sensors, actuators, cloud services, networks/protocols/standards, platforms, etc.)?
4. How interoperable is the solution?
5. How are security aspects addressed?
6. Where does the technology reside? (Within businesses, both businesses and agencies, agencies only, etc.)
7. Who is responsible/accountable for the technology solution?
8. Who owns the software and the associated intellectual properties?
9. What types of machine learning applications or other technologies are being used?
10. Are the solutions available as a package or are they being individually/separately sourced?
11. Were academic institutions involved in the design and development of the technology solutions?
12. How large (how much choice) and how mature (availability/quality/accessibility) is the marketplace for the required technology solution(s)?
13. What were the relative costs of possible technology solutions (on a per business and across the businesses)?
14. Who are the leading providers of technology solutions in the marketplace?
15. What were the challenges in implementing the solutions and how were they resolved?
16. What was the time-period for the entire life cycle of implementation (including proof of concept studies)?
17. What were lessons learned through the implementation cycle?
18. Who is responsible for maintenance of the technologies and how is it managed?
19. Are there any dispute resolution mechanisms in place?

Category VI: Data Framework

20. Has a data governance framework been established?
1. Who owns the data generated?

2. What is the data life cycle?
3. Is any data open
4. How is the data managed?
5. Are there provisions/opportunities for outsourcing the management/analysis of data to entrepreneurs (creating new opportunities)?
6. Who analyzes the data?
7. Are there data quality systems in place to manage the accuracy, relevance, timeliness, and completeness of the data?
8. What decisions are made/actions taken using the data?
9. How real-time are the responses/actions to the data?
10. Are periodic reports produced and shared with the public?
11. Is the data made available for free or is it "sold" to stakeholders, including the agency?
12. What is the current skill set and availability of competent resources to handle the data, including data analytics?
13. Is the data collected through the IOT applications part of an "open data" initiative?
14. Is the public able to access and use the data?
15. Are there reports/publications available on the use of IoT-based data?

Category VII: Value-Proposition and Benefits to Government and Businesses

1. What were the objectives of government?
    a. Efficiency?
    b. Compliance?
    c. Audit?
    d. Business environment?
    e. Competition?
    f. Innovation?
    g. Others?
2. What benefits do IoT-based applications provide to the agency?
3. What benefits do IoT-based applications provide to businesses?
4. Do businesses realize cost savings?
5. Do businesses increase their market share through such applications?
6. Are there efficiency gains within the agency?
7. What are the motivating factors (incentives) for businesses to adopt/use IoT-based applications?
8. Does the government provide subsidies/rebates to businesses or consumers for implementing such solutions?
9. What is the demand for such applications? Do businesses view the availability of IoT-based applications as valuable for their work?
10. Are there other tangible/intangible benefits that have been/can be realized through implementation (e.g., improvements in compliance, reduction in negative environmental/safety/health impacts, reduction in breakdowns/shutdowns, etc.)?
11. Has the city/jurisdiction benefited from the use of IoT-based applications (e.g., increase in new businesses, reputational impact, increase in investments, etc.)?

Category VIII: Financing

1. How is the technology infrastructure for the IoT solution funded?
2. What is the role of the agency in the financing model? (Subsidies, rebates, performance incentives, loans, grants for proof of concept or implementation, etc.)
3. How is the data infrastructure (through its life cycle) funded?
4. Is there a shared model for funding across businesses, technology providers, agencies, and the consumers?
5. Do stakeholders/users have to pay for the data?
6. Who pays for the maintenance of the infrastructure, including hardware such as the sensors?
7. What is the distribution of costs across the technology solution (hardware, networks, data, etc.)?
8. Is there a long-term strategy for the funding model?

APPENDIX B. IOT Systems, Platforms, and Applications

IoT technology systems comprise three elements:

- Sensors
- Networks
- Analytics

There are many types of sensors currently available in the market, including most common following ones:

- **Acceleration sensors:** These sensors measure acceleration of objects, and motion that provides useful information in industrial applications to monitor machines or tools. One example is a sensor that protects a laptop from damage when it falls.
- **Force sensors:** These sensors measure pressure and are often used to measure weight (to monitor loads on cranes or in grain silos, for example). Force sensors are used, for example, in IoT applications in medical and industrial instruments, packaging, and industrial machinery.
- **Flow sensors:** Flow sensors are used to measure the flow rate of liquids in various applications, typically vehicles, buildings, and factories. One example is measurement of flows in vented pipelines like drains or sewers to confirm whether they are at capacity.
- **Sound sensors:** Sound sensors are primarily used to measure the noise level and the intensity of sound in different settings, such as cities or factories/restaurants.
- **Vibration sensors:** Vibration sensors are used to sense vibrations of city infrastructure, factory machinery, power generators, and in vehicles. One example is the measurement of changes in vibration in factory machinery to predict maintenance requirements.
- **Humidity sensors:** Humidity is an important environmental parameter and humidity sensors are frequently used in climate-based IoT applications and for air quality measurement in urban areas.
- **Temperature sensors:** Temperature sensors, used to measure the temperature of outdoor and indoor environments, are the most common sensors used in IoT applications. One example is the measurement of heat to monitor the operation of machines and devices in industrial systems.
- **Gas sensors:** Gas sensors are used to measure gases such as CO, CO_2, and NO_2 for pollution monitoring and CH_4, H_2S, and NH_3 for emissions in the environment. They can be used for both indoor and outdoor environmental monitoring purposes.
- **Chemical sensors:** These sensors measure hazard levels of certain chemical compounds and radiations in the environment, mainly in harsh environments (for example, mining, chemical factories).
- **Motion sensors:** These sensors measure motion and rotation, which are important components in the automation industry. A very common example is a motion-sensing light that turns on when it detects motion in a room (if somebody walks in, for instance).
- **Magnetic sensors:** These sensors measure magnetic fields, which can be used in various industrial environments. Common applications include power steering, security, and current measurements on transmission lines.
- **Light sensors:** These sensors measure light strength for both energy management and environmental control applications. A common application of such sensors is to detect brightness in indoor settings and adjust the screen brightness of LCD monitors for optimum display.
- **Pressure sensors:** A pressure sensor measures pressure. A common example is seat occupancy monitoring in cars.
- **Medical sensors:** Small medical sensors such as ECG and heart rate monitors are designed to enable remote monitoring for IoT health care applications.

The following are common network technologies used in IoT systems:

1. **Mobile Communications and Wireless Wide Area Networks (up to 10 km)**
    a. 3G/4G: The "G" represents the next-generation technology development in mobile data communication, mostly focused on data speed, security, and more robust communication in the mobile networks. Most advanced features in smartphones, such as video calling, were introduced in 3G and are being improved with 4G technology.
    b. LTE: Long Term Evolution (LTE) is an international mobile communication standard for enabling high-speed wireless mobile communication networks to meet the increasing demand of data communication.

c. LTE Advanced: This is a more advanced LTE standard that targets 4G mobile technology network speeds. It is also known as LTE 4G. LTE advanced is expected to provide a faster communication link with more robust connections.
d. GPRS (General Packet Radio Service): A packed-based mobile communication service with low data rate communication.
e. CDMA: It is a cellular network standard primarily used in the United States.
f. GSM (Global System for Mobile Communication): It is the world's most used standard system. Both GSM and CDMA standards are used in 3G/4G and LTE technologies.
g. Sigfox: It is a low-power wide area network that has become popular for addressing the connectivity of low-energy remote objects (for example, smart meters). It is a narrowband technology with low-data network link, carrying up to 12 bytes.
h. LoRaWAN: LoRaWAN is a low-power wide area network system maintained by the LoRa Alliance. It is currently the most popular network used to connect objects in IoT applications. Unlike mobile communication networks, LoRaWAN has data rates from 0.3 kbps to 5 kbps and uses gateways to improve the coverage.
i. Weightless: Weightless is another low-power wide area network technology, delivering a solution for wireless connectivity of smart machines (for example, machine to machine [M2M] communications).
j. Narrowband IoT (NB-IoT): It is a recently developed standard for IoT projects, to form a low-power wide area network using small amounts of data communication over long distances.

LoRaWAN, NB-IoT, Weightless, and Sigfox are similar in providing connectivity solutions for IoT technologies; however, they use different wireless communication techniques, frequency bands, and network protocols.

2. Wireless Metropolitan Area Network (up to 10 km)

a. IEEE 802.16 (WiMAX): WiMAX (Worldwide Interoperability for Microwave Access) is a broadband wireless network system established for the deployment of wireless network systems in metropolitan areas around the world.

3. Wireless Local Area Network (IEEE 802.11) (0.5 km)

a. Wi-Fi: This is a wireless local area network standard (for example, IEEE 802.11 standard) used to connect smart devices such as smartphones, computers, smart TVs, and smart appliances to the Internet.

4. Wireless Personal Area Networks/Short-Range Device Networks (up to 100 m)

a. Bluetooth: Bluetooth is a wireless standard for data transfer between fixed and mobile devices. Bluetooth was initially developed to eliminate cables used with personal devices.
b. Zigbee/XBee: This is a wireless standard used by radio devices to low-power wireless connection. It uses the ISM band as the communication frequencies. Like LoRa systems, XBee/Zigbee is a popular low-power area network protocol for IoT applications.
c. UWB (Ultra Wideband): The UWB standard is used for low-power high-data-rate wireless connection for personal devices. It uses a transmission frequency different than XBee and Bluetooth.
d. Wi-SUN (IEEE 802.15.4g): Wi-SUN is a global wireless alliance that has been chosen by utility companies to enable interoperable wireless standards–based solutions.
e. 6LoWPAN (IPv6 over Low-Power Wireless Personal Area Networks): Its purpose is to apply Internet protocol to small devices to establish wireless Internet connectivity. It is another popular protocol for IoT applications.
f. Z-Wave: Z-Wave is a low-power wireless communications protocol, targeting mainly home and office automation applications.
g. Thread: Similar to XBee and Z-Wave, Thread is based on 6LoWPAN to enable IoT applications. Its wireless protocol uses mesh communication like XBee.
h. ANT: This is a wireless technology similar to Bluetooth.

5. Wired Connections

a. Powerline: It provides data transmission on the existing electrical wiring in home and offices without any additional network cables.
b. Local Area Network (LAN)/Ethernet: This is a wired-based network that links computing devices within a building.
c. Cable modem, dial-up, DSL, SONET: These are wired communication links used to connect the Internet to devices using either optical fiber (SONET) or cables.

6. Short-Range Communications (up to a few cm)

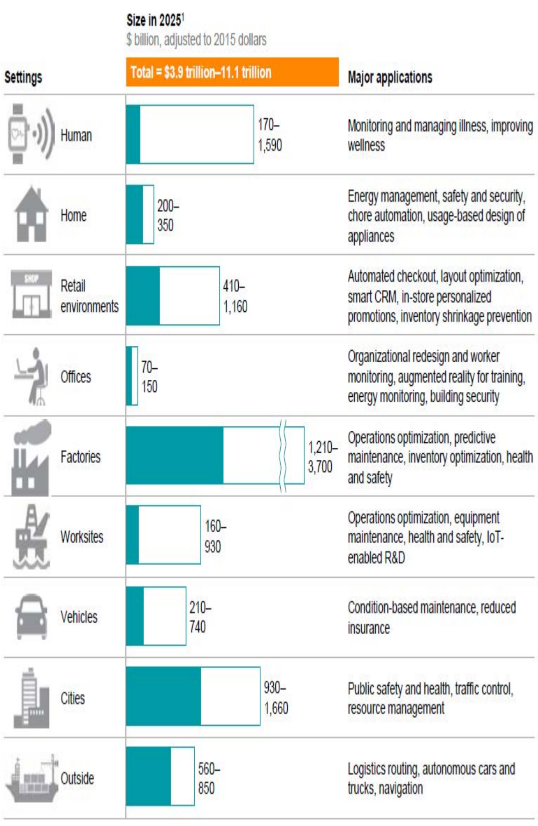
a. RFID: RFID devices are contactless systems that are widely used to track items and objects in many industrial environments. RFID uses electromagnetic waves with low bandwidth and low-data communication.
b. NFC: This is a communication protocol established to provide a very short (for example, 4 cm)

connection between small devices. It is implemented in contactless devices such as key cards and contactless payment systems. NFC technology is also widely used in smartphones to utilize them like a smart card.

7. All-IP or Next-Generation Network:
Mobile subscribers and Internet users demand access to the Internet, placing enormous load on the network infrastructure. Mobile communications (LTE, 3G/4G), M2M, and IoT technology will all be IP-based communication systems to access the network communication infrastructure for the Internet. Users of these new technologies require mobility, speed, easy access, and security for all possible new services. Operators of services demand high speed and increased revenue to establish new services and reach more customers, with reduced operating cost.

As the demand from these mobile communication devices increases, the next-generation network or all-IP should enable advanced telecommunications network, with higher security to meet the increasing demand. Therefore, the concept of next-generation network or all-IP is to establish an advanced Internet protocol (IP), facilitating a secure, cost-effective, high-bandwidth IP backbone for the next generation of telecommunication infrastructure, by connecting all existing networks into IP-based networks.

Figure B1. Nine Settings Where IoT Have Bigger Economic Impact



1 Includes sized applications only.
NOTE: Numbers may not sum due to rounding.

SOURCE: McKinsey Global Institute analysis

As the number of IoT devices has grown, so has the number of applications. Real-world deployment strategies are required for each application and sector (for example, deployments of Industry 4.0, Industrial Internet, Wi-SUN, and GS1 implementations). The German government initiative Industrial Internet (Industry 4.0), for example, was formed to redraw industry boundaries and create a new wave of disruptive hardware and software technologies for improving productivity and enabling new opportunities. It includes cyber-physical systems, IoT, and cloud computing targeting automation and manufacturing technologies. It is now being recognized as the industrial Internet of things (IIoT).

In a recent report, McKinsey Global Institute identified nine settings for IoT usage with the greatest economic potential, capturing over 100 IoT applications in environments such as homes, offices, factories, worksites (mining, oil and gas, and construction), retail environments, cities, vehicles, and the outdoors (figure B1). These applications are estimated to have a total value of $3.9 trillion to $11.1 trillion per year in 2025. The largest setting for the potential value created is factories, which could be as much as $3.7 trillion in 2025—about a third of the total potential value estimated for all IoT applications by McKinsey Global Institute.
And finally, as the number of devices and applications centered on IoT has grown, so has the IoT marketplace. Table B1 provides a list of major hardware, software, and computing companies focusing on IoT systems. This is only a partial list, but it provides further evidence of IoT-focused economic activity. Companies like Cisco, Samsung, Flex, IBM, Entrust Datacard, and Amazon are providing cloud computing services.

In terms of hardware and connection technology toolkits, Libelium is currently the leading company, presenting many sensor platforms for various IoT applications and deployments. They have partnered with many companies in the IoT domain as well as with cloud software solution providers to offer all the required components to deploy IoT, M2M, or projects to smart city activities. Their devices have been used for IoT applications such as smart parking, air and noise pollution, vineyard monitoring, gas monitoring, smart water, and radiation monitoring. Libelium provides a universal gateway called Meshlium, which was developed to connect any sensor to any cloud platform.

Many existing large electronic and IT companies are key industry players for IoT hardware developments. There are new start-ups, some included in table B1, taking place in the market for focusing supplications of IoT.

Table B1. Existing IoT Platforms for IoT Applications

Company	Module/s	Features	Website
Cisco	Cisco IoT System - Cisco Fog Computing - Physical and cybersecurity application platform - Network connectivity - Data analytics	- A set of products and technologies for creating IoT solutions from cloud to fog	http://www.cisco.com/c/m/en_us/solutions/internet-of-things/iot-system.html
Samsung	ARTIK IoT Module	- Integration of hardware modules and cloud services	www.artik.io
IBM	Watson IoT Platform Node-RED	- Cloud-hosted service	https://www.ibm.com/internet-of-things/ http://nodered.org/
Flex	Flex Sketch-to-Scale™ Solutions Flex Manage Cloud	- E-solutions and cloud service	http://www.flexmanage.com/managed-services/
Nectar	Nectar Cloud	- Cloud-hosted service	https://nectar.org.au/about/
NVIDIA Embedded	Jetson TX2 Embedded AI	- Hardware solutions for embedded computing	https://developer.nvidia.com/embedded-computing
Qualcomm	Snapdragon™ system on a chip	- Integrated processor and wireless connectivity	www.qualcomm.com
	Smart Cities	- Edge processing - Security interoperability - Deploying at scale	
	Snapdragon 835	- Processor platform - Robust mobile security	
	Wireless and RF	- Zigbee - Thread - Wi-Fi - Bluetooth - Proprietary	
	Sensors	- Low-energy sensor interface - Optical, humidity, temperature, capacitive touch sensors	
Amazon	AWS IoT Platform	- A cloud platform that can support billions of device connections	https://aws.amazon.com/iot/
GainSpan	Wi-Fi Module (FCC, CE, IC, Telec Certified)	- Development of hosted or hostless application software	www.gainspan.com
	Wireless	- Sub-1GHz - 2.4GHz - NFC	
	MiGLO	- Near-field magnetic induction (NFMI) hearables	
	Sensors		
Lantronix	PremierWave	- System-on-module - Wi-Fi, Ethernet	www.lantronix.com
Texas Instrument	All required hardware components available for an IoT implementation, end-to-end solutions	- MIMO Wi-Fi Bluetooth combo - Zigbee, RF4CE, 6LoWPAN, NFC, Proprietary	http://www.ti.com/ww/en/internet_of_things/iot-products.html

Intel	Intel Quark SE	- Microcontroller with sensor boards, interface shields, integrated communication modules	www.intel.com
	Intel IoT Gateway	- Aggregate data from edge/Fog to cloud	
Particle	Wi-Fi and cellular connectivity	- Prototype-to-platform development	www.particle.io
LinkLabs	Symphony Link	- LoRa: Low-power wide area network (LPWAN)	www.link-labs.com
	LTE-M LTE Cat-M1	- TCP/IP network - Extended discontinuous reception	
	AirFinder	- Real-time location system for asset tracking	www.airfinder.com
Libelium	WaspMote (WSN hardware)	- 110+ sensors - 16 radio tech. (cellular, LoRa, Sigfox, Zigbee, DigiMesh, Wi-Fi, etc.)	www.libelium.com/ http://www.libeli-um.com/resources/case-studies/
	MySignals	- Biometrical platform for measuring 20 differ-ent body parameters	
	Meshlium Xtreme	- Sensors to the cloud	
Freestyle	Freestyle Microengine M2M Switch	- Hardware and computing solutions for M2M	http://freestyletechnol-ogy.com.au/
Entrust Datacard™	IoT Software Platform	- Cloud service provider - Device and data security management tools	https://www.entrust-datacard.com
Silver Spring Networks	Hardware and software solutions	- IoT solutions, smart electricity, gas, water and city services	https://www.silver-springnet.com/
Autani, LLC	IoT platforms for energy man-agement	- Wired/wireless solutions - EnergyCenter platform, integrating appli-cations for metering, HVAC/environmental, refrigeration, sensors, lighting control	http://www.autani.com
ThingWorx IoT Technology Platform	An IoT platform	- Ecosystem, smart agriculture	https://www.thing-worx.com/ecosystem/markets/smart-con-nected-systems/smart-agriculture/
Thread	Thread network	- Network connections using smartphone, tablet, or computer - Network connection to 250+ devices in a single network with 6LoWPAN - Security at network and application layers	http://threadgroup.org
Trimble	Software IoT platform	- Across the entire agricultural supply chain	https://agriculture.trimble.com/software/connectedfarm/
IoTree Watchbox	Iotreecloud	- A solution for building and environmental monitoring - A cloud solution	https://iotreecloud.com
ThingBot	ThingBot-LoRa ThingBot-ESP ThingBot-15.4	- IoT sensor hardware solutions based on LoRa, XBee, Bluetooth, and Wi-Fi	http://www.thingtron-ics.com/
SensorUp	SEFG SensorUp SDK Gateways	- Sensor hardware, cloud solutions	http://www.sensorup.com/
IoT WoRKS (IoT business unit of HCL Technologies)	End-to-end IoT solutions	- Device, gateway, connectivity, security - IoT platform, data storage, device manage-ment, data science workbench	http://www.hcltech.com/Internet-of-Things-IoT/

APPENDIX C. IOT Standards and Consortia

The following organizations and consortia are working to establish standards of practices across the various aspects of IoT-based systems:

Industrial Internet Consortium
The goal of this consortium—formed in March 2014 by AT&T, Cisco, GE, IBM, and Intel—is to accelerate IoT growth by coordinating initiatives to define common architectures, provide interoperability, and influence the global standards for Internet and industrial systems. The group creates tests for real-world applications and creates IoT solutions to facilitate industry through intelligent, interconnected objects that dramatically improve performance, lower operating costs, and increase reliability.

IEEE (Institute of Electrical and Electronics Engineers)
IEEE has designated several initiatives and formed IoT groups with members from multidisciplinary backgrounds. IEEE has a working group (IEEE P2413 Working Group) focusing on IoT standards to define an architectural framework for the IoT. It presents solutions and recommendations for some of the challenges discussed in this report for IoT applications in key areas such as transportation and health care.

OneM2M
This group is also a global standards initiative that defines architecture, API specifications, security, and interoperability for M2M and IoT technologies. It was formed in 2012 by eight global standards development organizations (ARIG, ATIS, CCSA, ETSI, TIA, TSDSI, TTTA, and TTC) and seven industry groups.

Wi-SUN Alliance
The Wi-SUN Alliance promotes open industry standards for using wireless smart networks, and provides solutions to the interoperability challenge of IoT technology. Wi-SUN is becoming a global wireless alliance, chosen by utility companies enabling interoperable wireless standards–based solutions for advanced metering and home energy management of IoT applications. It contains the required solutions of interoperability among existing wireless standards that can be used in IoT technologies. Although it is mainly developed for utility and smart grid applications, Wi-SUN Alliance solutions are being adapted for a wide range of IoT applications, including agriculture, structural health monitoring and asset management, street lighting, parking systems, and more.

These existing alliances and consortia have outlined recommendations for governments and others. Some recommendations include funding local governments, funding large-scale national projects in certain cities, identifying economic and social impacts that could benefit social impacts, and eliminating policy hurdles that restrict the ability of international device manufacturers to enter the market. With regards to the security and privacy domain, according to a survey undertaken by IoTUK, it has become apparent that governments should be regulating these to minimize the abuse and maximize benefits. Therefore, a national strategy for IoT and well-established partnerships and relationships between public and private sectors are recommended.

APPENDIX D. IoT in Social Media, Social Groups, Meeting Groups, Alliances

IoT devices will have the biggest impact on social life ever expected. It is important for each government to discuss the developments and deployment of this technology with the public in mind. Many social groups in many countries are already meeting and discussing the implications of IoT platforms. Such social media groups give members the chance to network, share knowledge and experiences, and develop business opportunities. There are many IoT alliances in developed countries, and similar activities are beginning to appear in developing countries.

Table D1 outlines some active IoT groups. Social media like Facebook and Twitter have accounts that continuously present recent developments of the IoT technology. Alliances and standard groups are formed to undertake technical discussions, considerations and implications of the IoT technology implementation.

Table D1. Active Social Groups, Alliances, and Standards for IoT Development and Discussion

IEEE

http://iot.ieee.org/
Worldwide
All activities from IEEE societies are discussed and announced on this website, including standardization and regulations issues.

Wi-SUN Alliance

https://www.wi-sun.org
Worldwide
A consortium of global corporations and world leaders, focusing on solutions of interoperability among existing wireless standards IoT applications in utility services

ITU working group

https://www.itu.int/osg/spu/publications/internetofthings
Europe

Thread Group

https://threadgroup.org
USA
Founded in June 2013 by Yale Security, Silicon Labs Samsung, Next Labs, Freescale, Big Ass Fans and ARM. It is a standard focusing on IoT implementations in the home environment.

F-interop

http://www.f-interop.eu/
Europe
F-Interop is a H2020 European research project aimed at researching, developing, and supporting online tests for IoT. Many documents and reports can be found on this website.

Alliance for Internet of Things Innovation (AIOTI)

https://ec.europa.eu/digital-single-market/en/alliance-internet-things-innovation-aioti
Europe
European Commission initiatives on IoT

IoT Journal

http://www.iotjournal.com/

RFID Journal

http://www.rfidjournal.com/internet-of-things
RFID Journal has a section for IoT-related activities and projects around the world.

IoT Centrum

http://www.iotcentrum.com/
USA
IoT Centrum is a platform for individuals, companies, and organizations to communicate their key findings, products, events, and all the latest news on the IoT.

Wikipedia

https://en.wikipedia.org/wiki/Internet_of_things
General IoT information

Twitter Activities

IoT Guide

https://twitter.com/iotguide

The IoT Cloud

https://twitter.com/TheIOTCloud

IoT Thames Valley

https://www.meetup.com/Internet-of-Things-Thames-Valley/
USA

IEEE IoT
https://twitter.com/IEEEIoT
https://twitter.com/IoTwatcher
https://twitter.com/IoTwatcher

Meet IoT
https://twitter.com/MeetIoT

Internet of Things Rotterdam

Internet of Things
https://twitter.com/TechThings_IOT

IoT.do - DO the IoT
https://twitter.com/IoTdo

IoT Trends
https://twitter.com/IoT_tt

@arrayofthings in Twitter
USA

iotevent
https://twitter.com/iotevent

IoT
https://twitter.com/hashtag/IoT

The IoT
https://twitter.com/TheIoT

Cisco IoT
https://twitter.com/Cisco_IoT

Intel IoT
https://twitter.com/Inteliot

IBM Watson IoT
https://twitter.com/IBMIoT

Facebook Groups

Intel Internet of Things
https://www.facebook.com/Inteliot
More than 50,000 people follow this account.

IoT.do - Internet of Things
https://www.facebook.com/IoTdo

Internet of Things
https://www.facebook.com/courseIOT
An IoT community on Facebook

IoT Weekly News
https://www.facebook.com/iotweeklynews/
IoT Weekly News Facebook site

ioTree
https://www.facebook.com/iotree-457741164431092/
IoTree Cloud Facebook site

IoT Planet
https://www.facebook.com/IoT-Planet-705919092869278/
IoT workshop events

SensorCafe
https://www.facebook.com/sensorcafe
A website for online sensor news and resources

Internet of Things - Europe
https://www.facebook.com/InternetofThingsEU

Internet of Things - IOT India
https://www.facebook.com/india.iot

IOTknowledge
https://www.facebook.com/IOTknowledge

Cythings.com - Internet of Things
https://www.facebook.com/iofthings
IoT news and development

iot5g
https://www.facebook.com/iot5g

Internet of Things
https://www.facebook.com/Internet-of-Things-IoT-658363714256285/

reteiot
https://www.facebook.com/reteiot/
IOT Projects

APPENDIX E. Additional Notes on IoT in Government

Governments should play an encouraging role for IoT developers and companies to implement IoT platforms. Some countries have already supported many projects to fully understand the potential capacity of IoT technology and its benefits. Here are some of the initiatives.

Singapore
In November 2014, Singapore launched its Smart Nation initiative, allocating $1.6 billion to secure economic and social benefits through smart technologies, particularly the IoT. The funding will focus prominently on large-scale deployments of smart city applications using sensor and computing technologies. And in August 2015, SPRING Singapore, the Infocomm Development Authority of Singapore (IDA), and the Information Technology Standards Committee (ITSC), under the purview of the Singapore Standards Council (SSC), partnered to establish the Internet of Things (IoT) Standards Outline in support of Singapore's Smart Nation initiative [70]. Three standard categories—sensor network standards, IoT foundational standards, and domain-specific standards—have been identified under the IoT Standards Outline to enable the nation to exploit technology and to address challenges such as the increased demand on health care facilities, traffic planning and congestion prevention, and demands on energy and resources.

European Union
From 2007 through 2013, the European Union's 7th Framework Programme for Research and Technological Development (FP7) invested more than €130 million ($145 million) to projects related to the IoT. The funding was allocated to academic and industry groups with public-private partnerships. These projects have been the technological foundations for the IoT technology, with several projects targeting smart city initiatives and "living laboratories."

The EU's next research program, Horizon 2020, started in 2014 with a budget of €80 billion ($88 billion). Some of its projects seek solutions applicable to aging populations, food security, and energy efficiency and sustainability [71].

The European Commission launched the Alliance for Internet of Things Innovation (AIOTI) in March 2015 to work closely with all IoT stakeholders to establish a competitive European IoT market and to create new business models.

The European Commission publishes working documents as guidelines (for example, "Advancing the Internet of Things in Europe," in April 2016) to meet needs and specify the EU's IoT vision, which is based on three pillars [72]:

- A thriving IoT ecosystem
- A human-centred IoT approach
- A single market for IoT

United Kingdom
The United Kingdom's commitment in IoT technology has been significant. IoTUK was created to support the delivery of government policy and catalyze markets [34] [37]. In addition to participating in the EU's 7th Framework research program, the United Kingdom allocated an additional £45 million ($69 million) to the following IoT research projects [71]:

- Future Cities program 2014/15 — £18.5 million ($29 million)
- Enabling technologies for energy 2014/15 — £3 million ($4.6 million)
- Connected freight — £4 million ($6.2 million)
- Digital health — £5 million ($7.7 million)
- Location-based services — £5 million ($7.7 million)
- Reimagining the High Street — £6 million ($9.3 million)
- Secure remote working — £3.5 million ($5.4 million)

United States
The White House launched the Smart Cities Initiative in September 2015 with strong support ($160 million toward R&D in IoT technologies that cover more applications than just smart cities). Now there are many initiatives in the United States. For example, the successful Array of Things—a collaboration between the University of Chicago, Argonne National Laboratory (program operators), and the city of Chicago—provides some frameworks from its experiences in Chicago to implement and manage an IoT project implementation [48]. This project provides all the implications and roles of participants, including data availability, public meetings, and its governance and privacy policy, in reports that can serve as useful references for other government and policy makers seeking to make future implementations more efficiently.

Spain/Barcelona

The city of Barcelona has been a successful platform for IoT sensor deployments toward a smarter city project. The city is covered with many sensors for controlling and monitoring several infrastructures. Significant outcomes are already achieved, including reduced congestion and lower emissions, cost savings on water and power, and improved economic development. The Barcelona City Council has teamed up with Cisco, the Barcelona Supercomputing Center, and other technology partners, including Schneider Electric, the Technical University of Catalonia, and i2cat, to establish a proof of concept platform to centrally monitor the infrastructures in the city. Various technologies are used to control traffic, lighting, parking, and waste.

Republic of Korea

The Republic of Korea has been one of the most encouraging countries for providing some required service and necessary development steps for IoT platform design and implementation. Korea recently announced that they will invest a total of $5.6 trillion by 2020. Korea established the Global Council of Public and Private Sectors for IoT and the IoT Innovation Center to enable partnerships between software, device, or user businesses and large businesses/SMEs. The smart city project established in Goyang, just north of Seoul, will create an IoT model tackling issues around security, the environment, energy, and transport to support public services with benefits to the lives of its citizens. The Korean phone network LG Uplus team is managing these projects with local organizations in the city [51]. The IoT projects implement the environmental sensors that detect dust, exhaust fumes, and noise levels on the roads, as well as the automatic street lights control system, which turns individual lights on and off by detecting nearby pedestrians.

Australia

The IoT company Freestyle Technology received significant support from the Australian government; it launched its R&D IoT Innovation Centre in Melbourne and has created 150 highly skilled tech jobs in Australia. A nonprofit entity called the Internet of Things Alliance Australia (IoTAA) was launched in late 2016, with an executive council formed of representatives from CSIRO, the ACCC, the Business Council of Australia, Optus, Telstra, Nokia, NBN Co., IBM, Intel, Hewlett Packard Enterprise, and the Department of the Prime Minister and Cabinet of Australia.

Developing countries

For developing countries, IoT has the potential to deliver solutions to many aspects of daily life that could dramatically improve the delivery of services related to energy, health services, security, education, disaster management and monitoring, farming, and water quality. With populations increasing in developing counties, especially in their urban areas, developing countries are investigating how to increase and enhance services to address these growth challenges. IoT can create an intelligent platform for developing countries to overcome the existing challenges they face.

WORLD BANK GROUP