Chapter 8

Mitigating the Risks and Adverse Impacts of Implementing Services for the Internet of Things

Jootae Kim and Ahreum Hong

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Chapter 8

Mitigating the Risks and Adverse Impacts of Implementing Services for the Internet of Things

Jootae Kim
Dankook University
Republic of Korea

Ahreum Hong
Kyunghee University
Republic of Korea

1. Introduction

Information and communications technology (ICT) has been the primary source of several innovations in modern human society. Since the 1970s, the advent of personal computer, the internet, and smart phone has changed human life enormously, and other new ICTs will keep changing the human world in the future. The internet of things (IoT) is considered the next source for information technology-generating innovation. Even if IoT has huge potentials to improve human life, we must introduce new technology effectively and prevent any negative impacts. We need to maximise the benefits from using new technology and minimise the risks arising from its use. More careful examination of the implementation process should be studied. The aim of this chapter is to analyse both the benefits and risks from implementing new technology, and to prepare for its best use.

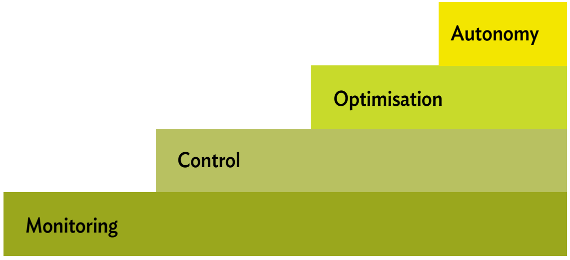
Our study first reviewed the positive and negative impacts of the introduction of IoT services. When new technology is introduced in our lives, we gain not only many benefits but also some negative outcomes. We will try to explain these positive and negative impacts of the implementation of IoT-based services from both the demand side and the supply side. The demand side usually represents customers and markets, and the supply side usually represents corporations. Next, we will discuss how we can manage this technological change to maximise the benefits and minimise the adverse outcomes. We will also analyse two cases where IoT is implemented to improve circular economy. These cases are the waste recycling system management and the intelligent transportation system (ITS) management. Through these case analyses, the benefits and risks coming from IoT implementation will be re-examined.

2. Basic Characteristics of Internet of Things

Information technology has influenced human life and organisation management very much. Personal computers were introduced in the 1970s and the internet opened a new era in telecommunication in the 1990s. Smart phones made mobile communication common since 2010. The current leading technologies in ICT are IoT, big data, location-based technology, cloud computing, and many more. The most important technology amongst these is IoT. Many applications using IoT are being considered and we will face many changes in our everyday life from the usage of IoT. IoT is expected to innovate human lives in areas such as home electronics, healthcare service, transportation, and manufacturing processes. IoT and the internet of everything (IoE) paint a vision of a seamlessly connected world where interconnected devices collect and share our most practical data to improve the functionality of products, the efficiency of homes and workplaces, the infrastructures of cities, and, fundamentally, the overall integration of our lives. But there are also hidden or lesser-known risks.

Porter (2014) explains four basic functions of IoT as shown in Figure 1. The first function is monitoring. Sensors and external data sources enable the comprehensive monitoring of many things such as the product's condition, the external environment, and the product's operation and usage. Next, we can control the processes. Software embedded in the product or in the cloud enables control of product functions and personalisation of the user experience. Third, we want to optimise the processes. Monitoring and control capabilities enable algorithms that optimise the production process and use to enhance production performance and allow predictive diagnostics, services, and repair. Lastly, we can expect an autonomous production operation. The manufacturing system can coordinate various operations and enhance the quality of the process. Self-diagnosis will also be possible. The innovation from using IoT comes from these four functions of IoT. These functions can be applied in most areas of human life and create many benefits.

Figure 1. **Capabilities of IoT Services**



IoT = internet of things.
Source: Porter, 2014.

One example of the application of IoT is the streetlights. When IoT is applied in streetlights, they monitor the darkness of the street automatically. Through sensor technology, the streetlight can send the signal to the central system when it becomes dark on the streets. This is the role of monitoring in the new system. After the central system receives the signal about the darkness on the streets, it can turn the lights on or off. From the automatic monitoring and control functions, the system can minimise the time to turn on the lights and the energy consumption. This can achieve the optimal condition for the operation of streetlights. Lastly, every process in monitoring, control, and optimisation is performed automatically. There is no human intervention in the entire process. The autonomy is achieved in the system. The use of IoT in providing these four functions can be limitless. These IoT applications can be possible in any area of human life and create new values to human society.

3. Impacts of IoT-based Services on the Demand side

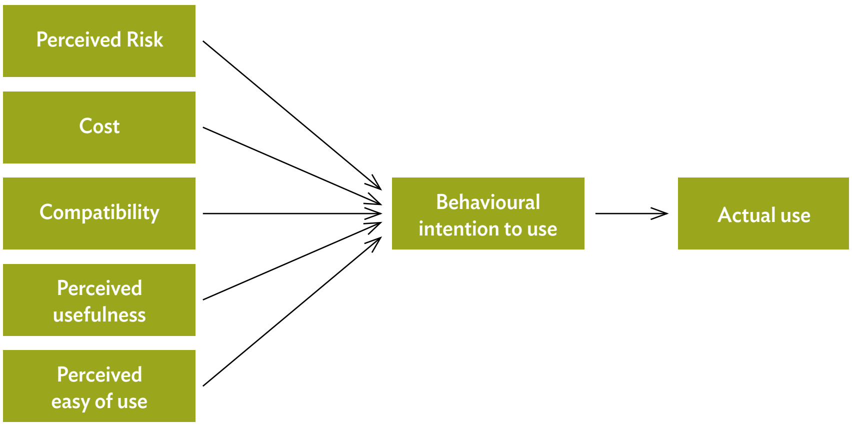
This chapter will consider the impacts of IoT on both the demand and supply sides. Demand side means the markets and consumers of IoT-based services and supply side means the corporate sector that supplies the services. We want to answer what sorts of positive effects can be made on consumers and markets from the implementation of IoT-based innovations and what will be the negative outcomes. Table 3 summarises the positive benefits and negative outcomes of the impacts of IoT- based services on the demand side.

3.1. Technology Acceptance Model

To determine the attitude of buyers in markets when a new product or service using new information technology is introduced, Davis (1989) suggested the technology acceptance model (TAM), which has two factors: recognised ease of use and recognised usefulness. After Davis (1989) presented this model, many scholars searched the diverse determinants to make technological innovation accepted in a market. Figures 2 and 3 show a revised or extended TAM.

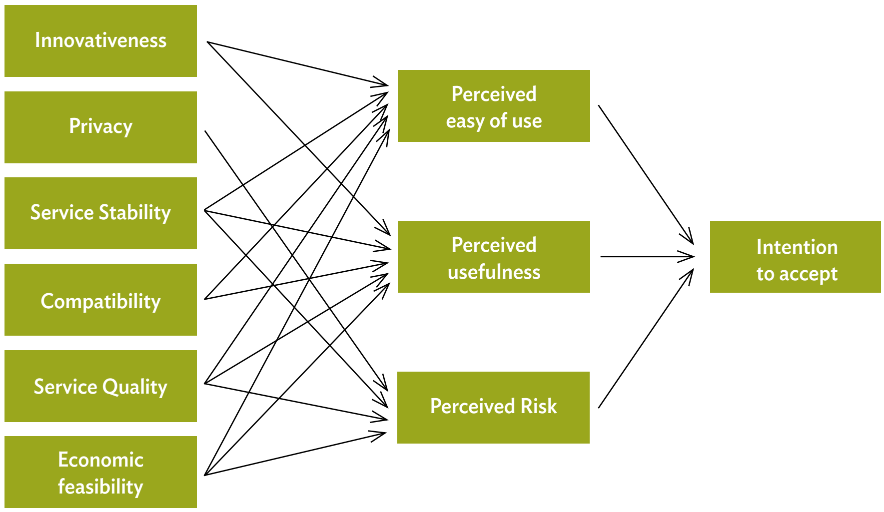
We need to consider several factors when we make a new product or service using IoT based on TAM. IoT will be applied in many areas in our lives, but whether the new services will be accepted in the market is determined by factors identified in TAM. Originally, TAM considered two factors that determine the acceptance of new technology: ease of use and usefulness. Consumers need to recognise that this new technology is useful in their lives and create new value, and that they can easily use it. There are many start-ups considering new business models with IoT usage and these two factors must be in the centre of the start-up manager's mind. Another important factor is economic feasibility. Even if a new product or service is very innovative, the high price can be an obstacle to be a successful business. It is true that IoT is a very innovative technology, but there are many requirements to consider for its acceptance in the market.

Figure 2. Technology Acceptance Model



Source: Davis, 1989.

Figure 3. **Extended Technology Acceptance Model**



Source: Legrisa, Inghamb, and Collerette, 2003.

The difficulty of acceptance in the market can be seen in the case of a smart farm in the Republic of Korea (Kim, Jung, and Lee, 2016). Even if a smart farm provides many kinds of benefits, it is not widely accepted in the Republic of Korea. There are various obstacles to delay the introduction of smart farms in the Republic of Korea. A smart farm is also a very potent area for using IoT. Table 1 shows three steps in the development of a smart farm. Agriculture information technology 1.0 (Agriculture 1.0) means automation in the production process. By using various machines, we can automate the production processes. The machines automatically cut flowers, move them, and make bundles. In Agriculture 2.0, we monitor the conditions by sensors and distribute the information through electronic communication network. We can control the temperature of the greenhouse even from a foreign country. In Agriculture 3.0, we use big data technology. We collect data from farmers and analyse the optimal production condition and share it amongst the farmers.

Table 1. Agriculture IT Development Process

Agriculture IT 1.0) Agriculture Automation	(Agriculture IT 2.0) Smart Farm	(Agriculture IT 3.0) IoT Platform Propagate
• Increasing the crop productivity and quality standardisation	• Monitor and control the crop cultural environment	• Disruptive innovation realisation
• Reduction of manpower	• Provide safety food	• Various connected farm
• Raise agriculture value added	• Climate change response	• Information sharing between users
• Partial control of the crop cultural environment	• Forecast market demand	• Low initial installation cost
	• Enclosed type	• Leading in agriculture IT
	• Low penetration rate because of high cost	

IT = information technology, IoT = internet of things.

Source: Asuming–Brempong, 2004.

The benefits from smart farms are summarised as follows. First, we can reduce the labour cost. A successful example is found in the flower production of the Netherlands where the impact of agriculture automation is very clear. For example, the minimum production size to realise scale of economy in the production of flowers in the Netherlands is at least 30 hectares. Second, we can improve productivity and quality. Agriculture production is not limited by the climate condition, and production is possible all throughout the year. Data can be collected from many farms and the optimal production condition can be calculated. This optimal solution can be shared amongst farms. Third, the early participants in smart farms can have first-mover advantage in this area. As ICT advances, the scope of smart farms will extend and the country with the first-mover advantage in smart farms will lead agriculture in the future. In some regions such as Eastern Europe or Middle East where the climate is not adequate for agriculture production, the adoption of smart farms is critical. Fourth, smart farms make agriculture production less restricted by external environmental conditions such as land, temperature, carbon dioxide, and many more. Light-emitting diode lighting can replace sunlight and water can be automatically supplied. The temperature inside greenhouses is controlled by the automatic opening of the ceiling. Typhoon, drought, flood, and insects cannot affect production, and the forecast of future production becomes possible.

But there are also some obstacles in building smart farms. An important challenge in introducing smart farms is the resistance from farmers. The introduction of new technology usually faces resistance or inertia from users. The interviews with owners of two successful smart farms in the Republic of Korea revealed that many farmers do not have positive attitude towards smart farms (Kim, Jung, and Lee, 2016). In the Republic of Korea, some large corporations intended to participate in agriculture production and they wanted to introduce large-scale production with new technologies. Most of these firms faced strong resistance from farmers and gave up their ambitious plans. Another critical hurdle is efficiency. The construction cost of a smart farm is so huge that it is not easy for a farmer to do it. Even if the possible benefits of smart farms are huge, their spread in the Republic of Korea is very limited due to the obstacles mentioned above.

We reviewed the factors that influence the acceptance of IoT technology on the demand side. We also investigated the impacts of IoT on the technical, social, and environmental aspects on the demand side.

3.2. Technical Aspects

Value creation and improved life. New treatments and materials can be developed by new IoT devices and sensors, and new values to customers can be created. One example of the new treatment is the e-healthcare device. Medtronics, a healthcare vendor in the United States (US), announced that its research prototype for a smart phone application will predict hypoglycaemic events in diabetes patients three hours in advance (Vermesan and Friess, 2013). In this process, the various requirements of customers are reflected on the new IoT products and services. The healthcare application of Medtronics is designed to provide relevant, real-time insights, and coaching to help people improve their ability to understand the impact of daily activities on their diabetes and adjust these as needed. Personalised diabetes management is also possible from the application of Watson's cognitive computing power to data from Medtronic's wearable medical devices, including insulin pumps and continuous glucose-monitoring devices. Those customised products and services provide easy-to-use and convenient technology.

Security and privacy. Previous research suggests that consumers are likely to put high value on cybersecurity. Many consumers require that data security professionals be hired and work in their organisations. As many kinds of IoT products and services are introduced in the marketplace, data security is likely to become a critical component. For example, e-healthcare applications need to consider data discovery and classification. All healthcare organisations must try to install secure IoT devices in their systems. Yet, according to more than 7,000 global IT and cyber security professionals, IoT device manufacturers are not supplying sufficient security measures.

System credibility. A remote patient-monitoring programme can collect from a remote site a wide range of health data such as vital signs, weight, blood pressure, blood sugar, blood oxygen levels, heart rate, and electrocardiograms. Health professionals can remotely monitor and treat patients based on this collected information. But those personal data may have two issues: privacy and the risk of data inaccuracies (Baliamoune–Lutz, 2003). Data are transmitted to health professionals in facilities such as monitoring centres in primary care settings, hospitals and intensive care units, skilled nursing facilities, and centralised off-site case management programmes. However, the probability of transmitting inaccurate data raises the possibility of incorrect treatment. The disclosure of personal information is also a critical issue.

3.3. Social Aspects

Increased connectedness. Basically, IoT means the connection amongst many things through sensors and digital network. Many kinds of information can be created and delivered to people. We can receive many kinds of data such as natural conditions, safety, and locations from remote places. IoT can increase globalisation through the improvement of transportation and communication technologies. IoT devices and sensors can support a hyper-connected ecosystem through smart phone usage (Friess, 2013). There is seamless connected technology through long-term evolution or 4G to 5G with higher data transmission capacity.

Upgrade of social function. The introduction of IoT can offer many valuable products and services, which would be impossible without IoT. New technology such as IoT can improve the function of society. For example, financial technology or fin-tech in China is being boosted to overcome its current inconvenient and outdated banking system. Therefore, IoT can upgrade China's current banking system and offer the future financial system to the Chinese. IoT technology can facilitate human progress and suitable social systems (Shin, 2014).

Social inequality. In addition to security issues, IoT services can deepen the inequality in our society and increase unemployment rate due to information gaps. Isolation of communication may occur between people and things. The advancement of technology can make the production system in a society more efficient and increase the total amount of wealth in society. But the increased wealth in society can be concentrated in a limited number of people. Another adverse effect is that the social norm can be changed from the introduction of new technology. The speed of wealth creation is different between people with information and people without information due to the social value of information and knowledge.

Job loss. Many experts are concerned that technological progress in ICT may bring about job loss. IoT and artificial intelligence can affect employment (Lohr, 2012). The World Economic Forum reports that robots will cut 25% of jobs in 4 years in the US. This report was based on a survey of senior executives from 350 companies across nine industries in 15 of the world's largest economies. Many experts warn that substitution of machinery for human labour from using artificial intelligence may lead to job loss (The Economist, 2016). Our past experiences showed that mass production during the second industrial revolution and the automation that occurred during the third industrial revolution led to both job loss and creation. We can expect this to happen again when we face the fourth industrial revolution and hyperconnected society. What matters is not only the job loss but also the wage gap coming from information and technology asymmetry. The importance of effective education and training should be considered to adapt successfully to the technology environment. Now is the time to prepare for a new employment framework, new legislation, and welfare system, and we should not waste one century again.

3.4. Environmental Aspects

Monitoring of environmental symptoms. The monitoring capability of IoT can be used to detect our environments (Fantana et al., 2013). We can monitor the significance of pollution and degradation in natural environments. Some places are difficult to be approached and protected by men. Deep seas, high skies, and deep valleys are examples. Remote monitoring and control makes possible more effective management of natural environments. Cook and Das (2007) report that we can monitor our environment by using physical sensor and make the information available over the communication layer. A database storing environmental information is a useful technique.

Environmental protection. In today's society, environmental protection is considered very important. IoT can be a tool to further reduce carbon emission and improve resource circularity to protect the environment. Now, economic prosperity and environmental protection are stressed at the same time. The innovative functions of IoT make these two objectives easily achievable. IoT can help reduce waste from the demand side. A region has diverse sources of wastes. In the agricultural region, the wastes from livestock excretion can be transformed to biogas and biogas can generate clean energy. In this process, we expect energy reduction. This technology reduces energy consumption and minimises the waste discharge. Efficiency in energy source minimises environmental pollution and represents a positive side of the circular economy.

Environmental harm. We can also recognise the adverse effects of IoT in the environment. It can raise environmental harm through heavy metal, radiation, and chemical disasters. The sensor of IoT consists of electromagnetic elements. Around 26 billion sensors and terminals of IoT system will be deployed in 2020 based on Gartner forecasting reports. We will face the problem of wastes from those unused sensors and terminals. It is not sure if these wastes would be recycled. The United Nations estimated in 2013 that 53 million tonnes of new electrical and electronic equipment and e-waste will be stacked in the increasing return to scale pattern. Therefore, we have a joint effort by the United Nations such as the Stopping the E-waste Problem Initiative, which can suggest ways to reuse and recycle those hazardous substances.

Table 2. Impacts of IoT on the Demand Side

	Positive Benefits	Negative Outcomes
Technical Aspects	1. Qualitative requirements are reflected on new products 2. Development of new materials 3. New treatment available 4. Ease of technology tool 5. Technical feasibility 6. Ease of technology	1. Privacy 2. Cybersecurity weakness 3. Standardisation of technology 4. Risk of data inaccuracies 5. Significant investment in the system 6. Information disclosure 7. Waste of resources to maintain the system trust 8. Complexity to have compatibility
Social Impact	1. Ease of transportation and means of working 2. Changes in lifestyle pursuit 3. Increased connectedness 4. Upgrade of social system	1. New social norms amendment 2. Lack of humanity in technology advances 3. Traffic accidents (AI unmanned car error) 4. Job loss 5. Social inequality
Environmental Aspects	1. Technology powered by clean energy 2. Environmental pollution monitoring 3. Resource savings and sustainability 4. Efficiency of energy resources 5. Minimising waste discharge	1. Increased wastes from electronics 2. Environmental harm (heavy metals, radiation, and chemical disasters)

AI = artificial intelligence, IoT = internet of things.

Sources: Palensky and Dietrich, 2011; Baliamoune-Lutz, 2003.

4. Impact of IoT on the Supply Side

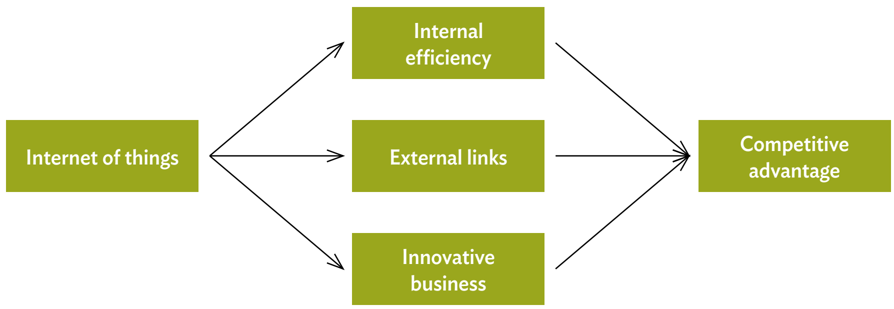
IoT can be effectively utilised in most industries and this will change the value chain of corporations. In some firms, IoT can be a new source to create competitive advantages, but new technological environments coming from IoT can provide competitive threats too. The following technologies are new environments for firms.

- The communications environment will be 1,000 times faster than the 5G or 4G Long-Term-Evolution (LTE) to accommodate the amount of data increase;
- The data centre must be built to prepare for the era of big data. Big data is generated in the digital environment. Its scale is vast and has a short life cycle. It includes large-scale numerical data as well as text and image data; and
- Sensors to measure temperature, humidity, heat, gas, light, ultrasound, motion, and sound generate different types of information.

4.1. IoT and the Competitive Advantage of Firms

Traditionally, ICT improves the competitiveness of firms through three paths: internal efficiency, external links, and innovative businesses. We want to review how these three paths contribute to corporate competitiveness through the implementation of IoT. It can make the internal processes in an organisation cheaper and faster and, as result, make these processes more efficient. Firms can also connect with external institutions more easily through IoT technology and, therefore, information flow from and to the outside of the firm increases significantly. As a new technology IoT offers the possibility of new business models; valuable business models developed through IoT can provide new growth opportunities to firms.

Figure 4. Competitive Impacts of IoT in Firms



IoT = internet of things.

Source: Powell and Dent-Micallef (1997).

Three sources of competitive advantage from the use of ICT can be applied to IoT. Will the adoption of IoT in corporate management bring about internal efficiency, external links, and innovative business? Can some other competitive advantages be created from the introduction of IoT? An example of IoT application in corporate management is Industry 4.0. The following are discussions about the concept and effects of Industry 4.0. From the description of Industry 4.0 below, internal efficiency, external link, and new businesses can be realised from the development of smart factories through Industry 4.0.

Industry 4.0 is the current trend of automation and data exchange in manufacturing technologies. It includes cyber-physical systems, IoT, and cloud computing. Industry 4.0 creates what has been called a 'smart factory'. Within the modular structured smart factories, cyber-physical systems monitor physical processes, create a virtual copy of the physical world, and make decentralised decisions. Through IoT, cyber-physical systems communicate and cooperate with each other and with humans in real time. Also, via the internet of services, both internal and cross-organisational services are offered and used by participants in the value chain.

Some examples of Industry 4.0 are machines that can predict failures and trigger maintenance processes autonomously or self-organised logistics, which react to unexpected changes in production. According to Davis (1989), 'it is highly likely that the world of production will become more and more networked until everything is interlinked with everything else'. While this sounds like a fair assumption and the driving force behind IoT, it also means that the complexity of production and supplier networks will grow enormously. Networks and processes have so far been limited to one factory. But in an Industry 4.0 scenario, these boundaries of individual factories will most likely no longer exist. Instead, they will be lifted to interconnect multiple factories or even geographical regions.

There are differences between a typical traditional factory and an Industry 4.0 factory. In the current industry environment, providing high-end quality service or product with the least cost is the key to success and industrial factories are trying to achieve as much performance as possible to increase their profit as well as their reputation. This way, various data sources are available to provide worthwhile information about different aspects of the factory. In this stage, the use of data to understand current operating conditions and detect faults and failures is an important topic for research. For example, in production, various commercial tools are available to provide overall equipment effectiveness information to factory management to highlight the root causes of problems and possible faults in the system. In contrast, in an Industry 4.0 factory, in addition to condition monitoring and fault diagnosis, components and systems have selfawareness and self-predictiveness, which will provide management with more insight on the status of the factory. Furthermore, peer-to-peer comparison and fusion of health information from various components provide a precise health prediction in component and system levels, and force factory management to trigger the required maintenance at the best possible time to reach just-in-time maintenance and gain near zero downtime.

4.2. Technical Aspect

Changed strategy and processes. IoT projects require long-term investment. Three out of four IoT projects can more than double over the current budget requirement due to various problems. As the scale of the project is large and complex, the budget increases, exceeding a certain point. Some projects should be harmonised with existing projects or budget and be weakened due to integration with existing processes. Even after solving the problem of time span and budget, companies are faced with human resource allocation issues. Most human resource allocation problems are critical for the stable introduction of new technologies model. It is very complex because a new business model requires a change in the process and culture of firms.

Technological standard. Technology standard is a very critical issue during the global spread process of IoT. Firms are very interested in capturing a dominant position and leading the standard. IoT standardisation is divided into areas: IoT platform/services and IoT devices. Standardisation issues discussed through the internet system, which is the 3rd Generation Partnership Project, the European Telecommunications Standard Institute, and the Institute of Electrical and Electronics Engineers, include a global mobile telecommunications standards body that has been operating since 2005. The world's leading standardisation organisations promoting technology standards aim to have minimal impact on the current mobile users' devices that are already optimised in IoT services.

Cyber protection and security. Enterprises try to maintain a cyber-secure workplace and provide data protection. IoT can potentially collect data from all places around us consistently. Data integration will play a key role in the decision-making process of individuals and businesses and will be important for verifying identity in medical diagnostics and protecting the environment. Eventually, extensive discussions about the role of government for individual privacy safeguards will be necessary. IoT security problems increased costs for annual security budget. Cybersecurity companies and service providers continue to customise security solutions even for small companies. Gordon and Loeb (2002) proposed how much investment is required to protect from security threats. Firms should plan huge investments to respond to cyberattacks.

4.3. Social Aspect

Change in industry structure. There can be a change in the scope of industries. Industry structures change when new technology is introduced and there is a shift in customer needs. Porter (1980) explained that industry structure is determined by five forces such as rivalry amongst existing competitors, threat of substitute, threat of new entrants, bargaining power of suppliers, and bargaining power of buyers. IoT as a new technology may change these five forces and cause a new industry structure. A changed industry structure can lead to different profit potentials and attractiveness of the industry. Corporations should modify their strategies to respond to a new industry structure.

Change in laws and regulations. Changes in laws and regulations are required for the successful implementation of new IoT services. Sometimes, the introduction of new services created by IoT may be delayed due to the existing regulation environments. For example, many new services, which can be possible by using drones, are illegal in the Republic of Korea and the government considers amendments to laws to accept the new services. Security vulnerabilities in IoT could be the target of hacking incidents, and new laws and regulations must be made to prevent the security risks (Lewis, 2002).

Improved corporate social responsibility. IoT may increase the social role of corporations. Currently, corporate social responsibility is being emphasised in the world and most corporate managers consider sustainable management significantly as one their top priorities. IoT can help private and public organisations contribute to society in many ways.

4.4. Environmental Aspect

The major issue is whether the use of IoT in many areas will increase pollution or improve environment protection. We will search many ways to apply IoT for sustainable development, resource efficiency, and air pollution prevention. IoT is expected to become a valuable tool to create a circular economy and pursue green growth in the future.

Environmental management. Today, corporations are pressed to pursue sustainability.[1] To achieve sustainability, more corporate social responsibility is expected, and environmental monitoring and protection has become a major social performance indicator of private firms. IoT can help firms play these roles by offering increased

[1] From management theory, sustainability includes socially responsible behaviours, ethics, and environmental protection. The concept of circular economy or green economy is part of environmental protection.

connectivity with outside environments. Corporations are evaluated through their social performance and environmental protection activities, as well as economic performance. Because IoT can help companies fulfil their social contributions, the importance of social and environmental performance in evaluating firms can be strengthened.

Proactive response. When a firm is forced to participate in social contribution and environmental protection, many successful firms tend to respond to the pressure more proactively. Proactive response seems to lead to better impact on corporate performance than does the passive response. IoT can become an effective tool with which firms can make proactive responses.

Table 3. Socio-technical Environmental Effects of IoT on the Supply Side

	Positive Benefits	Negative Outcomes
Technical Aspects	1. Research and development, and commercialisation 2. Technology standardisation 3. Changed strategies and processes	1. Technical dependence 2. Network attack/ heavy network traffic
Social Impact	1. Knowledge acquisition 2 Convergence of industries 3. Industrial development	1. National destruction 2. Revision of laws and regulations
Environmental Aspects	1. Industrial development, 2. Economic development 3. Minimised environmental pollution 4. Resource savings 5. Efficient energy resources	1. Natural environment pollution 2. Biological hazards: genetically modified micro-organisms 3. Ecosystem degradation by biological pollution (bio-pollution) which artificially manipulates life

IoT = internet of things.

Source: Authors' own framework using previous Socio-Technical and Environmental Aspects Stefik, 2000.

5. Cases of IoT Adoption for The Circular Economy

5.1. Lessons Learnt from a Smart Waste Recycling System

The first case is the smart waste recycling system. The system itself can leverage raw data from food waste with new smart waste recycling systems from a combination of biotechnology and high technology. With the new high-technology recycling system created by Redmond, a start-up in Washington state, retail shops, grocery stores, and restaurants can not only recycle their wastes conveniently but can also track many data. WISErg ('wise' + 'erg', a unit of work), a hybrid technology company that manages urban-generated organics, was established to reduce inventory loss, give businesses insight about the root causes of food waste, and prevent excess overstock of the restaurant business. This system can help cut down more than 40 million tonnes of food, otherwise thrown away every year in the US, and boost the bottom lines of food businesses. One example is The Harvester where biotechnology meets high technology. This is a nutrient recovery system that turns food scraps that might otherwise be destined for landfills into high-grade fertiliser. Introduced in 2011, the machine consists of a closet-sized garbage disposal and a cylindrical tank. It employs a proprietary oxidative conversion process. It grinds up organic wastes and quickly turns them into liquid that will be stored in a tank and later refined into nutrient-rich fertiliser. While composting is a good solution for organic waste from many kinds of food, it is still a problem that food waste will end up in landfills. This system can be a solution to this problem.

The second example of an IoT waste management system are the smart trash cans as seen on Figure 5, provided by BigBelly Inc. The company uses IoT to add wireless communication capability to the bins. It has a smart version of a high-value product through the trash cans. An IoT-based version that could also communicate real-time data would become much more versatile and much more valuable. It operates with a real-time monitoring system through the CLEAN Management Console while generating actual waste. This system allows the monitoring and testing of the fullness of bins automatically. Trash collections can be done on time based on real time data transferred from the system.

Figure 5. **The BigBelly's Trash Cans**

Source: https://bigbelly.com/

For the city to select this public service, the company offers managed service options to perform the analysis and management of the device. These trash cans can dramatically increase the speed and efficiency of the recycling programmes of the city. The intelligence system provides the infrastructure to support ongoing waste management and time scheduling for the manpower. Therefore, it uses new resources to support the expanded additional recycling programmes. CLEAN can make the necessary changes to create a more effective public recycling programme. The company reports that its system installed in Philadelphia[2] is the best example of how effective the system can be used.

In the Korean example, the government introduced a volume-based waste fee system that can reduce the domestic waste itself. The government started to sell the waste bags by volume. A few years later, the consciousness of citizens in waste management slowly changed and they have been looking for ways to make a positive impact on the world. In addition, they have several types of waste fee systems by food waste and business waste. After the smart waste management system was introduced, more and more citizens have become interested and have tried to find ways to decrease their waste.

2 BigBelly Co. Ltd., Philadelphia started with 210 recycling containers in 2009 and each bin collected 225 pounds of recyclables monthly on average, resulting in 23.5 tonnes of materials diverted from landfills. The city gets US$50 per tonne from the recycling and avoids the US$63 landfill tipping fee, with a total benefit to the city of $113 per tonne or US$2,599 per month.

5.2. Lessons Learned from the Intelligent Transportation System (ITS) case

ICT and sensor networks have the potential to contribute to increased efficiency in freight and passenger transport, as well as the potential to reduce transportation overall. On the one hand, increased use of ICT can avoid freight and passenger transport through better virtualisation, digitisation, and teleworking. Digital content is delivered electronically, and virtual conferences and teleworking reduce passenger transport. On the other hand, increased use of ICT can contribute to better management of transport routes and traffic, higher safety, time, and cost savings as well as reductions in carbon dioxide emissions.

Sensors and sensor networks play a vital role in increasing transport efficiency. For example, sensor technology contributes to the better tracking of goods and vehicles, which might result in a lower level of inventories and energy savings from less inventory infrastructure as well as reduced need for transportation. Further, sensors and sensor networks are pivotal parts of many ITSs.

An ITS can be defined differently at different institution. ITS Canada defines it as 'the application of advanced and emerging technologies (computers, sensors, control, communications, and electronic devices) in transportation to save lives, time, money, energy, and the environment'(Intelligent Transportation System Society of Canada, 2012). ITS is categorised into intelligent infrastructure and intelligent vehicles (see Table 4). Many of these applications are based on sensors and sensor networks. In the field of intelligent infrastructure, sensors in pavements are used for road traffic monitoring systems to measure the intensity and fluidity of traffic (vehicle count sensors) and to provide information for the control of traffic lights. These sensors are also able to detect whether, for example, public buses are approaching so that the green phase of traffic lights can be extended, allowing buses to keep their schedules. They also transmit information to update public transport panels. New sensor applications include intermittent bus lanes. In addition, sensors are used for motorway tolling purposes wherein they detect vehicle radio-frequency identification tags and retrieve the required information. Sensors also monitor the state of physical infrastructures such as bridges by detecting vibrations and displacements.

Table 4. Structure of ITS

Intelligent Transportation Systems		
Intelligent Infrastuctures		
Arterial and Freeway Management • Traffic Signal Control, Lane Management • Surveillance, Enforcement	**Crash Prevention and Safety** • Warning Systems • Pedestrian Safety	**Traffic Incident Management** • Surveillance, Detection • Response, Clearance
Emergency Management • Hazardous Material Management • Emergency Medical Services	**Electronic Payment and Pricing** • Toll Collection • Multi-Use Payment	**Roadway Operations** • Asset Management • Work Zone Management
Transit Management • Operations and Fleet Management • Transportation Demand Management	**Traveller Infromation** • Pre-trip and En-route Information • Tourism and Events	**Road Weather Information** • Surveillance and Prediction • Traffic Control
Infromation Management • Infromation Warehousing Services • Archived Data Management	**Commercial Vehicle Operations** • Carrier Operations, Fleet Management • Credentials Administration	**Intermodel Freight** • Freight and Asset Tracking • International Border Crossing
Intelligent Vehicle		
Collision Avoidance • Obstacle Detection • Collision-Avoidance Sensor Technologies	**Driver Assistance** • Navigation, Route Guidance • On-Board Monitoring	**Collision Notification** • Advanced Automated Collision Notification • In-Vehicle Crash Sensor

ITS = intelligent transport systems.

Source: Miles, 2014.

6. Conclusion and Implications

We examined several theoretical frameworks to understand the impacts and risks from IoT implementation. Porter (2014) explained four basic functions of IoT, and TAM shows what factors influence the successful acceptance of IoT-based services in the market. IoT can improve corporate competitiveness through internal efficiency, external links, and innovative businesses. We also summarised the impacts of IoT in three areas: technical aspect, social aspect, and environmental aspect. A smart waste recycling system and an intelligent transportation system were presented as examples of IoT adoption to improve the circular economy. These two systems are still in their early stage and more efforts should be made to be successful cases for the circular economy.

6.1 Theoretical Implications

Based on the discussions about the various issues arising in the implementation of IoT, the theoretical implications can be summarised as follows. These can be questions to be explored in future researches.

- The services using IoT can have four basic functions such as monitoring, control, optimisation, and autonomy. These functions can be applied to most areas of our lives. We can expect these four functions to help implement the circular economy. In smart trash cans or intelligent transport systems, these four functions can be realised.

  We can create many kinds of IoT applications. While some applications involve all these four functions, others may only have a few of them. What function amongst the four is most important and most used can be studied in future research.

- TAM shows what factors are important to make a new service using IoT that is accepted in markets successfully. TAM suggests many factors such as ease of use, usefulness, compatibility, enjoyment, and many more. Many business models that will use IoT will be developed, but only a few of them can be accepted in the market. From using smart trash cans or intelligent transportation systems, what kinds of benefits can users acquire? They should be able to use them very easily and experience new values from them. Otherwise, users will not accept them.

  We can study both determinants and outcomes of new IoT services. While Davis (1989) suggested ease of use and usefulness as determinants, many other factors affecting the successful acceptance of IoT services in markets can be found. For example, when the wearable smart watch device was introduced in the market, what factors significantly influenced its success? The seminal work of Davis (1989) was done for a personal computer environment. A little bit different explanation is possible for the IoT environment.

- IoT services will create new values and improve human life. However, security/privacy and system credibility have come up as new concerns about the use IoT-related services. Also, while social connectedness will be increased, job loss due to new innovative systems is a significant concern as well. Environmental protection and monitoring can be improved through IoT services. Smart waste systems can have significant impacts on the clean-up of our environment, and in ITS, the security issue is very important.

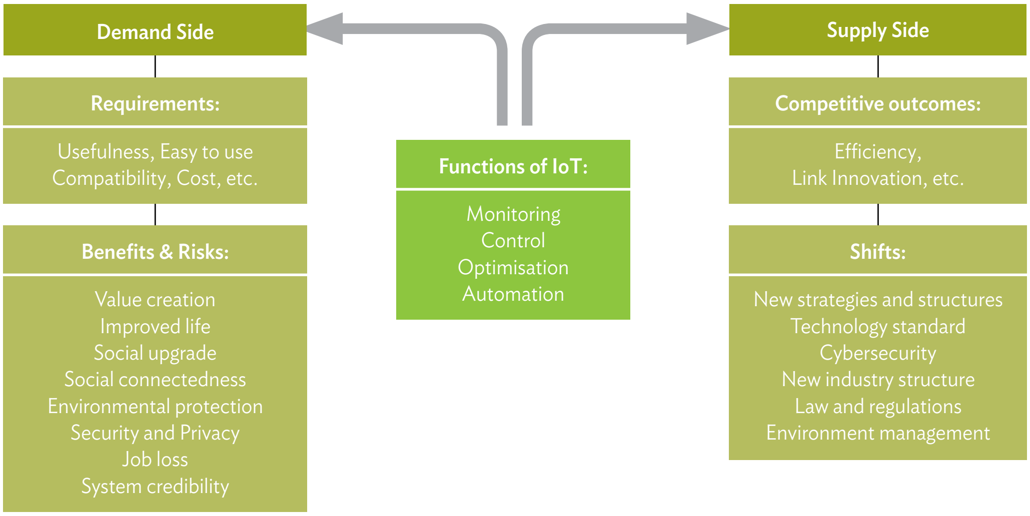
We can have both benefits and risks from using IoT services. Deeper analysis is required for both benefits and risks from IoT services implementation. Benefits such as increased connectedness and environment protection should be maximised, and the risks of security/privacy and job loss should be carefully scrutinised and prevented. Various tools to increase social connectedness by IoT services should be considered and the solutions to prevent job loss from the automation and to guarantee human prosperity should also be studied.

- Generally, the effective use of ICT can provide firms with diverse competitive advantages such as internal efficiency, external links, and new businesses. IoT applications in corporate management such as Industry 4.0 can reduce costs, increase connections with outside stakeholders, and offer new growth opportunities by creating new business models. When firms adopt IoT for resource recycling or environmental protection, this decision should improve their competitiveness. Smart waste management or smart transportation can be a new business opportunity for many corporations.

  Corporations are searching many innovative ways to use IoT. Corporate managers should have vision about the kind of competitive edge they will achieve from the use of IoT services. We can also analyse diverse conditions that enlarge or reduce the competitive benefits from IoT services.

- After introducing many IoT-based systems, processes and strategies in corporations will be changed. Even corporate culture can be changed due to new innovative systems. Technology standard in IoT is a very critical issue for firms that intend to participate in this area and decide to be the lead firm in the marketplace. Industry structure can also be changed and mergers amongst industries can happen. With improved environmental monitoring, sustainability management will be more stressed. The introduction of new technology such as IoT brings about significant changes in corporate organisations. There should be many researches about the impacts of IoT on organisations and how to deal with the changes successfully.

Figure 6. An Integrative Model



IoT = internet of things.
Source: Authors.

6.2 Policy Implications in the ASEAN Context

The concepts of IoT, Industry 4.0, and circular economy were developed in advanced economies such as the European Union and the United States. Industry 4.0 is about the picture of the future factories and the circular economy is an alternative to a past economic development model of linear economy. The Association of Southeast Asian Nations (ASEAN) countries are less developed economies and have different institutional environments from western countries. Therefore, ASEAN countries must find different solutions to achieve Industry 4.0 and the circular economy. ASEAN countries must build the foundation for Industry 4.0 and the circular economy based on their own situations.

One typical response is mere imitation to western countries. Based on institution theory (Meyer and Rowan, 1977; DiMaggio and Powel, 1983), leaders of societies or organisations make their decisions to follow outside pressure. This gives the leaders legitimacy and support from accepting the outside pressure. Government officials in ASEAN countries may face many pressures to reflect the concept of Industry 4.0 and the circular economy in their policies. Usually, it is not easy to develop a model for Industry 4.0 and the circular economy that fits a country's situation. We need a more creative approach for each ASEAN country to adapt to the new environment of Industry 4.0 and the circular economy.

To develop solutions reflecting each country's situation, Porter (1990) suggests that at least four dimensions be considered: factor condition, demand condition, supporting and relating industries, and firms and rivalry. These four factors usually explain what kinds of efforts should be made to make an industry competitive. From the framework of Porter (1990), we can list the following policy considerations for ASEAN countries.

- ***Factor condition:*** Labour is the most important input factor. Adequate education and training to prepare for Industry 4.0 and the circular economy are required. A big concern in ASEAN is that because most manufacturing processes will be automated, and the importance of cheap labour will be decreased, the production base of western multinational corporations in ASEAN will move back to their countries.

- ***Demand condition:*** Customer education is very important to make firms and governments realise the necessity of changes to new paradigms. The factor condition above is about technology of people, but demand condition is about the attitude of people. To achieve a circular economy, the commitment of ordinary people is very significant.

- ***Relating and supporting industry:*** This means the overall social infrastructure to accept Industry 4.0 and the circular economy. Financing, law/regulation, transportation/communication, democracy, and market economy are the examples. Most ASEAN countries have inferior situations in these infrastructures.

- ***Firms and rivalry:*** In pursuing both the circular economy and Industry 4.0, the role of the corporation is critical. The strategies, corporate culture, and corporate structure can influence how Industry 4.0 and the circular economy will be shaped in the region.

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