Designing Business Model for The Internet of Things in Elevator Service (Journal Format)

A thesis submitted to the University of Manchester for the degree of Doctor of Business Administration (DBA) in the Faculty of Humanities

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Abstract

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Designing Business Models for the Internet of Things (Journal format)

The increasing pervasiveness of the Internet of Things (IoT) offers a wealth of business model opportunities. Many conventional product-based companies are seeking to increase their competitiveness by moving towards a service-based business model whereby the IoT can bring tremendous opportunities. These traditional product sales manufacturing firms are required to consider business models beyond their conventional product-focused, firm-centric core competence business model innovation and respond to fast-changing digitalisation dynamics focused on promoting service-centric solution availability instead of physical products. However, the literature has not yet provided profound and actionable approaches to service business models in IoT-driven environments for manufacturing firms. This research aims to fill the gap and elaborate framework of design guidelines for designing service business models for the IoT in manufacturing firms; accordingly, the elevators industry is selected as the main case study applying proposed framework of design guidelines. The thesis adopts the journal format with four essays. The first paper focuses on deriving six guiding principles from an illustration of the value of the IoT and a systemic review of academic literature focusing on IoT business models: service centrism, value co-creation, resource integration, long-term relationships, the ecosystem, and capitalised value of information. Papers 2 to 4 contain three essays that delve deeper into each of the design guidelines under design framework. The second paper illustrates the criticality for firms to move toward the ecosystem business model approach from the conversational single and firm-centric business model, again using a comparable case study in the elevator industry. The third paper aims to demonstrate how the IoT can enable an elevator company to shift from having a product focus to being a service-centric company through value co-creation and resource integration, hence maintaining a long-term relationship business model. The fourth paper aims to depict how the IoT can enable an elevator company to achieve information-driven, condition-based maintenance in its service business model. Case studies of real-world IoT service business models demonstrate the applicability of the proposed guiding principles and their managerial implications and challenges, as well as options to overcome these challenges. The evaluation of the applicability of these implications pertaining to the emerging context of the IoT business model can enable researchers and practitioners to visualise and analyse service business model design in a structured and actionable way.

Declaration

I, Chia Tai Angus Lai, declare that no portion of the work referred to in the thesis has been submitted in support of an application for another degree or qualification of this or any other university or institute of learning.

Copyright Statement

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Shanghai, April 2020

Chia Tai Angus Lai

Journal Format Thesis

This thesis is based on journal format with four independent papers, all four papers have been published in different journal; These four published papers have co-authors with my supervisors Prof. Jackson and Prof. Jiang, the contribution of these papers follow the same pattern. I am the first and corresponding author which contribute main planning, execution, data acquisition, analysis and writing, Prof. Jackson contribute providing guidance on paper structure and research methodology, Prof. Jiang support on data analytical methods as well as essence of IoT technology.

Paper 1 (chapter 3)

Lai, C. T. A., Jackson, P. R. & Jiang W. (2018a). Designing Service Business Models for the Internet of Things: Aspects from Manufacturing Firms. American Journal of Management Science and Engineering, 3(2), pp. 7-22. DOI: 10.11648/j.ajmse.20180302.11

Paper 2 (chapter 4)

Lai, C. T. A., Jackson P. R. & Jiang W. (2018b). Internet of Things Business Models in Ecosystem Context-Cases of Elevator Services. International Journal of Computer and Software Engineering, 3(2):135, pp. 1-12. DOI: https://doi.org/10.15344/2456-4451/2018/135

Paper 3 (chapter 5)

Lai, C. T. A., Jackson, P. R. & Jiang, W. (2016). Shifting paradigm to service-dominant logic via Internet-of-Things with applications in the elevators industry. Journal of Management Analytics, 4(1), pp. 35-54. http://dx.doi.org/10.1080/23270012.2016.1259967

Paper 4 (chapter 6)

Lai, C. T. A., Jiang, W. & Jackson, P. R. (2019). Internet of Things Enabling Condition-Based Maintenance in Elevators Service. Journal of Quality in Maintenance Engineering, 25(4), pp. 563-588, https://doi.org/10.1108/JQME-06-2018-0049

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List of Abbreviations

AaaS: Answer as a service

AI: Artificial intelligence

API: Application programing interface

AQSIA: General Administration of Quality Supervision, Inspection and Quarantine, PRC

B2B: Business to business

BM: Business model

BMC: Business model canvas

BMI: Business model innovation

BS: British standard

CBM: Condition-based maintenance

CEA: China elevators association

CM: Corrective maintenance

DaaS: Data as a service

ERP: Enterprise resource planning

G-D Logic: Goods-dominant logic

HVAC: Heating, ventilation and air-conditioning

IaaS: Information as a service

IoT: Internet of Things

IP: Internet protocol

ISO: International Standard Organization

M2M: Machine-to-machine

OEM: Original equipment manufacturer

PaaS: Product as a service

PM: Preventive maintenance

RFID: Radio frequency identification

S-D Logic: Service-dominant logic

TBM: Time-based maintenance

UI: User Interface

WSN: Wireless sensor network

Chapter 1: Introduction

The Internet of Things (IoT) is a new technological paradigm envisioned as a global network of machines, sensors and devices capable of interacting with each other. The new capacities of pervasive and ubiquitous computing are defining new horizons for human creativity and connectivity, which are also arising because pervasive and ubiquitous computing is very often linked with other emerging technologies, such as big data, cloud computing, machine learning, artificial intelligence and the semantic Web (Tommasetti, Vesci & Troisi, 2015). The IoT is recognised as one of the most important areas of future technology and is attracting vast attention from a wide range of domains, such as manufacturing, healthcare, energy, and the quickly expanding consumer and service industry, to facilitate new business applications or improve existing ones. Since the IoT is a broad concept, it is not limited to using various sensors and actuators through networks in which information is gathered or remote monitoring takes place but also involves processing for information analytics and optimisation in central servers (now mostly in cloud computing) and, finally, is used for decision making and control targeted things (Fleisch, 2010).

The digitalisation of both the manufacturing and the service industry is arguably at the height of its hype cycle. Since the 1990s, the Internet has been playing a leading role in innovative changes in our business and society. As the next wave of the digitalisation revolution and the next stage of the Internet, the Internet of Things (IoT) has received considerable attention from both industry and academia. The IoT is now starting a new industrial revolution and has been claimed to be the backbone of digitalisation's development, which includes 'Industrie-4.0' in Germany, the 'Industrial Internet' in the US, 'Made in China 2025' in China and the 'Industrial Value Chain Initiative (IVI)' in Japan (Uchihira, Ishimatsu & Inoue, 2016). Notwithstanding the fact that the IoT is currently experiencing a phase of rapid growth, the number of connected 'things' has been estimated to have reached 4.9 billion in 2015, and predictions have shown that over 20 billion things will be connected worldwide by 2020 (Gartner, 2015), as many companies have started to develop various IoT-related products, applications and services. Cisco estimated that the global IoT market will generate $14 trillion in profit over the next decade (Bort, 2013) and that the global economic added value for the IoT market will be $1.9 trillion dollars in 2020 (Gartner, 2013). Simultaneously, the recent Redburn capital goods structural rhymes research report, published in September 2019, indicated that virtually all the companies covered by the research talked about the significant potential of the IoT, what it will cannibalise, what the monetisation potential is and why they are (or are not) better positioned than their competitors to win (Moore & Gruter, 2019). Furthermore, the fresh Morgan Stanley research report regarding the new era of urbanisation in China indicated that the IoT will be one of the key drivers of smart cities and enhance lifestyles, predicting that the total market size of IoT connected devices, software and services will triple to 1 trillion USD from 2019 to 2030 and that the average of 1 IoT device per household in 2019 will increase to 7 IoT devices by 2030 or sooner (Morgan Stanley, 2019).

Many real-world IoT applications have been postulated in many industries: the domain covers not only conventional industrial sectors but also the consuming industry of everyday life, to which the IoT can bring significant improvements, even leading to new business models. By providing services via precise analysis evolved using a multitude of sensors, firms can help to monitor and manage their clients' purchasing behaviours, operating equipment or manufacturing processes more precisely, raising efficiency and productivity and hence creating more revenue opportunities. In certain situations, hazardous operating environments can be monitored continuously, and objects can take predictive corrective actions to avoid safety incidents, reduce risks and avoid the costs incurred by operating system damage or downtime. However, the questions remain regarding the importance of and differences in the way in which companies are using IoT technologies; while many companies are using these technologies to achieve only incremental improvements, either cost reduction or productivity improvement, others are using them as an opportunity to re-envision and radically improve their business. More specifically, the exponential growth of digital information, combined with increasingly sophisticated analytical capabilities, means that data should be considered as an asset class in its own right. Analytics are useful for more than just optimising business processes. Many companies are using analytics, or even gathering new categories of data, to change their products and services radically, in other words embracing new business opportunities within new business models. In summary, with IoT technology, firms now have the capability, or simply more opportunities, to develop innovative business models that give them an advantage over their competitors (Chui, Löffler & Roberts, 2010). This thesis aims to expand the knowledge on the linkage between the use of IoT technology and the design of business models.

From the contextual scope perspective, this thesis has chosen a conventional elevator company as its main research focus to investigate how elevator firms are adopting IoT technology to design a new service business model, which uses the IoT not just for more efficient data acquisition but also for analysing data and ultimately for decision making, to serve their customers better. Elevators comprise a typical form of infrastructural equipment, closely related to the daily lives of the general public. Continued service after the installation of the equipment at a site is critical to ensure high operational reliability (Lai, Jiang & Jackson, 2019). As public safety is crucial when elevators are moving people from one place to another, the service strategy is a significant part of the overall elevator system to ensure reliability, safety and efficiency over a long period of continuous usage (Niu et al., 2008). There are a few main objectives for elevator services from the customer perspective other than safety and reliability, such as prolonging the useful life of the equipment, minimising inconvenience or business interruptions from equipment downtime, reducing or eliminating the cost of major repairs and identifying the probability of fault occurrence and troubleshooting (repair or replacement). From the perspective of service firms, in addition to attaining perceived value in their customers' eyes, companies are constantly seeking opportunities to develop a better service business model with a view to improving their productivity, including optimal maintenance planning, reducing the labour costs of maintenance through greater efficiency, increasing the analytical capacity to understand the key components of a useful life in different environments or situations and enabling feedback through performance measurement to afford better design opportunities for manufacturers through research and innovation centres (Lai, Jiang & Jackson, 2019).

Over the last few decades, service businesses have greatly evolved with the growth of technology (Ahmad & Kamaruddin, 2012a). The development of advanced sensors and IoT technology has made the remote acquisition of condition-monitoring data much more efficient and economical, increasing the attractiveness of the business case. As IoT-related technology has advanced rapidly and economically, it has enabled the development of global and real-time solutions, mainly wireless oriented and able to collect and exchange data. Such solutions have the capacity to monitor the environment remotely, track objects and ultimately provide comprehensive data analysis of the surrounding environment (Yang, Yang & Plotnick, 2013). The adoption of IoT technology is rapidly gaining momentum, as technological, societal and competitive pressures push firms to innovate. The IoT has the potential to disrupt industries through changing products, services and business models, just as the Internet did in the 1990s (Keskin & Kennedy, 2015). The advantage of adopting the IoT in elevator services is not limited to real-time remote monitoring in a more economical way but can also provide the capability for rapid data analysis to enable quick maintenance decision making based on the real-time conditions of the equipment through advanced cloud computing. Thus, the IoT could provide the ultimate solution for the elevator industry, further realised through a more predictive condition-based maintenance (CBM) strategy. Moreover, global elevator giants are already engaged in efforts to utilise machine learning, artificial intelligence (AI) and cognitive technology for improving elevator maintenance further through IoT technology. These benefits ultimately should be capitalised into new service offerings and business model generation for elevator services.

1.1 Problem Statements

There is a large amount of literature, including journal articles and conference proceedings, on subjects related to this research; this literature is presented in Table 3.2 (page 65) and has articulated that advanced IoT technology development will enable traditional manufacturing firms to innovate through new business opportunities from the technology advancement perspective. Most of the published studies have focused on the technical aspect of the IoT, which may offer breakthrough opportunities when applied not only by industrial goods manufacturers but also in the service industry, and some applications have been commercialised into real-world businesses. However, the challenges lie in the fact that technological advancement, along with existing product or service innovation, may not sustain a business's life unless a viable and sustainable business model exists. A viable business model will play an important role when it comes to leveraging the opportunities arising if new technology innovates, matures and is cost-effective and customers are willing to pay for the value. These studies have also indicated that business models based on today's largely static or historical information architectures are facing challenges as new ways of creating value arise among firms, clients and other stakeholders – in other words, ecosystem business models compared with conventional firm-centric core competence-based business models. Technology develops rapidly nowadays, so firms, particularly in the elevator industry, can no longer rely solely on their own innovative capability when developing service business models for the IoT if theoretically they could be in a different spectrum from the traditional business model framework. Therefore, this thesis, within the contextual scope of the elevator industry, needs to explore why business model design with advanced IoT technology could be different from traditional business model innovation and how to tackle these differences from the perspective of conceptual and managerial implications.

1.2 Motivation

Over the past two decades, researchers and practitioners have studied the IoT technology in elevator applications regardless of enhanced safety features, productivity improvement, energy consumption or machinery's operational optimisation spectrum (Borgia, 2014; Minoli, Sohraby & Benedict, 2017; Yamashina & Otani, 2001a, 2001b), but very little research has been conducted on how the IoT can create new business models or enhance existing business opportunities. Therefore, there is clearly a research gap concerning the development of a framework of design guidelines for IoT business models in the elevator industry as well as demonstrating how this framework can be utilised in real-world applications. To summarise, the motivation of this thesis is to elaborate how elevator companies can utilise the latest IoT digitalisation to enhance their capability and hence create new business opportunities and which framework of design guidelines with managerial implications is applicable when attempting to design a business model with the underlying IoT technology; furthermore, it aims to illustrate the similarities and differences between these design guidelines and conventional business model design and determine how they can be applied to practical and commercialised applications.

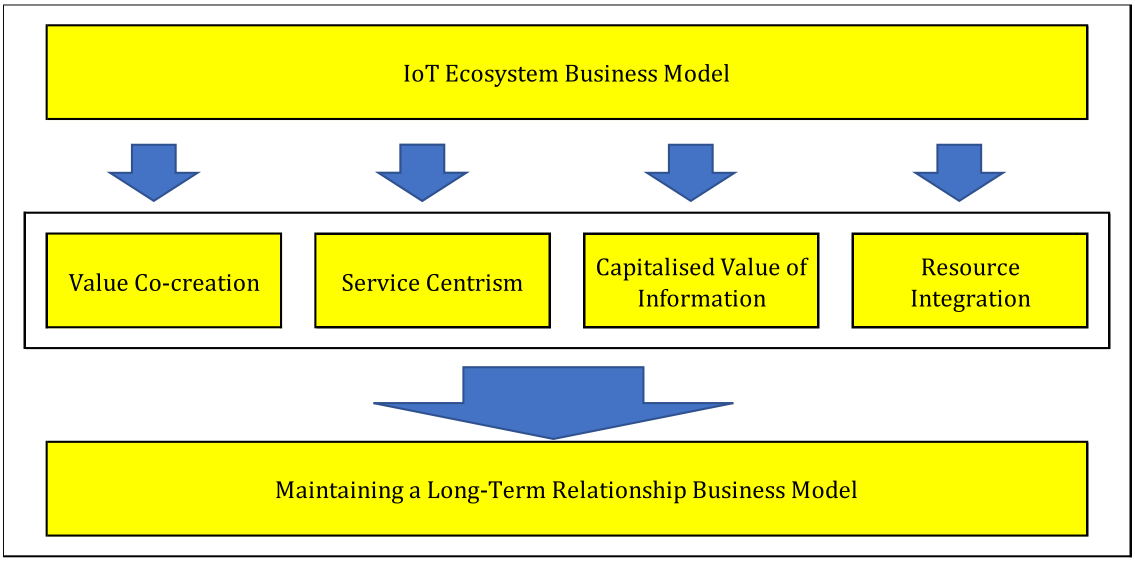
1.3 Objective

A framework of design guidelines is needed to provide a more comprehensive understanding of managerial implications, including whether firms should transition their firm-centric business model to an ecosystem business model or from a manufacturing goods-centric business model towards a service-centric business ecosystem and eventually embrace data-driven aspects within the business model design. Therefore, the objective of this thesis can be formulated as follows: ***to investigate how the IoT can assist an elevator company when attempting to design a new business model with ecosystem, service-centric, value co-creation and data-driven aspects to adopt technological advancement that is more accessible within the elevator company's new service offering through both a theoretical and a practical lens.***

1.4 Research Conceptual Framework

Despite the thoughts that along with the introduction of the Internet of Things new revenue opportunities, will rise if the existing business model studies will be applicable to do so, the question of which business models will be applicable remains (The Economist Intelligence Unit, 2013). Moreover, the literature review in this thesis ascertains that currently limited academic knowledge exists on how business models for IoT applications differ from business models for other applications and how they should be constructed. This thesis aims to fill the gap by presenting a conceptual framework of design guidelines for developing business models for IoT applications. The conceptual framework is based on several sets of intensive literature reviews on existing business models, business models for the Internet of things, the value of IoT, service-dominant logic transition, the IoT business ecosystem, data modelling and CBM subjects. Subsequently, 40 interviews are conducted with various IoT professionals and practitioners in 8 case studies in 5 companies, together with direct observations and publicly available exemplary application studies. Finally, these research efforts are divided between 4 independent published journal articles, presented in detail in chapter 3 to chapter 6. The framework of IoT design guidelines is shown in Figure 1.1, followed by a brief interpretation of each element.

Figure 1.1: Conceptual framework of IoT business model design guidelines



1.4.1 IoT Business Ecosystem

Business models based on today's largely static or historical information architectures are facing challenges as new ways of creating value arise among firms, clients and other stakeholders – in other words, ecosystem business models compared with conventional firm-centric core competence-based business models. Besides the ecosystem's core business, consisting of firms delivering goods/services along with their customers, market intermediaries and suppliers, the business ecosystem includes the owners and other stakeholders of the core as well as regulatory bodies and competing organisations. Thus, an IoT ecosystem of co-creating actors is established: essentially, every actor in this IoT ecosystem needs a distinct business model to serve its clients, and they all co-exist and share the value for which the final customer is willing to pay. Therefore, firms need to reposition themselves when designing business models for the IoT due to the fact that an ecosystem business model is a business model composed of value pillars anchored in ecosystems and focuses on both the firm's method of creating and capturing value and any part of the ecosystem's method of creating and capturing value (Leminen et al., 2012; Westerlund, Leminen & Rajahonka, 2014). It is defined in the framework of IoT design guidelines that firms should change their focus to an ecosystem approach as an umbrella to consider the ecosystem nature of the IoT rather than emphasising an individual company's self-centred objectives.

1.4.2 Value Co-creation

The essence of a business model is to create and capture value and, traditionally, value has been created within a firm's core competences with minimal interaction with customers during the development or even the delivery process. Under the business ecosystem design guidelines, the IoT makes it possible to incorporate and interact with customers in any phase of the value creation process; a common view of co-creation is that value is created by collaboration and facilitated by technology before people and the organisation. The IoT contributes to the reconfiguration of resources and services to create a new relational network facilitating customer participation in value creation by virtue of interaction with smart objects and embedded sensors. Such technologies enable access to and adaptation, selection and integration of resources in a continuous process of value co-creation (Tommasetti, Vesci & Troisi, 2015). The fundamentals of the Internet of Things lie within the idea that the network of things can think for itself intelligently. This part of the value creation process is all about taking advantage of the possibilities and using the Internet of Things as a co-creative partner in the same manner as co-creative collaborative projects are managed today between people using technology as an enabler (Mejtoft, 2011). When given the possibility to co-create in harmony with connected things, both in parallel and independently, greater flexibility in the development process will be achieved. As a result, the concepts of value co-creation and collaboration, along with the emerging Internet of Things, have been highlighted and reinforced as important trends for future business model development (Bughin, Chui & Manyika, 2010).

1.4.3 Service-Centrism

Many of the business models influenced by information technology (IT), regardless of the technology from which they emerged, follow the trend of service orientation, a solution with a business model of product and service integration (Fleisch, Weinberger & Wortmann, 2015). One feature of the IoT is the fact that the service portion of the business model outlined is always information rich and digital in nature: digitalisation that extends to the product itself must of necessity lead to an additional service orientation. There are exemplary service-centred business model scenarios for the Internet of Things – for instance, a shift from providing products to providing a service, called 'products as a service' (PaaS), and more manufacturers are following this trend to increase competition through low-cost manufacturing (Bucherer & Uckelmann, 2011). Another example is the focus on providing customers with a way to mine their own insights to choose their own adventures, a type of business model called 'data as a service' (DaaS). More specifically, providing useful information as service providers is 'information as a service' (IaaS), which creates new business opportunities for measuring and billing information. Other service-driven businesses from the IoT include providing real-time business analysis for decision making – 'answer as a service' (AaaS) – which hinges on a value proposition from supplying large amounts of processed data with the idea that the client's job-to-be-done is to find answers or develop solutions for its customers. Therefore, the key feature of the IoT enables the service portion of the business models always to be digital in nature; hence, the theory and practice of service orientation must be examined critically and expanded as necessary against the backdrop of the characteristics of a digital service (Fleisch, Weinberger & Wortmann, 2015).

1.4.4 Capitalised Value of Information

Traditionally, data are recognised as an asset for internal usage. Companies today consume a growing number of organisational resources and investments for data capturing, storage, processing and maintenance. However, the value of data conversion into useful information in general is not financially recognised in balance sheets nor even a possible revenue generator. As technology advances, data collected by different sensors and devices have various types of format and are inherently diverse in a more efficient and costly manner. The heterogeneity, ubiquity and dynamic nature of resources and devices, and the wide range of data, make discovering, accessing, processing, integrating and interpreting data from the physical world over the Internet a challenging task. IoT data are a type of big data that is not only large in scale and volume but also continuous and real time, with rich spatiotemporal dependency. The dynamicity of the environment and data enable the efficient use of IoT data on a global scale to create a number of business model opportunities (Barnaghi, Sheth & Henson, 2013). A company should reconsider its position, asking 'what data can we analyse today?' followed by 'how could we provide useful data to our clients to promote our products/services?' and 'how might we sell the data?' While designing a new IoT-driven business model, a company should reposition itself from a more innovative angle by looking at ways to monetise big data collected from smart devices, particularly real-time data, as a new revenue stream rather than as an add-on supplementary service. Thus, data with knowledge converted into information by themselves may become a major source of value creation and proposition. This includes information only made possible through IoT technologies as well as existing information on physical products (Bucherer & Uckelmann, 2011). In these design guidelines, it is suggested that the IoT may or may not directly generate value of information but definitely acts as an enabling technology, providing better information capabilities to achieve better opportunities through the reinvention of the classic business model.

1.4.5 Resource Integration

When designing an IoT business model, a company is not able to operate alone, particularly when evolving, fast-changing, advanced technology is involved. To this extent, a company needs to co-create value with not only internal but also external resources, as the prevalent resource-based view suggests that resources include both tangible and intangible resources (Barney, 1991) and S-D logic further elaborates resources as 'operant' and 'operand' (Vargo & Akaka, 2009). The primacy of operant resources has been established, defined as those that act on other resources to create benefit, such as knowledge, competence, experience and so on, over operand resources, which must be acted on to be beneficial, such as natural resources, goods and money (Constantin & Lusch, 1994). It has been suggested that the integration of operand and operant resources is fundamental to the co-creation of value (Ballantyne, Williams & Aitken, 2011). These resources are in a way a co-creator when designing an IoT business model: the effectiveness of a company's integration of these resources will decide whether the business model will be operated successfully. The technology has a direct influence on 'the way in which value is determined'; thus, when a specific technology is integrated with other resources, 'value is uniquely and phenomenologically determined and as technologies are repeatedly combined or integrated with other resources' (Akaka & Vargo, 2013).

1.4.6 Maintaining a Long-Term Relationship Business Model

The IoT, by linking a device at the customer's premises and the company's centralised cloud or in-house data centre, is a way to build a connecting relationship, at least in the machine-to-machine context (Sampson, 2010). Further relationship establishment from machine to machine, machine to human and human to human is defined by the business model that the company would like to deploy. As a huge amount of data accumulates in real time or on an interval basis, this creates an opportunity to build the mutual benefits of sharing valuable information among stakeholders. Thus, add-on services and co-creation solutions can be provided and can enhance the handshake lock for customers, making it difficult for them to abandon the partnership, therefore purposely designing a long-term relationship business model regardless of whether it operates on a recurring payment basis or is a free service, unless poor service is rendered or information from the IoT is not used effectively. Furthermore, with the value co-creation guidelines under the business ecosystem, mutually agreed value can enhance the co-existing relationship and that between firms and customers, hence maintaining the long-term relationship business model based on solutions or analytic information tailored to meet specific customer requirements. To summarise, it is claimed that one of the fundamental benefits of the IoT and the key difference from conventional business model innovation is ultimately the building of a long-term business relationship model instead of just focusing on a one-time value exchange.

1.5 Research Question

To fulfil the thesis's objective and construct the framework of design guidelines, one main research question and three subsequent research questions are formulated to align with four independent published papers, RQ1 being the main question and RQ2–4 being subsequent questions to indicate the sequence. The research questions are derived from the thesis's objective, together with literature studies and case studies that involve multiple sources of evidence, including direct observation, interviews with professionals from the elevator industry, authoritative bodies and academia, and a review of secondary source documents and publicly available information. The research questions are formulated in such a way that both academic and business factors are considered. Table 1.1 contains a list of papers on which this thesis is based. The summary of the papers indicates which papers answer which research questions and reveals the main message of each of the papers.

Table 1.1: Summary of the research questions and papers

Research Question	Paper	Abstract
RQ1: How can manufacturing firms design business models for the Internet of Things?	Paper 1 (chapter 3): Designing Service Busienss Models for Internet of Things: Aspect from Manufacturing Firms	To explore the design guiding principles when conventional manufacturing firms attempt to design a new business model based on the Internet of Things technology containing the six guiding principles of service-centric, value co-creation, resource integration, business ecosystem, a long-term relationship perspective and capitalized value of
RQ2: How can business models be designed for the Internet of Things in the ecosystem concept in elevator services?	Paper 2 (chapter 4): An Internet of Things Business Model in an Ecosystem Context: Cases of Elevators Service	The paper analyses the business model from both the business ecosystem and the IoT ecosystem perspective, specifically applied to a new service IoT offering in the elevator industry. The objective is to shed light on existing and potential models by discussing them in connection with the underlying ecosystems in designated domains.
RQ3: How can the Internet of Things enable an elevator company to transition from goods-dominant to service-dominant logic?	Paper 3 (chapter 5): Shifting Paradigm to Service-Dominant Logic via Internet-of-Things in the Elevator Industry	This paper takes a subjective view that attempts to engage fully the key resources and underlying IoT technology to gain a competitive advantage and make the service-centric transition. How can the IoT facilitate this transition, which acts as a key agent via value co-creation to maintain a long-term relationship business model? It also investigates whether the underlying technology can bring together different ways of thinking when deploying a new industrial service offering. A new elevator service offering is examined in a single-case study to demonstrate the
RQ4: How can the Internet of Things enable an elevator service to achieve data-driven, condition-based maintenance?	Paper 4 (chapter 6): Internet of Things Enabling Condition-Based Maintenance (CBM) in Elevator Service	This paper mainly addresses how the IoT could provide the ultimate solution for the elevators industry, further realized through an information-driven CBM strategy. The advantage of adopting the IoT in the elevator industry is that it is not limited to real-time remote monitoring in a more economical way but can also provide the capability for rapid data analysis to enable quick maintenance decision making based on the real-time conditions of the equipment; the main driver behind the theme concerns how to capitalize the value of information, which is one of the main design guidelines of an IoT business model.

RQ1) How can manufacturing firms design business models for the Internet of Things?

This is quite a broad question and is set as the main research question for the entire thesis. The contextual scope is limited to conventional goods-centric manufacturing firms' attempt to design a service-centric business model via the latest developed IoT technology. Some elements need to be defined before this research question can be answered: first exploring the main studies and frameworks of business model generation, followed by investigating whether technological advancement can change the spectrum of business models, meaning business models for the IoT, and finally exploring the main design principles applicable when manufacturing firms attempt to design service business models for the IoT.

The development of viable business models will play an important role when it comes to leveraging the opportunities arising if new technology innovates, matures and is cost-effective, but how will the IoT provide these many business opportunities? What are the main differences between designing IoT business models and designing conventional firm-centric core competence-based business models? Furthermore, what are the critical business model design guidelines when developing the underlying IoT technology for service businesses if theoretically they could be in a different spectrum from their traditional business model? These questions need to be addressed from both theoretical and practical perspectives, aiming to establish a framework of design guidelines for developing an IoT business model in manufacturing firms.

RQ2) How can business models be designed for the Internet of Things in the ecosystem concept in elevator services?

This research question examines the main design guideline business ecosystem in the research framework shown in Figure 1.1. In the modern global, competitive and collaborative business environment, should an IoT business model be designed as a business ecosystem due to the fact that no firm owns the content, networks, software and hardware in the same spectrum? Furthermore, how is business model design considering the business ecosystem required to bridge the gap between the expected value and the firm's existing core competence or innovative capability?

A viable business model will play an important role in leveraging the opportunities of new technological innovation, ensuring that it matures and is cost-effective. However, business models based on largely static, firm-centric core competences or historical information architectures are facing challenges in today's more dynamic environment as new ways of creating value arise across industries and among firms, clients and other stakeholders. The business ecosystem and IoT technological ecosystem co-evolve in combination to create a commercialised business model, leading to clients' choice concerning the platform of the ecosystem. Furthermore, adapting the established technologies of an industry to develop innovative products and services is ultimately the cornerstone for breakthrough business model development, and embracing the business ecosystem concept when adopting an IoT technology ecosystem may facilitate novel applications and business models. Prior research has remained silent on the types of IoT business models and their links to the underlying ecosystems.

To address this research question, paper 2 (Lai, Jackson & Jiang, 2018b) in chapter 4 aims to analyse the business model from both the business ecosystem and the IoT ecosystem perspective, specifically applied to a new IoT service offering in the elevator industry. The objective is to shed light on existing and potential models by discussing them in connection with the underlying ecosystems in designated domains.

RQ3) How can the Internet of Things enable an elevator company to transition from goods-dominant to service-dominant logic?

To address this research question, the study can examine service-centric design guidelines within the framework in Figure 1.1. A new competitive environment for manufacturing and service industries has been forcing a change in the way in which manufacturing enterprises are developed. The service sector is gradually taking the main stage of the global economy, and manufacturing firms, particularly industrial goods manufacturers, are adopting a more proactive service strategy and embedding it into their overall company strategy. As firms attempt to remap their offerings from goods to services, interdisciplinary and cross-disciplinary approaches are required to understand how services should be designed, delivered and supported. Among many subsets of service operations research, a fundamental shift in the worldview has been proposed to match the analogous shift in the economy: from goods-dominant (G-D) logic to service-dominant (S-D) logic (Spohrer et al., 2008; Vargo & Lusch, 2004a). This suggests that firms may need to redirect the production and marketing strategies that they have adopted for manufactured goods by adjusting them to the distinguishing characteristics of services.

Many studies and researchers in the IoT domain have attempted to determine how the true value of the IoT can be realised for enterprises and what benefits firms can gain when they design new service offerings with real-life business applications (Fleish, 2010; Haller & Magerkurth, 2011). The same discussions have also taken place concerning what S-D logic actually means to service operation in utilising IoT technology in business applications in traditional industrial goods manufacturing. To address this research question, paper 3 (Lai, Jackson & Jiang, 2016) takes a subjective view that attempts to engage the key resources fully to gain a competitive advantage, which is a crucial element of firms' service-centric transition and may enable them to engage the latest IoT technology to facilitate the transition, which acts as a key agent to promote shared information, knowledge and skills enhancement and hence to embrace value co-creation. By providing an answer to the research question, this paper aims to contribute to the effort of traditional manufacturing firms in embracing the IoT when attempting to make the transition to S-D logic. It conducts an in-depth case study of a new service solution for an elevator service business that wishes to move to the S-D model through the adoption of the IoT to ascertain whether the underlying technology can bring together different ways of thinking when deploying a new industrial service offering.

RQ4) How can the Internet of Things enable an elevator service to achieve data-driven, condition-based maintenance?

This research question examines mainly the critical design guidelines for the capitalised value of information together with the concept of service-centric and business ecosystem design guidelines within the framework in Figure 1.1. The elevator industry has explored the adoption of a maintenance strategy based on the condition of a component/system; one can improve the diagnosis and prognosis of failures to reduce the maintenance-related costs. This is known as CBM and has attracted considerable attention from researchers, who have studied it in relation to complex engineering systems over the past few decades (Jardine, Lin & Banjevic, 2006; Peng, Dong & Zuo, 2010). At the heart of CBM is the condition-monitoring process to collect and analyse a huge amount of data for decision making, in which signals are continuously monitored using certain types of sensors or other appropriate indicators (Campos, 2009). It is usually not feasible to implement CBM in relatively light engineering systems due to the limitations of the technology and the high costs of collecting data on a real-time basis (Alsyouf, 2009). Elevator equipment is installed at widespread and distributed locations, with varied site conditions and different frequencies of usage. It is a challenge to deploy CBM without an efficient, effective and economical continuous monitoring mechanism to capitalise the value of data. The existing studies on CBM have largely focused on proposing simulations or statistical models to coordinate maintenance activities among the components under a CBM policy from a theoretical perspective, and little research has been conducted to investigate the optimal way of utilising data fully by investigating the method of collecting and analysing the data (Lai, Jiang & Jackson, 2019). There is a lack of empirical studies on how CBM can be realised in industries such as those related to elevator equipment.

Nowadays, the development of advanced sensors and IoT technology has enabled the remote acquisition of condition-monitoring data to be much more efficient and economic, making the business case more attractive. Thus, to set forth the research question, paper 4 (Lai, Jiang & Jackson, 2019) mainly addresses the IoT's potential to provide the ultimate solution for the elevator industry, further realised through a CBM strategy. The advantage of adopting the IoT in elevator CBM is not limited to the ability to carry out real-time remote monitoring in a more economical way but also provides the capability for rapid data analysis to enable quick maintenance decision making based on the real-time conditions of the equipment, the main driver behind the theme being how to capitalise the value of data, which is one of the main guiding principles of an IoT business model.

1.6 Outline of the Thesis

This thesis is structured around one conceptual framework of IoT business model design guidelines as figure 1.1plus four self-contained empirical papers, presented in chapter 3 to chapter 6. It encompasses an introduction and the research methodology in chapter 1 and chapter 2, respectively, and concludes with chapter 7 on the contribution of this thesis and chapter 8 conclusion also contains with limitations and future research. Each paper has a separate introduction, literature review, methodology, case description and analysis, and conclusion. All these papers use the terms 'we' and 'our' rather than 'I' and 'my', respectively, to reflect the fact that each paper is associated with a published paper format co-authored with Professor Paul Jackson at Alliance Manchester Business School and Professor Wei Jiang at Shanghai Jiaotong University.

For the sake of consistency throughout this thesis, the content and format may be slightly different from the published work from each of the publishers, particularly in reference to styles, figures and tables, following an overall thesis format and sequence. All the references, including those for the four published papers in chapter 3 to chapter 6, are listed in chapter 9 despite the papers originally being self-contained; this is to avoid repeated references and to maintain the overall integrity and readability of the entire thesis.

Chapter 1 starts with the background of the project, the problem statement and the motivation for this thesis; hence, the research objectives are derived. The conceptual framework of IoT business model design guidelines is formulated based on a set of research processes from multiple research methods using various sources and evidence to set forth the research questions to be addressed in four independent journal articles and, finally, the outline of the thesis.

Chapter 2 presents the methodological approach to the research. It discusses the research's philosophical worldview, research roadmap and framework for the overall thesis and each of the papers and a summary of the research methods. Thereafter, it explains, in terms of the theoretical research methodology that has been presented, how this research was conducted and reflects on its validity and reliability.

Chapter 3 presents the first paper, addressing the main research question concerning how to design business models for the IoT from manufacturing firms' perspective. This chapter explores the guiding principles for designing business models for the IoT, derived from examining the value of the IoT, undertaking intensive literature reviews and concluding six design guiding principles, and describing three exemplary cases to demonstrate the applicability of these design guidelines to real-world business model applications.

In chapter 4, the second paper is presented to depict the main design guidelines of the conceptual framework of the ecosystem business model and show how the business ecosystem and ecosystem business model concepts have to be deployed under IoT ecosystem circumstances. It suggests that the elevator industry has to move away from a firm-centric, core competence and product innovation focus towards an offering based more on ecosystem business models with a focus on an IoT service-centric design. Among the discussions, value co-creation among ecosystem actors is the key element to ensure the success of business model innovation in an environment of technological advancement. Three elevator companies are selected to demonstrate the different service-centric business models under a similar business and IoT ecosystem.

Chapter 5 presents the third paper, which examines service centrism, which is one of the design guidelines under the conceptual framework of the IoT business model, in depth. This chapter mainly describes how the IoT can facilitate conventional manufacturing firms' transition from G-D logic to S-D logic. This paper also states that a successful transition has to embrace value co-creation and maintain a long-term relationship business model for resource integration (operand plus operant resources) to move towards a service-centric business model. Accordingly, a single case in an elevator company is examined in depth to ascertain how the IoT enables S-D logic transition in an actionable approach.

In chapter 6, the fourth paper mainly describes how an information-driven IoT system can enable elevator companies to implement CBM in a real-world business environment. This paper examines the theory and value of CBM and the beneficial value over conventional corrective maintenance (CM) and time-based maintenance (TBM) in relation to an IoT-connected service. The key is to present the design guidelines of the capitalised value of information and service centrism in an ecosystem environment. The same case study as in paper 1 to paper 3 is discussed to indicate how CBM can be deployed with help from the IoT in real-world business applications.

Chapter 7 presents the outcomes of the research and hence demonstrates the contribution of the thesis. The contribution is described for each of the papers within the research project. Finally, a summary of the overall reflection on the thesis's contributions is provided.

Chapter 8 presents the conclusions through both theoretical and practical lenses to address the summary for each of the research questions and the overall thesis. At the end of the chapter, the thesis also declares the limitations of the thesis and makes suggestions and proposes directions for future research.

Reference contains a list of all the references used in the thesis from chapter 1 to chapter 8, including the four independent papers from chapter 3 to chapter 6. This is to avoid repeating references in each of the papers as well as to maintain a consistent reference style and readability throughout the thesis, despite the different reference styles of the different publishers.

Appendix A displays the cover pages of each of the published papers.

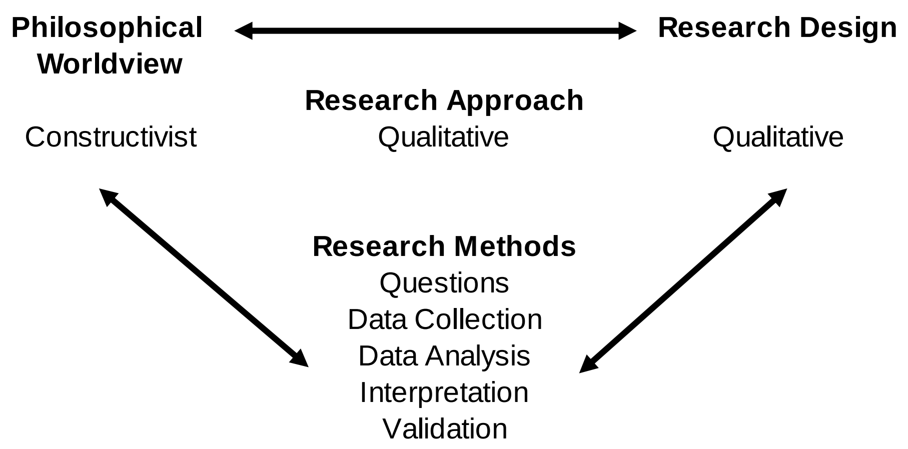
The appendix B provides the interview protocol for data collection in each of the papers in sequence as well as different interview questions by interviewee category in the four papers, respectively.

Chapter 2: Research Methodology

2.1 Research's Philosophical Worldview

This thesis adopts a qualitative research design. Qualitative research is an approach to exploring and understanding the meaning that individuals or groups attribute to a social or human problem. The process of research involves emerging questions and procedures, general data collected in the participants' setting and data and analyses building inductively from particulars to general themes (Creswell, 2014). A qualitative research report has a more flexible structure, honours an inductive style and recognises the importance of conveying the complexity of a situation. The advantage of qualitative research is that it enables researchers to conduct in-depth studies about a broad array of topics, including researchers' favourites, in plain and everyday terms. Moreover, qualitative research offers greater latitude in selecting topics of interest, because other research methods are likely to be constrained (Yin, 2011a). The thesis's assumption is based on a constructivist worldview from the philosophical worldview perspective. Under a constructivist worldview, the goal of research is to rely as much as possible on the participants' views of the situation being studied. In this situation, the researcher seeks to establish the meaning of a phenomenon from the views of the participants, and the questions, originally from a related theoretical background, become broad and general so that the participants can construct the meaning of a situation, typically forged in discussions or interactions with other persons (Creswell, 2013). Often these subjective meanings are interpreted through more open-ended interviews, fieldwork observations and document and observation data, together with philosophical assumptions and a theoretical framework for establishing themes and interpreting patterns. This thesis's research design framework is summarised in Figure 2.1.

Figure 2.1: Framework of the research design



2.2 Research Roadmap

This thesis aims to fill the gap identified by the literature review by presenting a novel business model conceptual framework of design guidelines for IoT applications. The framework is created on the basis of several sequences of intensive literature reviews in four papers on the subjects of existing business models, business models for the Internet of Things, the value of the IoT, service-dominant logic transition, the IoT business ecosystem, value co-creation, resource integration and CBM domains. Subsequently, 40 interviews are conducted with various IoT professionals and practitioners within 8 case studies respectively in 5 conventional elevator-related companies, together with a number of direct observations from site visits and reviews of data as well as secondary research such as cross references from publicly available exemplary IoT applications in companies' annual report or on their website and information disclosed both in news and in financial analyst reports. Finally, these research efforts are presented in 4 independently published journal articles in chapter 3 to chapter 6, each of which has slightly different research methods. The construction of the overall thesis's conceptual framework is shown in Figure 1.1; a more detailed interpretation of each of the design guidelines is provided in chapter 3 to chapter 6. In this section, a research roadmap is highlighted, together with the identical frameworks at each of the papers.

2.2.1 Research Roadmap for Paper 1: Designing Service Business Models for the Internet of Things: Aspects from Manufacturing Firms (Lai, Jackson & Jiang, 2018a). This paper utilises an exploratory research design featuring multiple methods, which leads to the conclusion of IoT business model design guiding principles for manufacturing firms. This paper starts with the need for IoT business model design guidelines (guiding principles) in the introduction, followed by theoretical background studies of 'the value of the IoT' and conventional 'business model' frameworks, then conducts a comprehensive and relevant literature content analysis of the IoT literature focusing on business models derived from a web search of Google Scholar, ScienceDirect and Scopus. From the 21 journal articles on IoT for business models that are reviewed and analysed, 6 guiding principles for designing IoT business models from traditional manufacturing firms' viewpoint are construed. These journals and their brief contents are listed in Table 3.1 and Table 3.2.

Finally, three case studies are conducted to examine the six proposed guiding principles and discuss how conventional manufacturing firms adopt IoT service business models in a structured way. This case study research is conducted using multiple sources of evidence, including direct observations, reviews of companies' publicly available case examples and three interviews with company key leaders in China. These three companies are selected according to a few criteria: a) conventional manufacturing firms with a production and after-sales service business for many years, all with a manufacturing facility based in China, b) companies adopting IoT technology to expand their business revenue and c) one of the companies is designated as having this thesis's main contextual scope – an elevator company – which is selected as the main target research case and is discussed throughout the entire thesis. The other two companies are identified through referrals from the business network and in agreement with the interviewees.

This paper's research roadmap is shown in Figure 2.2, the literature content analysis is provided in Tables 3.1 and 3.2, the interview protocol with interview questions is presented in the appendix B and the conceptual framework developed and adopted in this paper is shown in Figure 2.3.

Figure 2.2 Research roadmap for chapter 3 (paper 1)

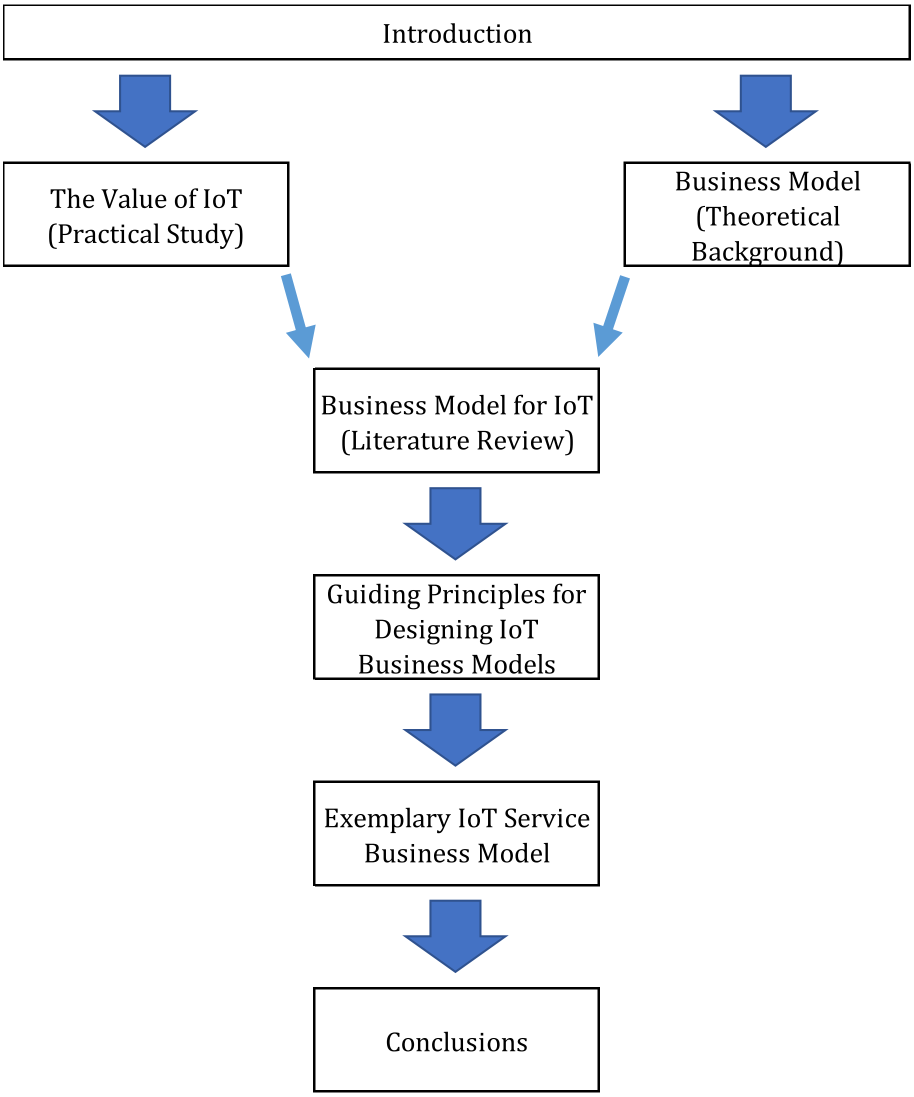
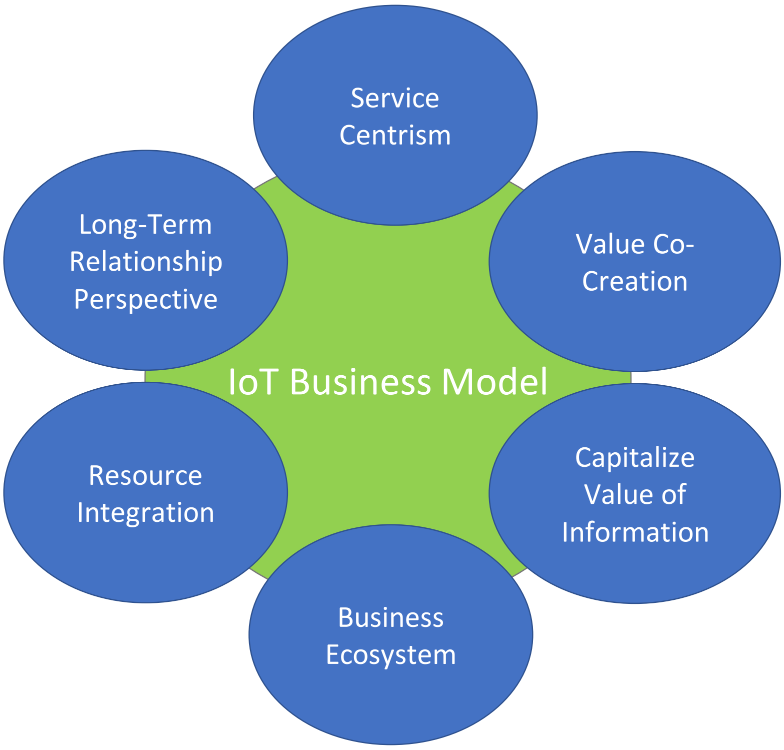


Figure 2.3 Framework of guiding principles for designing business models for the IoT



2.2.2. Research Roadmap for Paper 2: Internet of Things Business Models in the Ecosystem Context – Cases of Elevator Services (Lai, Jackson & Jiang, 2018b). This paper utilises an explanatory research design featuring a literature review and a case study with 15 interviews, and it examines the critical design guidelines for IoT business model design, which has to follow the business ecosystem nature instead of the traditional firm-centric or core competence nature of business model innovation. Firstly, a literature review of both the business ecosystem and the ecosystem business model is conducted to form a consolidated view of the theoretical background. Secondly, further comprehensive literature on specific ecosystem business models for the IoT is analysed. Thirdly, the conclusion is reached that the value design framework comprising four pillars – value drivers, value nodes, value exchanges and value extracts – proposed by Leminen et al. (2014) is appropriate from an ecosystem perspective on business models to help understand possible IoT business models and the challenges involved in building them, and the framework is shown in Figure 2.5. Fourthly, in the following three comparable case studies, this four-pillar value design framework to analyse business models in the IoT ecosystem is employed to investigate three companies in the same industry in similar IoT business ecosystems that offer business models in different ways. Case study data are collected from multiple sources in addition to accessing perspectives and concrete information from the elevator firms directly or indirectly, and fifteen semi-structured interviews are conducted with these three companies' executives and the project directors in charge, the authoritative body and IoT vendors; the interviews in general last for one hour, and many follow-up calls are made to confirm the validity. The interview protocol is provided in the Appendix B at the end of this thesis. Finally, the challenges and conclusion are discussed.

The research roadmap shown in Figure 2.4, and the interview protocol with the interview questions is in the appendix.

Figure 2.4 Research roadmap for chapter 4 (paper 2)

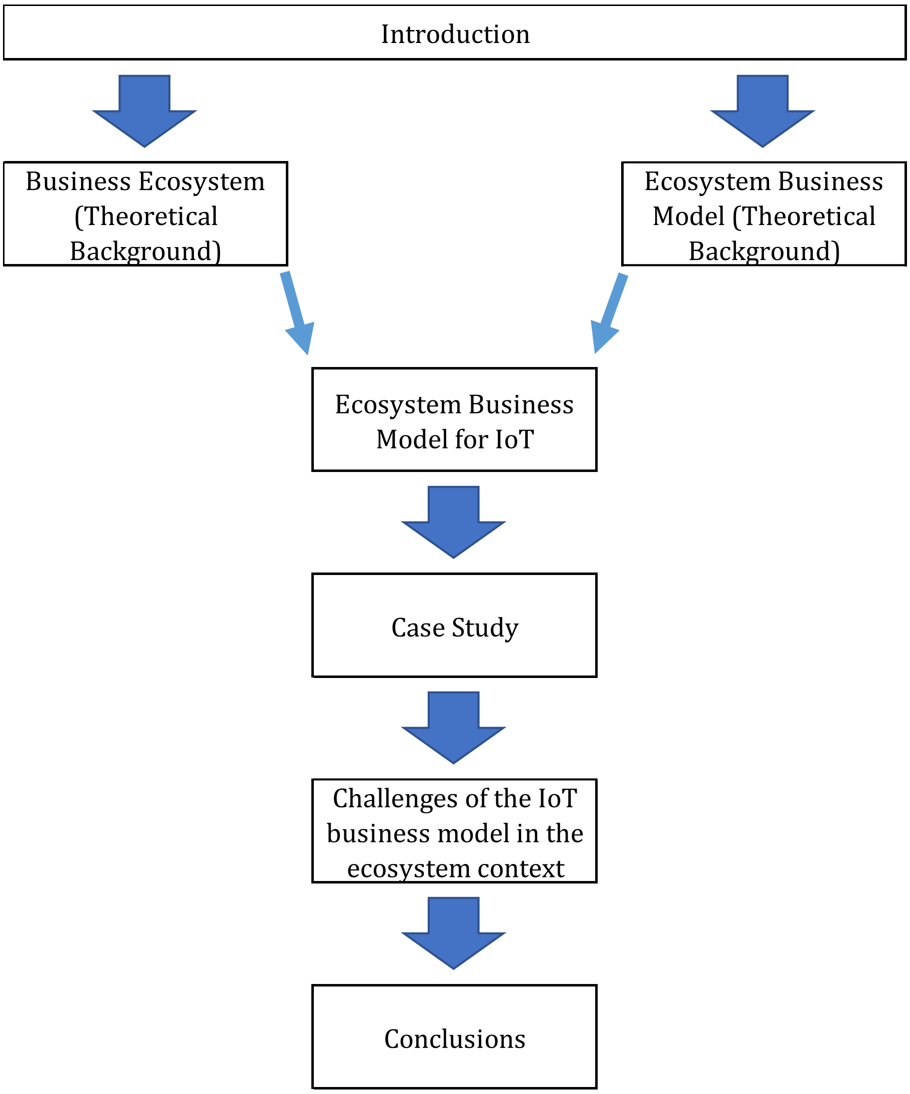
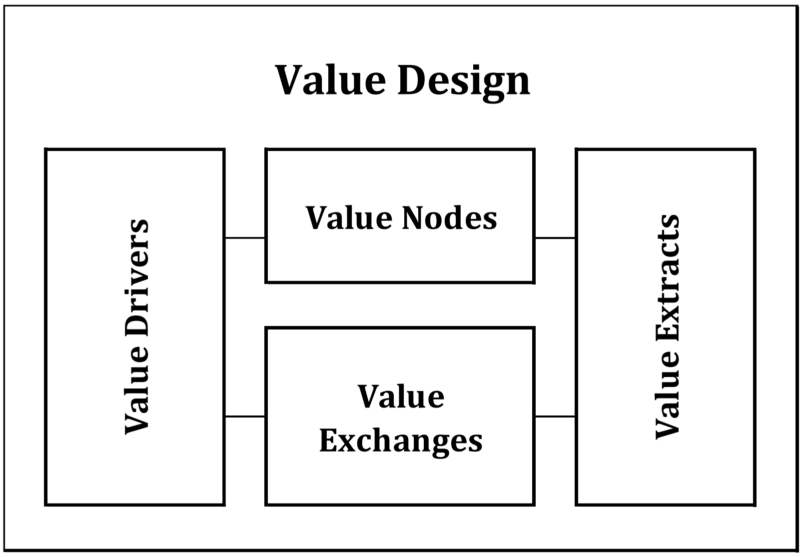


Figure 2.5 Key pillars of a business model design tool for IoT ecosystems (Westerlund, Leminen & Rajahonka, 2014, p. 11)



2.2.3 Research Roadmap for Paper 3: Shifting the Paradigm to Service-Dominant Logic via the Internet of Things with Applications in the Elevator Industry (Lai, Jackson & Jiang, 2016). This paper utilises an explanatory research approach featuring a literature review and case study using interview methods, which examine the critical design guidelines of service centrism, value co-creation and resource integration under the ecosystem umbrella to achieve a business model for maintaining long-term relationships. This paper starts with a detailed literature review of both the service-dominant logic and the Internet of Things. Then it describes how the IoT can enable company transition from G-D logic to S-D logic following the inductive approach. An in-depth case study of an elevator company is conducted to examine the underlying managerial implications concerning how the IoT can enable elevator companies to transition to S-D logic as well as to construct an interpretation from real business applications. The data collected for this research are obtained from several sources. First, participatory observation is undertaken, in which the researcher works with a global elevator company in China, participating in developing the elevator IoT solution for the company; therefore, it is possible to obtain case study-related information from direct or indirect interactions with other stakeholders. This not only enables insights to be gained into their perspectives but also facilitates access to data, including a variety of strategic and operational meetings, documentation, meeting minutes and presentations. Second, in addition to accessing perspectives and concrete information from the elevator firm directly, 12 semi-structured interviews are conducted with individuals from the China Elevators Association (CEA), a property/facility management company, a third-party service company, a property developer and end-users. The interview length varies, but the interviews typically last for about one hour, and the interview protocol is provided in the appendix at the end of this thesis. The objective is to gain insights into this contemporary phenomenon (Yin, 2011b) and to understand the value that can be co-created from these stakeholders towards the IoT offering.

The research roadmap is shown in Figure 2.6, and the interview protocol with interview questions appears in the appendix B. The framework of S-D transition is presented in Figure 2.7.

Figure 2.6 Research roadmap for chapter 5 (paper 3)

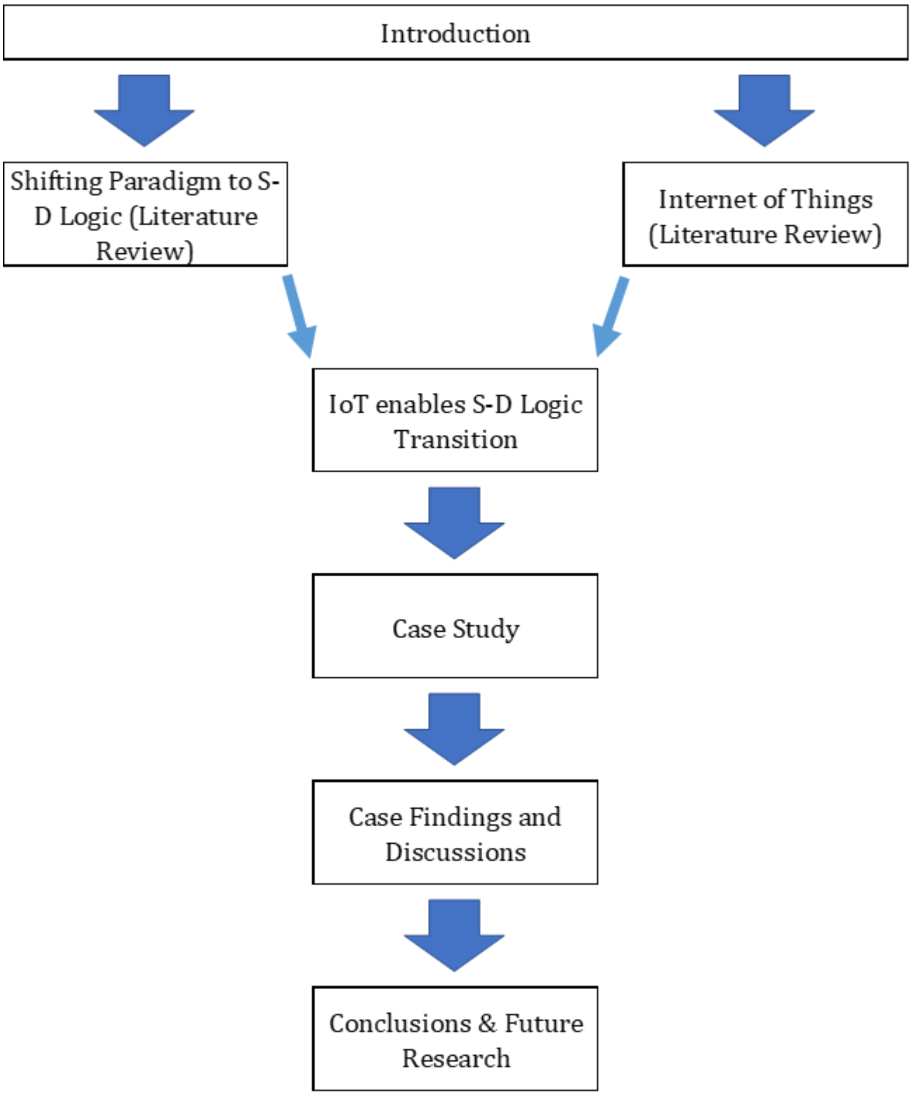
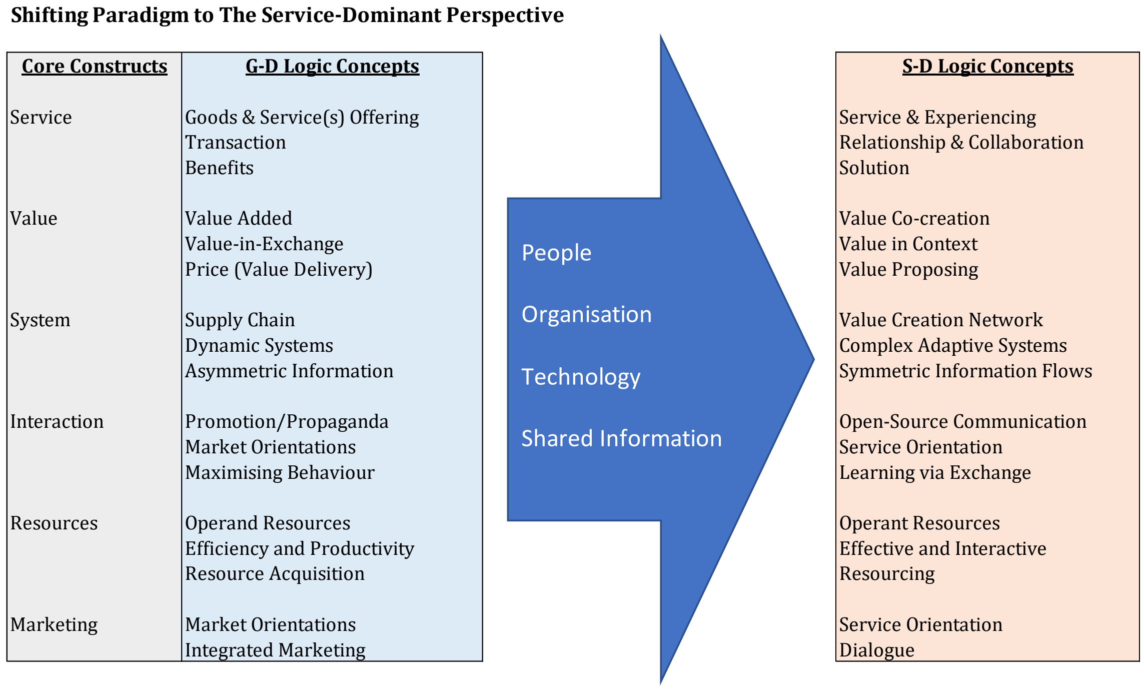


Figure 2.7 Shifting paradigm to the S-D logic conceptual framework

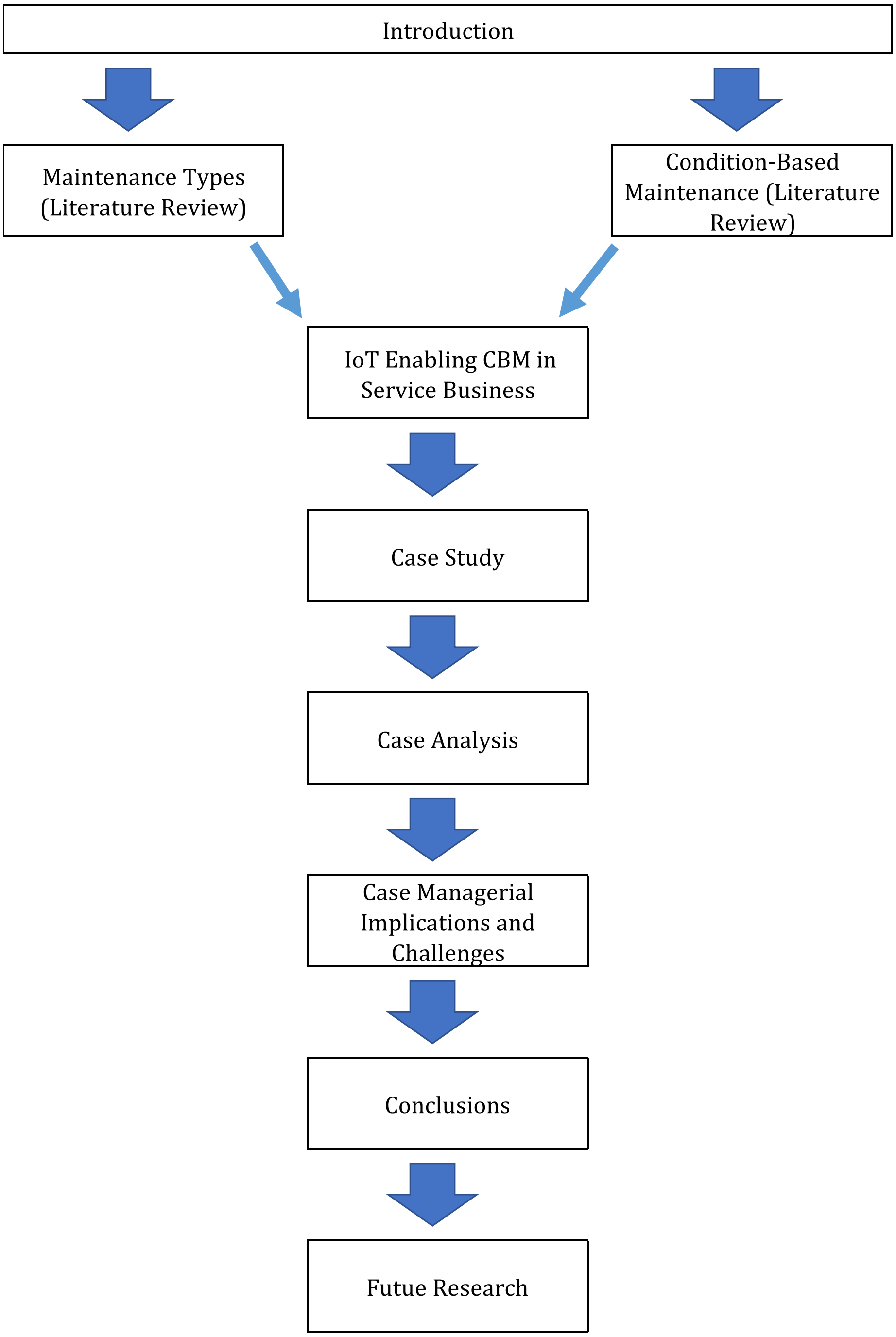


2.2.4 Research Roadmap for Paper 4: The Internet of Things Enabling Condition-Based Maintenance in Elevator Services (Lai, Jiang & Jackson, 2019). This paper utilises a straightforward explanatory research approach featuring a literature review and case study with interviews and direct observation methods, which examine the design guidelines of capitalised value of information to achieve CBM benefits and hence create a novel business model. This paper starts with a literature review of both maintenance strategies and CBM to form the theoretical background of this paper; it demonstrates how the IoT can enable CBM in an elevator company in a real-world application.

The study is a single, in-depth case study of a company operating in the elevator industry in China. The case studies are investigated from paper 3 to paper 6, and the motivation for continuing to study the same company is that it enables us to carry out in-depth research on certain phenomena in a real-life context. This case is an exceptionally interesting illustration of the importance of integrating technology and CBM in elevator maintenance as well as the specific challenges inherent in the IoT and CBM. The data for this research are obtained from a number of sources. First, information is collected through participatory observation, which involves working with a global elevator company, participating in developing an IoT solution for the company. This means that it is possible to obtain case study information through direct or indirect interactions with other stakeholders and provide insights into the perspective of various stakeholders. Second, publicly available information is collected from the company, including exemplary CBM cases described in its public documentation and on its website. Third, seven semi-structured interviews are conducted with company leaders involved in the IoT project, including service operation executives, an IoT project manager, the service innovation director, a sourcing manager and service maintenance managers located at various sites. The interviews vary in length but typically last for one hour. The interviews are conducted at various stages of the project: proof of concept, practical implementation, when customer feedback becomes available and when the outcomes of implementations are evaluated. Fourth, three additional interviews are conducted with various IoT vendors from a digitalisation consultancy who help to integrate IoT resources, a software company that designs user interfaces for coordinating data analysis and maintenance actions and a global partner offering cloud computing services that provide statistical analysis and cognitive data modelling. Finally, the researcher is able to review the outcomes of the analytical modelling, which encompasses more than six hundred installed IoT units running in a time frame of one to two years.

The research roadmap is shown in Figure 2.8, and the interview protocol with interview question is provided in the appendix B.

Figure 2.8 Research roadmap for chapter 6 (paper 4)



2.3 Summary of the Research Methods

This thesis is based on the qualitative research approach; the choice of research method includes both theoretical and empirical studies. It incorporates multiple research methods, including literature reviews, case studies (single, multiple and comparable case studies) and interviews as well as observation of the physical movement of real-world applications and a documentation review on quantitative, text and image data. Theoretical studies are performed to find out where the state of the art lies within the IoT business model and to research the IoT business model in the ecosystem context and the IoT facilitating service transition, enabling CBM as an input to determine which empirics should be collected in the elevator industry, on which this thesis focuses.

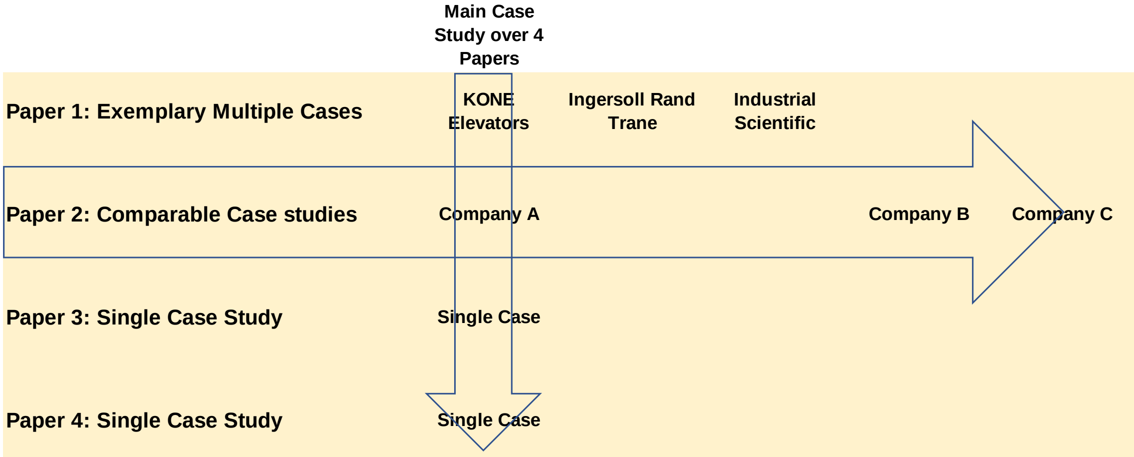
2.3.1 Case Studies (Single, Multiple and Comparable Case Studies)

According to Yin (2014), 'a case study is an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident'. Yin further elaborated that performing case study research would be preferable in a situation in which (1) the main research questions are 'how' and 'why' questions; (2) the researcher has little or no control over behavioural events; and (3) the focus of the study is a contemporary phenomenon. One prejudice against case study research is that it is difficult or impossible to obtain generalisable results. Yin stated that the results cannot be generalised to populations or the universe but that they can be generalised to theoretical propositions.

In this research, case studies are the main method across four independent papers; they are conducted to gather empirics when 'how' questions are asked and mainly investigate a contemporary phenomenon (the cases) in its real-world context. The main case company studied is linked through four papers within a four-year time frame (from proof of concept to commercialisation) at different stages to explain the contemporary phenomenon and hence address different levels of research questions. This is a leading global company based in Europe that provides solutions for the installation, maintenance and modernisation of elevators and escalators. It has a strong presence in China. In addition to manufacturing elevator equipment in China, the company is aggressively expanding its service business by providing maintenance, major repairs, retrofits and a full replacement service at the end of an installation's useful life. The company installs much of its own equipment nationwide, providing a platform for attracting customers to its service offerings. Therefore, the company has an incentive to seek opportunities aggressively to expand its service offering and achieve higher revenue, improving the service productivity internally and lowering the cost. The company's new IoT offering is connected services based on remote monitoring and a condition-based approach, which customers can purchase in addition to either the standard or the comprehensive service package. These additional service offerings are not mutually exclusive to the current service strategy (Lai, Jackson & Jiang, 2016).

In paper 2 (chapter 4) of this research, comparative case studies are used. The method is not entirely easy, even though the researcher is basically just comparing different events, products or suchlike. Researchers might believe that they are comparing two objects that involve a similar phenomenon, but in real life they could be completely different. In comparative studies, researchers' objects are cases that are similar in some respects but different in others, and the goal is to find out why the cases are different (Routio, 2004). Paper 2 applies both a descriptive and a normative style when performing a comparative study based on the theory or framework adopted from the literature; it aims to explain the differences between the cases and to describe and possibly explain them. In this research project, a comparative study is performed to test the IoT ecosystem framework with the aim of explaining how three different companies applied very similar IoT ecosystems but implemented their commercialisation strategy in slightly different ways, implying different business model approaches. A summary of the case studies is presented in Figure 2.9.

Figure 2.9: Summary of the case studies



Note: A total of 8 case studies in 5 companies over 4 papers.

2.3.2 Literature Review

All research should be based on, or take into account, previous research that has been undertaken regarding the same phenomenon or subject. This means that it is an advantage for research projects to start with a broad literature review that is narrowed down and becomes more specific at later stages. In this thesis, literature reviews are performed throughout the whole project from paper 1 to paper 4. In the first paper, an intensive literature review based on past studies is performed at a comprehensive level concerning business models for the IoT to explore the guiding principles of the IoT business model design, in manufacturing firms in particular, and thereafter is narrowed down in the different studies (chapters 4 to 6) performed to answer each of the research questions. The keywords used in the literature review in each paper are presented in Table 2.1.

Table 2.1: Summary of the literature by keywords

Study	Paper No.	Literature Key Words
Designing business models for the Internet of Things	Paper 1	Internet of Things (IoT), business model (BM), business model innovation (BMI), business models for IoT
Ecosystem context in elevator service	Paper 2	Internet of Things (IoT), business ecosystem, IoT ecosystem, ecosystem business model
Transition to service-dominant logic in elevator Industry	Paper 3	Internet of Things (IoT), goods-dominant logic, service-dominant logic, service science (service systems), value co-creation
Enabling condition-based maintenance in elevator service	Paper 4	Internet of Things (IoT), condition-based maintenance (CBM), corrective maintenance (CM), time-based maintenance (TBM), condition performance monitoring

2.3.3 Interviews

One of the most important data-collecting techniques within case study research is interviews (Yin, 2012, 2014). Interviews are generally used in qualitative research, in which the researcher is interested in collecting ‘facts’ or gaining insights into or an understanding of opinions, attitudes, experiences, processes, behaviours or predictions (Rowley, 2012). Interviews are a suitable method for carrying out research when the researcher is looking for answers about views, feelings, opinions, knowledge and so on within a population. Interviews can be performed in many different ways, depending on the knowledge or information that is sought. In an open-ended interview, in which the researcher and respondent more or less have an ordinary conversation, questions regarding ‘what something is’ and ‘what meaning it has’ are asked (Myers & Newman, 2007). The respondents’ perception and experience are captured. A structured interview gives the opportunity to answer questions regarding ‘how much’ of different phenomena exist. Thus, an open-ended interview regards qualities, and a structured interview regards quantities. In this research project, interviews are performed to gain knowledge of phenomena within different business models of IoT theories; hence, using a mixture of open-ended and semi-structured interview approaches is appropriate. Certain levels of questions need to be predefined from theories; however, interviewees are also allowed room to be flexible in expanding the knowledge when answering questions, which will enable more insightful information to be obtained from different angles.

In this thesis, paper 1 conducts three interviews mainly to reconfirm and ensure that the researchers understand the data and cases from three exemplary case companies. In paper 2, fifteen interviews for three case studies focus on the ecosystem business model, and, in paper 3, twelve interviews are conducted to investigate the phenomenon of service transition. Finally, in paper 4, ten interviews are related to the IoT enabling CBM. The details of the interview companies and interviewees are provided in Table 2.2, and the interview protocol is presented in the appendix at the end of this thesis. Despite the four independent projects (papers), some of the interviews are repeated during the four-year time frame; predefined interview questions are divided into common and specific questions; and common questions may be asked repeatedly either to reinforce the same outcome or to amend it during commercialised or technological advancement changes. The specific questions vary due to the different focus subjects in each of the projects.

Table 2.2: Summary of interviews by paper

Company and interviewees	Paper 1 (chapter 3)	Paper 2 (chapter 4)	Paper 3 (chapter 5)	Paper 4 (chapter 6)
Main Case Company				
KONE Elevators (Company A)				
Senior Executive, Greater China	X	X		
Service VP, Greater China		X	X	X
New Service Offering Head, Global		X	X	X
Project Manager, China		X	X	X
Code Manager, China				X
R&D Director, China				X
Sourcing Director, China		X	X	X
Service Finance Director, Greater China		X		X
Chinese Elevators Manufacturer (Company B)				
Managing Director		X		
Finance VP		X		
Chinese Elevators Control and System Provider (Company C)				
Sales VP		X		
Project Manager		X		
Ingersoll Rand Trane				
Senior Executive, China	X			
Industrial Scientific				
VP Operation, China	X			
Authoritative Body				
China Elevators Association				
Secretary of Operation		X	X	
Code and Regulation Director				X
IoT Vendors				
Global IoT Partner				
Account Manager		X	X	
Director of Support Operation		X		X
Application User Interface Suppliers				
General Manager		X	X	
Support Manager			X	
Data Transmission Unit Supplier (Hardware)				
General Manager		X	X	
Project Manager				X
Customers/End Users				
Facility Management Company				
General Manager			X	
Property Developer				
Project Manager			X	
3rd F Project Manager				
General Manager			X	
Subtotal (Number of Interviews)	3	15	12	10

Note: A total of 40 interviews are conducted among 8 case studies in 5 companies over a time frame of four years and presented in 4 published articles.

2.4 Summary of the Research Process

According to Yin (2014), each type of empirical study has some sort of research design. Yin also defined a research design as ‘an action plan for getting from here to there’, with ‘here’ meaning the initial sets of questions and ‘there’ meaning some sets of research outcomes. This section will explain the research process, demonstrating how the research is performed from the start to the result of this thesis. Accordingly, it reiterates Figure 1.1 containing the framework of IoT business model design guidelines that forms the main theme of this thesis, followed by Table 2.3, which provides a summary of the research methods, the unit of analysis, the different studies performed during the project and the objective of each of the four projects.

Figure 1.1: Framework of the IoT business model design guidelines

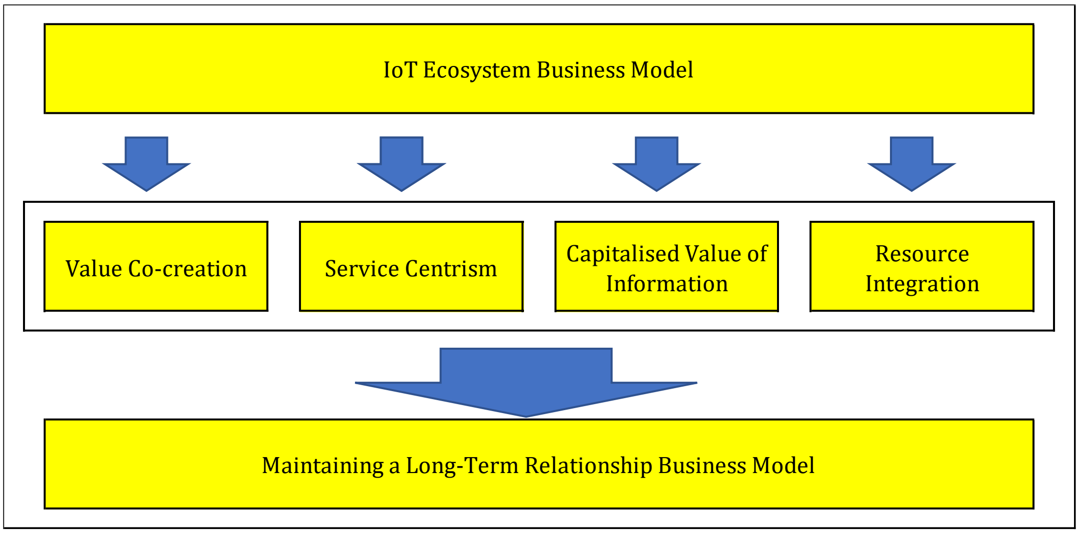


Table 2.3: Summary of the research method and objectives of each paper

Study	Paper	Research Methods	Unit of Analysis	Objective
Designing business models for the Internet of Things	Paper 1	Literature review, case study, interview	Literature (the Internet of Things, business model, business model innovation and IoT business model), three exemplary case studies, 3 interviews	Identify 6 guiding principles of designing business model of the Internet of Things
Ecosystem context in elevator service	Paper 2	Literature review, comparable case study, interview	Literature (business ecosystem, IoT ecosystem and ecosystem business model), three comparable case studies, 15 interviews	Elaboration of the Internet of Things facilitates business ecosystem and the value co-creation context
Transition to service-dominant logic in elevator Industry	Paper 3	Literature review, case study, interview	Literature (Internet of Things, service-dominant Logic), single case study, 12 Interviews	Elaboration of the Internet of Things facilitates service-centric transition, value co-creation, long-term relationship and resource integration
Enabling condition-based maintenance in elevators service	Paper 4	Literature review, case study, interview	Literature (maintenance types, condition-based maintenance, time-based maintenance, elevator maintenance), single case study, 10 interviews	Elaboration of the Internet of Things strives to achieve capitalized value of information and hence enabling condition-based maintenance in elevator service

As can be seen in Table 2.1, literature studies are performed throughout the project. At the beginning, more general literature studies relating to the business model of the IoT are conducted as the research questions are formulated. As the papers and reports are written, more directed literature studies are performed in each of the papers. The literature is collected from books, journals, conference proceedings, lecture notes, doctoral dissertations and, in some cases, web searches.

The first study in chapter 3 aims to address the main research question concerning the critical guidelines to be used when developing service business models for the IoT and whether theoretically they could be in a different spectrum from the traditional business model. The study is performed theoretically, and the research method comprises mainly literature reviews together with three exemplary cases involving a straightforward documentation review and interviews. To address the research question and provide the researchers' input and recommendations from both theoretical and practical perspectives, the aim is to explore the critical guiding principles when designing an IoT business model in manufacturing firms, in which it is argued that there should be a business model that is service-centric in nature. Paper 1 begins with an illustration of the fundamental attributes of the IoT, with further elaboration of the potential applications and value of the IoT, followed by a discussion on business models and business model innovation from a theoretical perspective; it is believed that these theories or frameworks form a critical link in our studies. Subsequently, a systematic review of the literature is conducted, addressing the designing of business models for the IoT for manufacturing firms. Then, guiding principles are proposed for a company that decides to adopt the IoT to develop a new business model with a service nature; these guiding principles are service centrism, value co-creation, a long-term relationship perspective, capitalised value of information, resource integration and the business ecosystem. Finally, three exemplary case studies are described, showing how legitimate manufacturing companies develop their new service-centric business models based on IoT technology to test the guiding principles proposed. The first study establishes the main framework of the overall thesis; these six guiding principles are discussed in more detail in papers 2 to 4 (chapters 4 to 6).

The second study in chapter 4 on IoT business models in an ecosystem context is based on cases of elevator services. This study addresses the second research question, which concerns the ecosystem business model as an overall umbrella of IoT business model design guidelines proposed in the framework in Figure 1.1. Accordingly, this paper begins with a review of the theoretical foundations of the business ecosystem, business models and the IoT ecosystem and their relationship, with similarities and differences. Then it presents a discussion of the IoT business model in the ecosystem context based on different frameworks. This is followed by a comparable case study based on an existing ecosystem business model framework using real-world IoT business model cases in the elevator industry to illustrate similar IoT technological applications in the same industry that adopt different business model approaches in the ecosystem environment. Finally, the key findings are reviewed to draw conclusions regarding the challenges of IoT business model development and possible solutions.

The third study, in chapter 5, concerning how the IoT can enable companies' transition from G-D to S-D logic, aims to address the third research question as well as to explain four of the IoT business model design guidelines that the framework outlines: service centrism, a long-term relationship perspective, value co-creation and resource integration. The paper starts by explaining the distinction between G-D logic and S-D logic and its implication for manufacturing firms, mainly through a literature review. Then it investigates how the IoT can facilitate the transition from the key S-D logic managerial implication perspective, and finally it conducts an in-depth case study of a new service solution of an elevator service business that intended a transition to the S-D model through the adoption of the IoT. The aim is to investigate whether the underlying technology can bring together different ways of thinking when deploying a new industrial service offering. This single-case study format consists of two sections: the initial stage aims to develop a service offering proof of concept by experimenting with value co-creation with all the stakeholders among collaborative networks; once a proof of concept has been established, further studies will carry out longitudinal research to monitor this service offering's implementation in a real-life business model, enabling the researcher to present the findings in a more assembled and responsible manner.

The fourth study in chapter 6 investigates how the IoT can enable elevator services to achieve CBM. This study aims to address the fourth research question as well as to explain the capitalised value of information design guidelines proposed in this thesis's framework. This paper begins with a review of the theoretical foundations of maintenance types, including CBM, and maintenance strategies in the elevator industry. An in-depth case study is constructed of how the IoT enables CBM in the elevator industry from the data collection, data analysis and decision process perspectives to illustrate the benefits of CBM compared with conventional TBM and CM. Finally, the key findings and challenges are discussed based on the outcome of the case study, and possible options are proposed to overcome these challenges, leading to the identification of issues to be addressed in further research. The case study focuses on the same international elevator manufacturer used for paper 2 and paper 3, from the proof of concept in paper 3 to the implementation phase in paper 2 and the commercialisation of the outcome in paper 4. This paper, aiming to continue the research, further considers how the IoT can enable the full utilisation of rich information-driven CBM in elevator services and identifies the main benefits compared with conventional CM and TBM in real practical cases based on 2 years of data collected from more than 600 installations at different sites and under various conditions. The objective is to discuss existing and potential maintenance approaches in connection with the underlying CBM and IoT in designated domains. This study intends to contribute to recent IoT business case studies from the perspective of effective and efficient CBM implementation, developing advice for the elevator industry in embracing similar concepts when designing a service offering based on IoT technology.

2.5 Summary of the Theoretical Background

As discussed in relation to the research process, there are theoretical background discussions in each of the four papers, mainly from a literature review of past related studies. The literature keywords can be seen in Table 2.1. At the beginning, more general literature studies related to the IoT and business model are conducted as the research questions are formulated. In each of the papers, a more in-depth discussion of the subject matter of the theoretical background is elaborated, and the papers provide a summarised viewpoint or critical thinking from past studies of related books, journals, conference proceedings, lecture notes, doctoral dissertations and, in some cases, web searches. These discussions from past studies aim to provide recommendations regarding the main problem statement and, hence, provide answers to each of the research questions.

Internet of Things: In general terms, the IoT is emerging such that the physical world itself is becoming a type of information system. Sensors and actuators embedded in physical objects are linked through wired and mostly wireless networks, connecting through the Internet in a central data server to collect and exchange a huge amount of information for analysis. These objects can be simple, like performance data collectors to sense the environment, or smart objects that intelligently communicate and perform complex interactive tasks. It is revolutionary that these physical information systems are now beginning to be deployed, and some of them even work largely without human intervention. Chapter 3 discusses the value of the IoT; chapter 5 describes the main attributes, technology and potential value of the IoT; and chapters 4 and 6 discuss the real-world application and the benefits and challenges.

Business model: Business model frameworks and theory are a broad subject that has frequently been discussed in studies through both academic and practitioner lenses. Consensus on a common definition of a business model has yet to be reached in the management literature. However, one early definition that has been widely influential stems from Amit and Zott (2012): 'A business model depicts the content, structure, and governance of transactions designed so as to create value through the exploitation of business opportunities. Essentially, every company has a business model, whether it articulates it or not. However, complications arise with the most basic questions. What is a business model? What constitutes a firm's business model? Chesbrough (2010) suggested that a business model performs two important functions: value creation and value capture. Chapter 3 discusses a series of scholarly developments of business models and business model innovation. It also features an in-depth discussion concerning the amount of literature directly related to the IoT business model, through either the design framework or the monetised value lens. Chapter 4 touches on the ecosystem business model literature to articulate the difference between the ecosystem business model and conventional firm-centric business model conceptual frameworks.

Service-dominant logic: One of the most developed criteria from past studies is that the IoT facilitates manufacturing firms' transition to service centrism, and S-D logic has been the main marketing vision in many articles. This can be inferred from chapter 3's IoT business model literature review. S-D logic is a service-centred alternative to the traditional G-D paradigm for understanding economic exchange and value creation and has been identified as an appropriate philosophical foundation for the development of service science (Maglio et al., 2009). S-D logic is the main theoretical background in chapter 5, with several paragraphs dedicated to elaborating the detailed concept of S-D logic as well as describing how the IoT can enable firms' transition to S-D logic from G-D logic from similar studies.

Business ecosystem and IoT ecosystem: Business ecosystem theory originated in the work of Moore (1993) and states that successful businesses must attract resources of all sorts, drawing in capital, partners, suppliers and customers to create cooperative networks. Such networks should, under the rubric of strategic alliance, virtual organisations and the like, nurture the complex business communities that bring innovations to the market. In these networks, each member contributes to the ecosystem's overall well-being and is dependent on other members for its survival. Reciprocally, the survival and success of each member are influenced by the ecosystem as a holistic entity that is undergoing continuous evolution (Iansiti & Levien, 2004a). The ecosystem concept greatly influences the essence of the IoT ecosystem, which implies the physical world of things with the virtual world of the Internet, software, hardware and network platforms as well as the standards commonly used for enabling such interconnections; these may become the core of an IoT ecosystem. The main objective of the theoretical discussion is to derive the conceptual framework of the ecosystem business model in an IoT environment in chapter 4.

Condition-based maintenance: CBM has been a research topic offering a more economical, more effective alternative to traditional maintenance strategies. Due to the massive advances in information technology, much more research is now being performed in this area. The formal definition of CBM states that it is a method used to reduce the uncertainty of maintenance activities and involves carrying out maintenance activities according to need, as indicated by the condition of the equipment. The key assumption of CBM is derived from the modelling of the deterioration process and is that 99% of equipment failures are preceded by certain signs, conditions or indications that a failure is going to occur (Bloch & Geitner, 1983). Thus, CBM assumes that there are indicators that can be used to detect and quantify the possible failure of equipment before it actually occurs. In chapter 6, CBM is discussed from a more holistic viewpoint, starting from maintenance types in general, then moving on to more specific CBM over TBM and CM and lastly focusing more on the elevator maintenance strategies discussed in past studies. General implementation strategies for CBM are also discussed, including the most critical data collection, data analysis and decision process. The purpose of this theoretical discussion is to bring forward one of the most prominent aspects of IoT business model design, namely capitalising the value of information, which makes CBM possible in elevator services.

2.6 Reflections on the Research Methods

There are different ways of judging the quality of a research project. In this section, I apply the most common method, which is to discuss the validity and reliability of the research to judge the quality of the given design according to certain logical tests. Yin (2014) defined four tests of validity and reliability, and these have commonly been used to establish the quality of empirical social research, particularly in case study research; these four tests are construct validity, internal validity, external validity and reliability. To reflect the research process of this thesis, these four tests are discussed in the following section.

Construct validity is achieved by establishing correct operational measures for the concept being studied. This test of validity is more problematic in case studies than in other research, although it is equally important (Yin, 2014). According to Yin, there are several approaches to reinforcing the construct validity, including the use of multiple sources of evidence, to establish a chain of events and to have a draft of the reports studied by the key informants. In this thesis, the literature review, interviews and case studies are the three main research methods throughout the entire thesis, including four projects (four papers). Firstly, multiple sources of evidence are used from paper 1 to paper 4; interviews, documentation reviews, direct observation, quantitative outcome reviews and intensive literature are analysed. Secondly, these four studies are based on a chain of events and have a strong linkage to each other. In particular, the research applies the same case study from paper 1 to paper 4 over the past four years; hence, a clear chain of events can be investigated and traced. In paper 2, a comparative study is performed in which the literature is compared with a real development to highlight the differences but particularly the similarities, which is also one of the approaches used to increase the construct validity. Thirdly, as the same case is used over four studies, the case study and interview results are always reviewed and agreed with the informants; in particular, a number of the same participants are interviewed several times throughout the thesis. Every interview can reinforce the prior ones and confirm the validity of the contents. Furthermore, the projects have been both presented at international conferences and published, which is also one of the approaches followed to reinforce the construct validity.

Internal validity is achieved by establishing causal relationships to indicate that certain conditions lead to other conditions (Yin, 2014). The test of internal validity has been paid the most attention in experimental and quasi-experimental research. In this research project, internal validity is not treated to a great extent. Paper 1 explores six guiding principles based on the literature; causal relationships are thus not in focus. External validity is achieved by establishing the domain from which the findings of a study can be generalised to other populations (Yin, 2014). A theory developed from a case study must be replicated with roughly the same results several times before a researcher can state that the results are generalisable to populations other than the one being researched. The main case of this research is studied over four years; generalisation can possibly be applied to other elevator service companies in the same spectrum. For companies outside this industry, external validity is difficult to prove; however, the official publications and acceptance by directly related journals are a type of external validity and can be examined publicly.

Reliability is achieved by demonstrating that a study can be performed on a later occasion with the same results. The assumption of reliability is that, if a later researcher follows exactly the same procedure as described by an earlier investigator and conducts the same case study all over again, the later investigator should arrive at the same findings and conclusions (Yin, 2014). In this thesis, investigating the prevailing latest technology for IoT business model design, it is understandable that technology moves rapidly and that new technology can at any time replace old technology at a lower cost. Similar to a business model, it is constantly changing due to the fact that the best way of developing a business model is to experiment in the real world and make corrections along the way, which has been part of the studies in real dynamic markets and real business applications. However, this is not to say that replications are not possible, particularly in relation to the proposed guiding principle, the service transition framework and the concept of CBM implementation. One of the most important aspects in achieving reliability is to document the procedures that a case study has followed. In this research, project reliability is addressed by documenting all the data collection routines – the interview questions, interview results, documentation, direct observation and reviewed literature. The researcher's intention in this thesis is to investigate a modern phenomenon and provide recommendations for practical implications, without the expectation that case studies will produce the same results in every single way. As the researcher is directly involved in IoT business model design in real cases, it is difficult to remain completely objective, as the case company and the researcher's personal views are bound to affect the interpretation of the results.

This research project cannot be completely perfect; there is always space for improvements. It proposes guiding principles that are relatively subjective due to the researcher serving for many years in the elevator industry as well as the influence from the interview respondents. Papers 2 and 3 are written more from the marketing vision and strategy perspective, and there is no guarantee that an interview from a case study will produce the same result; even when interviewing the same person two years later, a different outcome may be obtained. It is believed that, in real-world practical applications, continuous adjustments and corrections of the business model design are made as long as they benefit the commercialisation and acceptance in the market. Even when investigating different companies in the same industry adopting the IoT to design a business model, it is doubtful that any breakthrough observations can be explored due to the fact that the whole industry is following the same digitalisation path to enhance its service offering. However, for the objective of this project, it is believed that the number of companies and interviews is sufficient to be able to elaborate the most important business model and technical constituents and to decide which would be the most interesting ones for the continuation of the project.

Chapter 3: Designing Service Business Models for the Internet of Things: Aspects from Manufacturing Firms

Abstract: The increasing pervasiveness of the Internet of Things (IoT) has offered a wealth of business model opportunities. Many conventional product-based companies are seeking to increase their competitiveness by moving toward a service-based business model where IoT can bring tremendous opportunities. These traditional product-sales manufacturing firms are required to look at business models beyond their conventional product-focused, firm-centric core competence business model innovation and respond to fast changing digitalization dynamics focused on promoting service-centric solution availability instead of physical products. However, studies and literatures have not yet provided profound and actionable approaches to service business models in IoT-driven environments for manufacturing firms. This research aims to fill the gap and elaborate the guiding principle for designing service business models for the Internet of Things in manufacturing firms. The guiding principles are derived from illustration of value of the Internet of Things and systemic review of academic literatures focusing on IoT business models. Exemplary real-world IoT service business models cases are demonstrating the applicability of the proposed guiding principles. Evaluation of the applicability of guiding principles pertaining to the emerging context of IoT business model can enable researchers and practitioners to visualize and analyze service business model design in a structured and actionable way.

Keywords: Business Model, Internet of Things, Business Ecosystem, Value Co-creation, Service-Dominant Logic

3.1 Introduction

Many real world Internet of Things (IoT) applications have been postulated in many industries: the domain not only covers conventional industrial sectors, but also the consuming industry of everyday life, where IoT can bring significant improvement, even leading to new business models. However, the business model based on today's largely static or historical information architectures is facing challenges as new ways of creating value arise between firms, clients, and other stakeholders—in other words, an ecosystem business model instead of a firm-centric business model. In durable goods industrial sectors, selling products is no longer simply goods exchange for their monetary value—for example, paying by usage or by performance is now a common option. In the consumer industry, customer purchasing behavior under a dynamic environment is based on situational preference and analyzing customer behavior is more difficult based on today's general customer survey; for example, firms need to adjust by means of dynamic pricing to attract customer purchasing desirability based on real time data analysis of specific customers and locations, or, in the industrial service industry, providing a real-time remote monitoring service to tailor customers' specific needs becomes more critical and necessary. By providing additional service through precise analysis evolved with the use of a multitude of sensors, firms can help to monitor and manage their clients' purchasing behaviors, operating equipment or manufacturing processes more precisely, raising efficiency and productivity, and hence creating more revenue opportunities. In certain situations, operating environments can be monitored continuously for hazardous environments where objects can take predictive corrective action to avoid safety incidents, reduce risks, and avoid costs incurred by operating systems damage or down time. With IoT technology, firms now have the capability, or simply more opportunities, to innovate business models that give them an advantage over their competitors (Chui, Löffler & Roberts, 2010).

IoT is a broad concept and a consensus has yet to be built concerning a common definition. This paper focuses on conventional manufacturing companies expanding their new offering in providing IoT services to bring value to their clients and other stakeholders, hence generate additional revenue and profitability. In the IoT service domain, information is gathered from various sensors through networks, processed for information analytics and optimization in a central repository and finally suited to decision making. These services are expected to find users in a wide range of smart applications related to home, factories, energy, healthcare, logistics and maintenance and could revolutionize society. Especially, there are several initiatives aimed at promoting IoT services in the industry sector, including “Industry 4.0” in Germany, “Made in China 2025” in China, the “Industrial Internet” in the United States (US) and the “Industrial Value Chain Initiative” in Japan (Uchihira, Ishimatsu & Inoue, 2016). In particular industry 4.0 foster automation and data exchange over cyber-physical systems, internet of things, cloud computing and cognitive computing, which communicate and cooperate each other and with human in real time both internally and across organization service offered and used by actors of the value chain (Wollschlaeger, Sauter & Jasperneite, 2017). Hermann et al. proposed six design principles for Industry 4.0 implementation; they are interoperability, virtualization, decentralization, real-time capability, service orientation and modularity which rely on full transparency of communication among physical things, physical and virtual network (Hermann, Pentek & Otto, 2016). Some examples are machine which can predict failures and trigger maintenance processes autonomously or self-organized logistics which react to unexpected changes in production, as well as services through machine to machine interface. All these effects requiring everything is interlinked with everything else, it is a fair assumption of driving force behind IoT (Sarvari et al., 2018).

There are many literatures articulating that IoT will enable traditional manufacturing firms to innovate new business models; these studies will be examined thoroughly in later sections. These literatures indicate that technology advancement in terms of product or service innovation alone may not sustain business life unless a viable and sustainable business model exists. A viable business model will play an important role when it comes to leveraging the opportunities if new technology innovates, matures, and is cost effective—but how will IoT provide us with these many business opportunities? What are the main differences when designing IoT business models compared with conventional firm-centric core competence-based business models? And what are the critical guidelines when developing service business models for IoT, if theoretically they could be in a different spectrum from the traditional business model? In this paper, these questions are addressed and provide input and recommendations from both theoretical and practical perspectives, aiming to analyze the critical guiding principles when designing an IoT business model in manufacturing firms, where it is argued there should be a business model service-centric in nature.

This paper begins with a definition of the Internet of Things, with further elaboration on what are the potential applications and value of IoT, followed by a brief discussion on business models framework mostly applied to IoT business model from a theoretical perspective, as well as the discussion on busienss model development relating to technology advancement, where we believe that these theories or frameworks are a critical link in our studies. Subsequently, a systematic review of literatures is conducted addressing designing business models for IoT for manufacturing firms; from there, this study derives proposed guiding principles for when a company decides to adopt IoT to develop a new business model in service nature. Finally several exemplary real-world practical cases are illustrated on how legitimate manufacturing companies develop their new service-centric business models based on IoT technology, and hence test the guiding principles proposed.

3.2 The Value of the Internet of Things

It is emerging that the physical world itself is becoming a type of information system, called the Internet of Things. Sensors and actuators embedded in physical objects are linked through wired and mostly wireless networks, often using the same Internet Protocol (IP) that connects the internet to a central data server to collect and exchange a huge amount of information for analysis. These objects can be simple, like performance data collectors to sense the environment, up to smart objects that intelligently communicate and perform complex interactive tasks. It is revolutionary that these physical information systems are now beginning to be deployed, and some of them even work largely without human intervention.

IoT technology can enable firms to promote solutions which integrate product and service operations—for instance, wireless sensor networks or remote monitoring systems that consist of distributed autonomous sensor-equipped devices to monitor the physical or environmental conditions and that can cooperate with internal systems to monitor the real-time status of a product or equipment, such as its location, temperature, movement or even component utilization status (Atzori, Iera. & Morabito, 2010), cloud computing, and finally IoT applications to enable device-to-device and human-to-device interaction in a reliable and robust manner (Lee & Lee, 2015). The true value of IoT for enterprises can be realized when connected devices are able to integrate with in-house business intelligence applications, traditional enterprise resource planning (ERP) systems, and supply chain systems, collecting big data and business analytics for further decision support systems (Bradley, Barbier & Handler, 2013).

The adoption of new technology is rapidly gaining momentum as technological, societal, and competitive pressures push firms to innovate their new offering and business model. Data collection and analytical capability from IoT technology is an advantage for company executives, enabling them to consider that the information they collect could do even more than support product and service offerings: companies commercializing big data on their own have the advantages of economies of scale, control over strategy, and much greater revenue potential. Partnerships built upon IoT ecosystems also share risks and take advantage of the partners' knowledge and skills, assets, or data to create new opportunities and get to market quickly.

A great deal of advanced technology has been developed in the IoT field for conventional manufacturers. However, in this paper authors do not focus on IoT from a technical perspective: instead, it examines the value of IoT which can enable these firms to redesign or innovate new business models from better generated information and analyses, which can enhance decision-making significantly and so establish a business model for which clients are willing to pay. Before investigates how to a design business model for IoT, firstly has to understand the power of IoT in general. In brief, the fundamental attributes of IoT technology can be summarized as follows: (i) IoT is a global and real-time solution; (ii) IoT is mainly wireless oriented; (iii) IoT has the capability of remote monitoring of the environment and tracking objects; (iv) IoT is able to collect and exchange data from objects; and v) IoT is able to provide comprehensive data analysis about its surrounding environments (Yang, Yang & Plotnick, 2013; Lai et al., 2016). Based on the key attributes of IoT, technology trends, and a literature review, it is concluded that IoT can enhance manufacturing firms' value in various areas: tracking behaviors and monitoring; enhanced situational awareness; decision-making support; automation; navigation and control; optimized resource consumption; information sharing and collaboration; and complex autonomous systems. Followed by elaborating on how each of these values of IoT can be commercialized and hence develop possible economic power in the market, which will act as a critical component of the firm's business model innovation.

3.2.1 Tracking Behaviors and Monitoring

When 'things' have smart sensors embedded, fundamentally they can track the movement of the object and can even communicate or interact with the object if they are smart enough. However, tracking objects may not itself create value: firms have to analyze the movement of objects in a valuable pattern and hence create business opportunities, either from more productive or an increase in revenue perspective. Real-time information processing technology based on sensors can realize instant monitoring of almost every link in the supply chain, from commodity design to raw material purchasing, production, transportation, storage, and distribution and after sales service (Atzori, Iera & Morabito, 2010). For example, traditional manufacturers installing RFID (Radio-frequency identification) tags in products can improve inventory management; jet engine providers can track flying hours for both a chargeable usage business model and predictive maintenance; consumers wearing sensor devices can keep track of exercise outcomes as well as health monitoring; insurance companies can use sensors installed in cars to analyze driver behaviors to determine premium charges; and, in retailing, smart chips installed in a membership card can track and therefore predict purchasing power.

3.2.2 Enhanced Situational Awareness

Data collected from numerous sensors can be analyzed for situational awareness, wired or wirelessly. These data patterns can range from a simple dataset to voice or high resolution visualization tools; they can give decision makers a heightened awareness of real-time environmental conditions. Good situational awareness is an important factor for minimizing property damage and injury, and for saving people's lives in emergency response operations (Yang, Yang & Plotnick, 2013). Some examples are real-time video cameras for monitoring purposes and infra-red detectors for security functions, up to more complex traffic control and people flow management.

3.2.3 Decision-making Support

IoT can also support more complex human planning and decision making. This requires building sophisticated statistical models in order to generate certain patterns or graphical displays from big data analytics. For example, shop floor production line design can be based on analysis of the production flow in order to avoid a production bottleneck; public traffic lights can be designed based on analysis of big data from transportation situation patterns. In healthcare, sensor links offer the possibility of monitoring a patient's symptoms in real time, hence allowing physicians to better diagnose disease and prescribe tailored treatment. Or, on a more sophisticated level, hundreds of sensors located in a sensitive earthquake zone can possibly predict activity and provide an early alert.

3.2.4 Automation

Manufacturing firms are utilizing sensors and actuators in their precision machinery to modify processes through an automated looping and feedback process. These intelligent actuators can fine tune the production position or temperature, or modify ingredients based on situational analysis. This continuous looping from data to automated applications can raise productivity, as systems that adjust automatically to complex situations make many human interventions unnecessary; this move will hence help to enhance process optimization.

3.2.5 Navigation and Control

Cars, trains, and buses, along with the roads and the rails, equipped with sensors, actuators, and processing power may provide important information to drivers and passengers to allow better navigation and uphold safety. A few car companies are already testing their autopilot or robot navigation car: soon these cars will be running on the road based on sensors and navigation systems in the cars connecting to the cloud and satellite for driving. These cars respond to real-time traffic movements of the city, and are calibrated to reduce congestion at bottlenecks in the city and to service pick-up areas that are most frequently used. In a similar concept, an IoT smart city is based on the concept that the status and performance of each building and urban public facility, such as walkways, cycle paths, subways, rail lines, and bus corridors, is continuously monitored by the city government and made available to third parties via a series of application programming interfaces (API). These APIs can be available for the public to improve their urban life.

3.2.6 Optimised Resource Consumption

Networked sensors and automated feedback mechanisms can change usage patterns for scarce resources, particularly in energy consumption, often by enabling more dynamic pricing (Chui, Löffler & Roberts, 2010). Smart meters can show residential and industrial customers their energy usage and the real-time cost on their handy mobile device and application. Based on time of use pricing, commercial customers can shift energy-intensive processes and production away from high priced periods of peak energy demand to save costs. HVAC (heating, ventilation, and air-conditioning) solution providers can build district cooling facilities to provide an intensive compound by charging according to usage through smart meters everywhere. A central cooling facility can also generate ice storage during non-peak energy consumption periods and can be used for air conditioning and chilled water on a usage chargeable basis, so firms and clients together can maintain sustainable energy consumption.

3.2.7 Information Sharing and Collaboration

IoT can provide identification and authentication through fingerprint or face recognition systems for access control. Sensor devices enable functions centered on patients, and in particular on diagnosing patient conditions, providing real-time information on patient health indicators. Searches can be easily conducted for things that help in finding objects that have been forgotten, lost, or even stolen. Information sharing and collaboration in IoT can occur between people, between people and things, and between things. Sensing a predefined event is usually critical for information sharing and collaboration; it enhances situational awareness and avoids information delay and distortion (Lee & Lee, 2015).

3.2.8 Complex Autonomous Systems

The most demanding use of the Internet of Things involves the rapid, real-time sensing of unpredictable conditions and an instantaneous response guided by the automated system without human intervention (Chui, Löffler & Roberts, 2010). Other than autopilot cars in the progress of development, scientists have also developed robots that maintain facilities or clean up toxic waste. In the defense sector, unmanned aircraft and armed forces are being developed and used in real combat. While such autonomous systems will be challenging to develop and perfect, they promise major gains in safety, productivity, and cost.

3.3 Business Model

This section outlines the grounded theory and framework developed for business models over the past few decades. This study particularly identify the most frequently applied theories in IoT business model-related literatures which will address in more detail manner at following sections. These theoretical frameworks should be inspiring and provide a level of abstraction that will help when scholars choose to illustrate business model development for the Internet of Things from different angles, while the literatures will form the basis for discussion of whether the frameworks are concrete enough to be actionable for innovators in business and society at large.

Consensus on a common definition of the business model has yet to be reached in the management literatures (Zott & Amit, 2002). However, one early definition that has been widely influential stems from Amit and Zott (Amit & Zott, 2012): "A business model depicts the content, structure, and governance of transactions designed so as to create value through the exploitation of business opportunities". Also, a business model is an organization's approach to generating revenue at a reasonable cost and incorporates assumptions about how it will both create and capture value to benefit enterprises (Brandenburger & Stuart, 1996). Essentially, every company has a business model, whether it articulates it or not. However, complications arise with the most basic questions. What is a business model? What constitutes the firm's business model? Chesbrough (Chesbrough, 2010) suggested that a business model performs two important functions: value creation and value capture. Similarly, Teece (Teece, 2010) defined the essence of a business model as defining the manner by which the enterprise delivers value to customers, entices customers to pay for value and converts payment into profit. Pavie et al. (Pavie et al., 2013) offered a good overview of various business model concepts in their 2013 paper for the ESSEC business school; no matter what market a business organization is competing in, it will – either implicitly or explicitly – create or apply a business model. A business model can be defined as the architecture and mechanism of actual value creation by an organization. All these concepts have in common a focus on the rationale for how an organization creates, delivers and captures value.

More detailed frameworks for the design and classification of business models have been developed since the early publications on the topics. Teece (Teece, 2007) defines a business model as reflecting management's hypothesis about what customers want, how they want it and how an enterprise can best meet those needs and be paid. Gassmann, Frankenberger and Csik (Gassmann, Frankenberger & Csik, 2013; Gassmann, Frankenberger & Csik, 2014a; Gassmann, Frankenberger & Csik, 2014b) employ a conceptualization that consists of four central dimensions – the who, the what, the how and the value – in the magic triangle. By answering the four associated questions and delineating 1) the target customers, 2) the value proposition for the customers, 3) the value chain behind the creation of this value and 4) the revenue model that captures the value, a business model can then be established. Based on this magic triangle, Gassmann's St. Gallen Business Model Navigator (BMN) identified 55 repetitive patterns that form the core of many new business models, having looked at several hundred business model innovators. Alexander Osterwalder (Osterwalder & Pigneur, 2010) introduced the business model canvas (BMC) in the Business Model Generation Handbook, offering a set of nine interdependent "building blocks", beginning with key partners and key activities, together with key resources, moving on to the value proposition to target the customer segment based on customer relationships and channels and ending with the cost structure and revenue streams defined by the other elements. This business model canvas aims to expand along with the sum of resources and activities which the company organizes and implements in order to provide a specific value for a particular target segment (Kralewski, 2016).

These frameworks developed appear to analyse the related challenges of innovating and implementing new business models in practice (Visnjic & Neely, 2011). In particular, technology can bring about disruptive business model opportunities in terms of the ability to experiment and through progressive introductions of new products or services. Systematic data collection on usage and performance is important in the development of business models (Chesbrough, 2010). From another angle, challenges have also been witnessed in emerging industries with regard to technology, application and organization. It is argued that there is the need for a new business model or novel technology to connect ecosystem stakeholders and initiate a new way of commercializing the business model and technology (Rong et al., 2015). These challenges require stakeholders to achieve interoperability between different levels of the organizations to cope with uncertainties (Gassmann et al., 2010; Rong, Shi & Yu, 2013). Therefore, it is argued that while existing business model templates and frameworks are adequate for examining the challenges faced by single existing organizations (Osterwalder & Pigneur, 2010; Sinfield et al., 2012), they are less suited to analysing the interdependent nature of growth and success among companies that are evolving in the same innovation "ecosystem" (Rong et al., 2015). Traditional industrial-era business models held that competitive advantage was based on product excellence, in-house technological innovation and careful management of scarce resources and supply chains (Carbone, 2009). More recent academic research suggests the need to expand the focus in business models from a single company point of view to an ecosystem perspective (Leminen et al., 2012), particularly in the climate of increasing complexity, with more adaptive technical solutions and changes in the roles of business actors compared to the traditional way of managing partners to support firm-centric value design. Furthermore, companies are seeking new commercialized offerings, shifting the focus from industry-specific applications to applications spanning multiple industries; under such circumstances, the challenges increase substantially (Gassmann et al., 2010). Zott and Amit (Zott & Amit, 2010) defined a business model as a system of activities dependent on each other through the focal company and the surrounding network. Adopting the established technologies of one industry to develop innovative products and services in another industry is ultimately the cornerstone of a breakthrough in a new offering in today's business society, although challenges need to be overcome. In building business models for emerging ecosystems, the most critical challenges typically are not at the firm level, but lie at the ecosystem or network level and industry interfaces (Leminen et al., 2014). Changes in industry boundaries and service architectures require the development of value design from an ecosystem business model perspective. Companies are sometimes forced to work on development within a network of partners, which include their customers or even competitors. This implies not only a lead users' approach but also encompasses an entire ecosystem as a facilitator. In the digital world, the one who brings the most developers to its platform wins (Fleisch, Weinberger & Wortmann, 2015).

3.4 Business Models for the Internet of Things: Literature Review

As discussed in the earlier business model section, a firm cannot create and capture value out of an innovative idea or technological development alone: that by itself does not represent any value until it is commercialized in some way via a business model. Even firms owning leading edge technology cannot sustain competitive advantage without a viable business model. However, we cannot rule out that advances in technology have a significant impact on the business model that a company operates (Whitmore, Agarwal & Xu, 2015). Rapid technology advance in a way forces a firm to adjust quickly and to modify business models in order to adopt a market challenge. The characteristics and increasing power of IoT's pervasiveness and ubiquity undoubtedly drive the development of a new business model (Ju, Kim & Ahn, 2016). In terms of commercializing an IoT business, it differs from the traditional firm-centric core competence type of business model innovation. Firms need to collaborate with partners and other companies across industries because of the nature of the IoT ecosystem (Chan, 2015).

In this section, we have investigated a range of twenty-one literatures focusing on business models for IoT, complete list illustrates in Table 3.2. Among these literatures, there are fifteen literatures related to our product/service/manufacture contextual research scope, if we rule out two literatures specific to healthcare, two focused on logistics, one exclusively for smart cities and one for telecom service. These 15 literatures in general are grouped into: 1) research on technology and different IoT technology layers, and what business values bring to business model development which enables additional value that gives rise to more business model innovation opportunities; 2) scholarly attempts seeking to increase understanding of the emerging IoT business model in terms of matching the framework introduced in the previous section; the most prevalent are the business model canvas (BMC) and Gassmann's St. Gallen Business Model Navigator (BMN), where 55 business model patterns were categorized; and 3) research applying various models and approaches that are normally used in the information technology and system design areas: researchers believe that these models can be adopted in IoT to replace the conventional business model innovation framework.

Bucherer and Uckelmann (Bucherer & Uckelmann, 2011) emphasized that the business model for IoT has to derive from value creation in IoT, particularly the elaboration value of information (law of information); service focus instead of product focus opportunities; the principle of revenue generation in the IoT business model; and utilizing Osterwalder's business model canvas (BMC) to illustrate exemplary business model scenarios for the Internet of Things. Chan (Chan, 2015) proposes a framework based on Osterwalder's magic triangle of BMN focusing on who, where, and why, with the intention of addressing how, and then integrating with IoT strategy, tactics, and value chain elements. Dijkman et al. (Dijkman et al, 2015) present a business model framework for IoT application through a literature survey, thus matching real case IoT applications with the business model canvas. A comprehensive study of business models and the Internet of Things has been written by Fleisch, Weinberger and Wortmann (Fleisch, Weinberger & Wortmann, 2015). A Bosch IoT lab white paper, it investigates the economic power of IoT from both business and technology perspectives, followed by a business model pattern matching Gassmann's 55 identified business model patterns. Two critical criteria, value creation and high resolution management, identified as valuable in IoT, are used in a business model pattern suitable for IoT (Fleisch, Weinberger & Wortmann, 2015). IoT enables business processes with different properties when compared with common enterprise service modeling, provides IoT-aware process challenges, and contributes to firms' desire to redesign processes based on IoT technology (Haller & Magerkurth, 2011). Ide et al. (Ide et al., 2015) applied a lean design methodology to business models and applied it to IoT business model development. The authors repeatedly used design business model hypotheses in their research, by means of which corporate businesses can create new business value utilizing IoT, mainly focused on the value of revenue generation in a lean design. A generic business model framework for IoT through literature analysis and interviews follows a test framework in real-world case studies under the business model canvas (BMC). The findings suggest that capability for data analytics is an essential element of IoT service (Ide et al., 2015). Keskin and Kennedy (Keskin & Kennedy, 2015) believe that in order to achieve the highest profit, firms should redesign their service business models around externalities across markets that link through platforms and be specific about which markets to serve. Their research focuses on a number of business service models that link four sides of a market, and compare the advantages and disadvantages of network externalities generated by IoT in each model. Similarly, Keskin, Tanrisever and Demirkan (Keskin, Tanrisever & Demirkan, 2016) examine the opportunities and challenges of different business models in IoT-enabled markets and provide a basic roadmap to managers for sustainable growth. In the long run, manufacturers may need to move to a fully integrated business model. Kralewski (Kralewski, 2016) applied Gassmann's 55 business model patterns and concluded that 33 models can be applied to the Internet of Things based on the magic triangle definition. Lai, Jackson and Jiang illustrate that manufacturing firms establish an advanced service business model by utilizing advanced IoT technology, helping firms shift to service-dominant business: a single in-depth case study was examined. Leminen et al. (Leminen et al., 2012) suggest a four box framework for IoT business model analysis which is adapted from Osterwalder's business model canvas. They consider business model canvas thinking useful for the endeavor due to it suggested value proposition, customer, infrastructure, and financial perspective as the basic elements of business models. They consider the complexity of the IoT ecosystem and closeness to customers as the two foundational dimensions in the framework to analyze the diverse aspects of IoT in a 2X2 matrix framework for business model design. Li and Xu (Li & Xu, 2013) define the IoT business model as a multidimensional structure composed of technology, industry, policy, and strategy, four dimensions based on the multiple open platform model to design an IoT business model. Turber et al.'s (Turber et al., 2014) research is the first to propose that service-dominant logic provides the right perspective when applied to a business model design in the IoT environment. Fundamentally different from the traditional business model in the IoT environment are value co-creation collaboration within the ecosystem, service-centered or solution revenue generation instead of product selling, operant resource integration, and capitalized value of shared information. Westerlund, Leminen and Rajahonka (Westerlund, Leminen & Rajahonka, 2014) investigate challenges pertaining to business model design in the emerging context of IoT in relation to two underlying trends: 1) the change of focus from viewing IoT primarily as a technology platform to viewing it as a business ecosystem; and 2) the shift from focusing on the business model of a firm to designing an ecosystem business model.

From the descriptive statistics at Table 3.1, the most applied theory and framework are Osterwalder and Pigneur's business model canvas (BMC), which accounts for 47 percent (7 of 15) of literatures we reviewed, service-dominant (S-D) logic, which accounts for 27 percent (4 of 15), and St. Gallen Business Model Navigators (BMN), with 55 business model patterns accounting for 27 percent (4 of 15), they are not mutually exclusive. From the business patterns discussed in these literatures, the majority of papers mention that IoT can enable a product-focused company to move toward innovating a service-centric or service-enabled business model, with IoT technology value co-creation becoming critical when designing an IoT business model due to a firm being unable to work alone and design a business model based on its own core competence and firm-centric nature under the complex IoT environment. Instead, working with stakeholders to co-create commercial value is essential and critical to the development of a win-win ecosystem business model, the end purpose being to maintain a longer-term relationship with clients or stakeholders. Many literatures also emphasize the criticality of resource integration under the IoT business model, these resources being both intangible (core competence, creativity, information, partnership spirit, knowledge, and skills) and tangible (hardware, software, applications) from different actors, and equally important under the complex ecosystem environment. Please refer to Table 3.2 for more detail abstraction of each study.

Table 3.1 Descriptive statistics of literature review

Descriptive statistics - Literature Review	**number of studies**	**%**
Theory Applied		
Business Model Canvas (BMC)	7	47%
Business Model Navigator (BMN)	4	27%
Service-dominant logic	4	27%
Business Patterns		
Service-centric business model	10	67%
Value co-creation	8	53%
Ecosystem business model design	9	60%
Value of Information and Data	7	47%
Resource integration (tangible and intangible)	8	53%
Maintain long term relationship perspective	7	47%

Table 3.2 Summary of IoT business model literature review.

AUTHORS	TITLE	PATTERNS	SEGMENTS	THEORY
Bucherer & Uckelmann, 2011	Business models for the Internet of Things	Service as new type of business in IoT (service-centric), value-focused perspective from end users' involvement (value co-creation), information as major source of value creation, IoT value partnership (ecosystem), integration of different actors (resource integration),	Physical products & services	BMC
Chan, 2015	Internet of Things business models	Service-dominant logic, value co-creation, value network and ecosystem, maintain long term relationship business model, information driven value chain	Products & services	BMN and S-D Logic
Dijkman et al., 2015	Business models for the Internet of Things	Survey reveal most important building blocks in business models are value proposition, customer relationship and key partners (ecosystem)	Manufacturing & supply chain	BMC
Fan & Zhou, 2011	Analysis of the business model innovation of the technology of internet of things in postal logistics	Value of real-time information, resource integration from all actors	Supply chain - logistics	
Fleisch, Weinberger & Wortmann, 2015	Business models and the Internet of Things	Integration of users and customers (value co-creation), service orientation, value of data, long term business relationship (digital add-on, digital lock in, remote usage and condition monitoring…), challenges on IoT partnership (IoT ecosystem)	Both digital and non-digital industries	BMN, BMC and S-D Logic
Glova, Sabol & Vajda, 2014	Business models for the internet of things environment	Integration of products and services, capitalized value of information, IoT collaborative environment (ecosystem) with value co--creation with customers and stakeholders	Health care	BMC
Haller & Magerkurth, 2011	The real-time enterprise: IoT-enabled business processes	Service-oriented architectures and processes under IoT, data as critical elements of value (real-time)	General industry	
Ide et al., 2015	A lean design methodology for business models and its application to IoT business model development	Applied to service business of traditional manufacturing (service-centric), value creation from technology and create value for customers (value co-creation), IT value matrix with partnership (IoT ecosystem)	Manufacturing	BMC
Ju, Kim & Ahn, 2016	Prototyping business Models for IoT service	IoT service business model, IoT ecosystem, actors resource integration	Service	BMC
Keskin & Kennedy, 2015	Strategies in smart service systems enabled multi-sided markets: business models for the Internet of Things	IoT reinforces the integration of products and service business model, value creation to all sides of market instead of consumers only, maintain long term sustainability, data provide a critical role no matter chargeable or free of service.	Manufacturing	
Keskin, Tanrisever & Demirkan, 2016	Sustainable business models for the Internet of Things	IoT enhances service for durable goods sales, resource integration between software provider and manufacturers, maintain long term relationship with customers for durable goods manufacturers	Manufacturing	
Kralewski. 2016	Business models of Internet of Things	Each agent has its own business model (IoT ecosystem) and resource integration (focus on skill and knowledge)	General industry	BMN
Lai, Jackson & Jiang, 2016	Shifting paradigm to service-dominant logic via Internet-of-Things with applications in the elevators industry	Transition to service-dominant logic, maintain long term relationship with customers, value co-creation, resource integration and working with partnership (ecosystem), data as a critical value co-creation with partners	Manufacturing	S-D logic
Leminen et al., 2012	Towards IoT ecosystems and business models	IoT ecosystem is the core of business model creation, value co-creation with actors, resource integration inside and outside of firms, product and service integrate with information, principle in service context (service-centric)	Manufacturing	BMC
Li & Xu, 2013	Research on business model of Internet of Things base on MOP	Resource integration from multiple platforms (technology, industry, policy and strategy)	General industry	
Liu & Jia, 2010	Business model for drug supply chain based on the internet of things	Value creation and resource integration among actors	Health care	
Perera et al., 2014	Sensing as a service model for smart cities supported by internet of things	Service-centric IoT business model, resource integration for service, economic value of data	Smart cities	
Qin & Yu, 2012	Research on the internet of things business model of telecom operators based on the value net	Customer-centric, resource integration, information sharing and collaboration	Telecom Service	
Sun et al., 2012	A holistic approach to visualizing business models for the internet of things	Resource integration and value chain, IoT partnership (ecosystem)	Supply chain - logistics	BMC
Turber et al., 2014	Designing business models in the era of Internet of Things	Integration of partners giving rise cross-industry ecosystems, apply the S-D logic into key artifacts, value co-creation with customers, value network and partners, resource integration and multi-partner collaborations	Non-digital products	BMN and S-D Logic
Westerlund, Leminen & Rajahonka, 2014	Designing business models for the Internet of Things	Ecosystem business model, resource integration, monetize value of information, long term relationship building	General industry	BMC

3.5 Guiding Principles for Designing IoT Business Models Aspects from Manufacturing Firms

This paper does not intend to provide a framework or model design for IoT business models; instead, instead is to propose core guiding principles when designing a business model for IoT for manufacturing firms, and hence elaborate what are the major differences compared with designing conventional business models. Following the above intensive and systematic review of literature on IoT business models, the literature commonly reveals a certain business patterns of perception of IoT business model development (see Table 3.1 and Table 3.2). Together with study of IoT real world applications and an understanding of IoT technology advancement and its potential value, this section is go deeper into each of the business patterns. By adopting these guiding principles from a theoretical point of view, we aim to provide contributions for manufacturing firms when attempting to design innovative business models adopting this emerging technology, inspiring firms to encompass additional thinking compared with the conventional business model framework.

3.5.1 IoT Promotes a Service-Centric Business Model

Many of the information technology (IT) influenced business models, regardless of the technology from which they emerge, follow the trend of service orientation, a solution with a product and service integration business model (Fleisch, Weinberger & Wortmann, 2015). IoT interacts with machines or humans, enabling a company to shift the paradigm from a goods-dominant business model to a service-dominant business model which integrates goods and service to offer a value co-creation solution. Regardless of whether it is providing an additional service by integrating resources in order to promote goods selling or adding on value by selling a service-based solution, the key is treating service as the center of the business model innovation. One feature of IoT is the fact that the service portion of the business model outlined is always information rich and digital in nature: digitalization that extends into the product itself must of necessity lead to an additional service orientation. There are exemplary service-centered business model scenarios for the Internet of Things—for instance, a shift from providing products to providing a service, called ‘products as a service’ (PaaS), and more manufacturers follow this trend to increase competition through low cost manufacturing (Bucherer & Uckelmann, 2011). Another example is the focus on providing customers with a way to mine their own insights to choose their own adventures, a type of business model called ‘data as a service’ (DaaS). More specifically, providing useful information as service providers is ‘information as a service’ (IaaS), which creates new business opportunities for measuring and billing information. Other service-driven businesses from IoT include providing real-time business analysis for decision making—‘answer as a service’ (AaaS)— which hinges on a value proposition from supplying large amounts of processed data with the idea that the client’s job-to-be-done is to find answers or develop solutions for its customers. As a summary, we suggest that the key feature of the Internet of Things enabling the service portion of the business models is that it is always digital in nature;

hence the theory and practice of service orientation must be critically examined and expanded as necessary against the backdrop of the characteristics of a digital service (Fleisch, Weinberger & Wortmann, 2015).

3.5.2 IoT Facilitates a Value Co-creation Business Model

The essence of a business model is to create and capture value and, traditionally, value has been created within a firm's core competences with minimal interaction with customers during the development or even the delivery process. The Internet of Things makes it possible to incorporate and interact with customers in any phase of the value creation process; a common view of co-creation is that value is created by collaboration and facilitated by technology, before people and organization. The technology has a direct influence on the way value is determined; thus, when a specific IoT technology is integrated with other resources, value is uniquely and phenomenologically determined, as technologies are repeatedly combined or integrated with other operant resources (Akaka, & Vargo, 2014). IoT contributes to the reconfiguration of resources and services to create a new relational network facilitating customer participation in value creation by virtue of interaction with smart objects and embedded sensors. Such technologies enable access to and adaptation, selection, and integration of resources in a continuous process of value co-creation (Tommasetti, Vesci & Troisi, 2015). The fundamentals of the Internet of Things lie within the idea that the network of things can intelligently think for itself. This part of the value creation process is all about taking advantage of the possibilities and using the Internet of Things as a co-creative partner, in the same manner that co-creative collaborative projects are managed today between people using technology as an enabler (Mejtoft, 2011). When given the possibility to co-create in harmony with connected things, both in parallel and independently, a wider flexibility in the development process will be reached. Essentially, the concepts of value co-creation and collaboration, along with the emerging Internet of Things, have been highlighted and reinforced as important trends for future business model development (Bughin, Chui & Manyika, 2010).

3.5.3 IoT Strives to Maintain a Long-Term Business Relationship Business Model

IoT, by linking the device at the customer's premises and the company's centralized cloud or in-house data center, is a way to build a connecting relationship, at least in the machine-to-machine context (Sampson, 2010). Further relationship establishment from machine to machine, machine to human, and human to human is defined by the business model the company would like to deploy. As a huge amount of data accumulates in real time or on an interval basis, this creates an opportunity to build the mutual benefits of sharing valuable information around stakeholders. Thus add-on services and co-creation solutions can be provided and can enhance the handshake lock for customers, making it difficult for them to jump ship, therefore purposely designing a long-term relationship business model regardless of whether on a recurring pay basis or free of service, unless poor service is rendered or information from the IoT is not effectively used. Literatures reveal that monetizing an IoT business model is to design a business model from customers' eyes, meaning the establishment of value co-creation around the technology with clients or stakeholders. This co-creation value concept of business establishment will enhance the value of the co-existing relationship and that between firms and customers, hence maintaining the long-term business model based on solutions or analytic information tailor-made to meet specific customer requirements. Thus it is claimed that one of the fundamental benefits of IoT and the key difference compared with conventional business model innovation is building a long-term business relationship model instead of just focusing on a one-time value exchange.

3.5.4. IoT Business Models Should Capitalise on the Value of Information

Traditionally, data are recognized as an asset for internal usage. Companies today consume a growing number of organizational resources and investment for data capturing, storage, processing, and maintenance. However, the value of data conversion to useful information in general is not financially recognized in balance sheets, nor even possibly a revenue generator. As technology advances, data can be collected and analyzed in more efficient and cost effective ways. A company should reconsider its position, asking 'what data can we analyze today?' followed by 'how could we provide useful data to the client in order to promote our products/service?' and 'how might we sell the data?' While designing the IoT-driven new business model, a company should reposition itself from a more innovative angle by looking at ways to monetize big data collected from smart devices, particularly real-time basis data, as a new revenue stream rather than an add-on supplementary service. Thus data with knowledge converting to information by itself may become a major source of value creation and proposition, and so a source of value co-creation between a company and its customers. This includes information only made possible through IoT technologies, as well as existing information on physical products [Bucherer & Uckelmann, 2011). IoT makes information collection much more efficient on a real-time basis: with sophisticated big data analysis, firms can develop an information base offering a business model, hence integrating the information stream with physical products and the money stream. Moody and Walsh (Moody & Walsh, 1999) define seven laws of information, explaining the specifics of information compared with other assets. From these 'laws', we can deduce approaches to value co-creation and adopt conceptual value of information in the Internet of Things business model innovation. These 'laws' tell us that: 1) information is shareable and can be shared with others without loss of value; 2) the value of information increases with use and does not provide any value if it is not used at all; 3) information is perishable and depreciates over time; 4) the value of information increases with accuracy; 5) the value of information increases when combined with other information; 6) more information is not necessarily better; and 7) information is not depletable (Moody & Walsh, 1999). An innovative and sustainable IoT business model is as pervasive and sought after as it is elusive. We suggest that IoT may or may not directly generate value of information, but definitely acts as an enabling technology, providing better information capabilities to achieve better opportunities through reinvention of the classic business model.

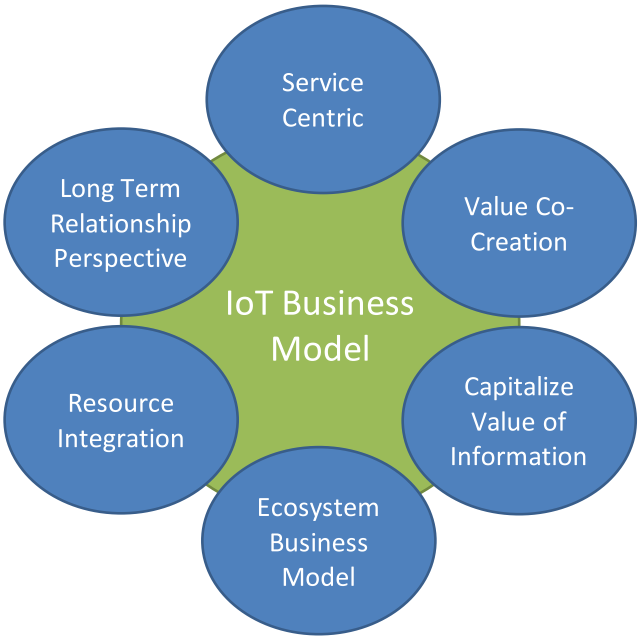
3.5.5 IoT Business Model Reinforces Resource Integration

In designing an IoT business model, a company is not able to operate alone, particularly where evolving, fast-changing, advanced technology is involved. These technologies and the surrounding network facility may not lie in a company's core competence and may involve significant investment. To this extent, a company needs to co-create value with not only internal but also external resources, as the prevalent resource-based view suggests that resources include both tangible and intangible resources (Barney, 1991), and S-D logic further elaborates resources as 'operant' and 'operand' (Vargo & Akaka,2009). The primacy of operant resources is established, defined as those that act upon other resources to create benefit, such as knowledge, competence, experience, and so on, over G-D logic's focus on operand resources, which must be acted on to be beneficial, such as natural resources, goods, and money (Constantin & Lusch, 1994). That is, operant resources, such as knowledge and skills, are the underlying source of value to sustain a competitive advantage over others; this fundamentally transforms the traditional thinking that value occurs in exchange for operand resources. It is suggested that the integration of operand and operant resources is fundamental to the co-creation of value under S-D logic (Ballantyne, Williams & Aitken, 2011). These resources are in a way co-creators when designing an IoT business model: how effectively a company can integrate these resources will decide whether the business model will be operated successfully.

3.5.6 IoT Business Model Reflects Business Ecosystem

As discussed above, regardless of how sophisticated an IoT business model a company would like to deploy, it will evolve more or less different level of partners; therefore, the core of an IoT ecosystem refers to the interconnections of the physical world of things with the virtual world of the internet, the software, hardware, and cloud computing platforms, and the standards commonly used for enabling interconnection (Mazhelis, Luoma & Warma, 2012). From a business ecosystem perspective, Moore (1993) defines a business ecosystem as “an economic community supported by a foundation of interacting organizations and individuals”. A business ecosystem includes the network of buyers, suppliers, and makers of related products or services. Besides the ecosystem’s core business consisting of the firms delivering the goods/service along with their customers, market intermediaries, and suppliers, the business ecosystem also includes the owners and other stakeholders of the core, as well as regulatory bodies and competing organizations. Moore (Moore, 1993) argues that the leadership of companies has a strong influence over the co-evolutionary processes: the operation of the system cannot be understood by studying its parts detached from the entity. Thus an IoT ecosystem of co-creating actors is established: essentially, every actor in this IoT ecosystem needs a distinct business model itself to serve its clients, and all co-exist together and share the value that the final customer is willing to pay. Therefore, firms needs to reposition themselves when designing business models for IoT due to the fact that an ecosystem business model is a business model composed of value pillars anchored in ecosystems and focuses on both the firm’s method of creating and capturing value and any part of the ecosystem’s method of creating and capturing value [Leminen et al., 2012; Westerlund, Leminen & Rajahonka, 2014]. We argue that a viable business model for IoT should change its focus to an ecosystem approach to doing business and, if it uses business model design tools that consider the ecosystem nature of the IoT rather than emphasize an individual company’s self-centered objectives, it will move toward a common ecosystem goal instead of different goals for each of the stakeholders in the ecosystem.

Figure 3.1 Guiding principles for designing business models for the Internet of Things.



In summary, we offer these guiding principles from a theoretical perspective along with managerial implications for practitioners to truly reflect the need for a business to design a viable business model under the IoT environment. We believe that with these guiding principles, it is possible for a product focus manufacturing firm to develop a service business model from both a conventional core-competence and an advanced technology perspective, as summarized as Figure 3.1.

3.6 Exemplary IoT Service Business Model in Manufacturing Firms

Hereby three IoT business model real-world exemplary cases are introduced in order to construct an interpretation of the proposed guiding principles. The cases selected are all manufacturing companies that traditionally focus on designing and selling innovative products, further developing their service business originally to provide after-sales for the purpose of promoting goods. The last few decades have seen a transition from product focus back up with after-sales service, gradually moving toward a solution business model with an integrated product/service offerings, onto a more service-centric business model where physical products are seen merely as means of distribution of service. Now, these companies are proactively adopting IoT technology in their solution business and hope to provide a more attractive business model to their clients. These practical cases aim to examine the guiding principles this study proposed above with the business model currently deployed in the real-world applications.

The data collected for this research were obtained from a number of sources. Firstly, information was collected mainly from companies' publicly available documentation and web site information. Secondly, semi-structured interviews were conducted with company leaders, interviews varying in length but typically lasting for one to two hours. The objective was to gain insights into this contemporary phenomenon to understand what criteria a company considers when designing IoT business models. Thirdly, we interviewed various IoT vendors from a digitalization consultant company that helps firms to integrate IoT resources, sensors hardware manufacturers, and a software company that is contracted to develop a user interface application to facilitate more friendly and effective shared information.

Industrial Scientific (www.indsci.com) is a global leading precision gas detector hardware manufacturer mainly operating in the mining, oil refinery, environmental, and hazardous industry. In recent years, the company has shifted its business model gradually from selling products to providing a solution of service. In its vision, it claims that providing great products and services is not enough, but it aims to provide customers with data that give them control over all risks in their operations. The data, known as leading indicators, help them to see problems before they happen and give customers the opportunity to make changes and save lives. The company has pioneered this concept in gas detectors with iNet. Its sister company, Predictive Solutions, is doing the same with safety observations and inspections. When customers have data that include safety equipment and human behavior, they are better equipped to eliminate death in their workplaces.

The newly promoted iNet service adopting IoT technology covers: 1) instrument maintenance: schedules instrument bump tests and calibrates automatically; it will also detect a malfunctioning instrument and send replacement units from the company; 2) information: provides required records on demand; eliminates the prone-to-error task of manually maintaining records; 3) field visibility: understands the instrument being used and uses information to proactively correct poor use behaviors. The idea of the iNet offering was originally co-created with their long term clients by understanding the challenges from their clients, these challenges firstly including difficult justifying what kind of detectors they really required at first; secondly, even purchasing the right equipment and learning to use it in proper way became challenging due to clients being in their own mining or refinery business; thirdly, the highly sophisticated and precision equipment needed to be regularly maintained and calibrated in order to ensure the level of precision: maintaining the equipment at widespread locations was physically impossible, and how was the equipment to function properly and when it needed to be maintained? Finally, collecting and analyzing data needed special knowledge and skill; should the client invest both tangible (investment, assets and employee) and intangible (knowledge and skill) internal resources?

The offering of iNet uses the regular annual total solution fee to cover the entire service which replaces the traditional buying of pieces of equipment plus additional post-sales maintenance fees. The service includes providing the right magnitude of equipment, maintenance (remotely or on-site), data collection, and analysis. The fee structure is based on real requirements on an actual basis; key factors are the customer-centric and service mind-set, the success of which is based on how the company can help the customer to do their job better. This new business model enables efficient and effective use of instruments without redundancy. From the customer side, it is a cost-effective solution that has removed the hassle of managing a gas detection fleet and has made employees safer; they can focus on their own core business. From the company perspective, it will use the instruments more effectively, locking in a long-term win-win relationship with customers and operating a value co-creation chain as well as more integrated resources to better serve customers.

In this case, we recognize the paradigm shift from goods selling to service-oriented; the equipment itself is part of the service provision. A hardware manufacturer even promotes to the customer “do not buy gas detection instruments: we will take care of your instrument and let you focus on your core business.”

Ingersoll Rand Trane Air Conditioning (www.trane.com) is one of the world leaders in air conditioning systems, services, and solutions. Trane’s mission is to control the comfort of the air for people in their homes and in many of the world’s largest and most famous commercial, industrial, and institutional buildings. The company offers a broad range of energy-efficient heating, ventilation, and air conditioning (HVAC) systems, dehumidifying and air cleaning products, service and parts support, advanced building controls, and financing solutions, applying its expertise in environmental technology and energy conservation to make a difference in energy efficiency around the globe.

Trane promotes energy solutions to retrofit and upgrade antiquated HVAC and pneumatic controls for inefficient building and industrial air conditioning systems, these aged systems resulting in high energy usage and comfort issues throughout the building. Trane provides special customized solutions for clients seeking to reduce energy and operational costs and to take advantage of rebates from local utility companies, as well as to better align with an energy sustainability program. This service-oriented solution includes complete assessment of energy efficiency, using Trane Energy Optics to analyze the inefficient root causes, validating and prioritizing energy conservation measures (ECMs). Energy Optics provides a low cost, rapid method of analyzing building performance using smart sensors, meters, and real-time weather data to focus on energy use patterns and behaviors that encompass equipment, controls, energy management, lighting, and services.

This energy conservation focus program enables clients to generate significant energy saving to cover the upgrade investment. Trane can even provide a performance guarantee to make sure billing is based on the performance of energy saving by period. By installing sensors and actuators all over the system, integrated with Trane’s unique building automation system (BAS), it ensures that all equipment is optimized for maximum savings. Building operators can access their BAS from any device on the web or any mobile device, monitoring equipment, making set point changes, and managing alarms. Trane’s wireless communicator eliminates the need for communication wires between the system controller, unit controllers, and zone sensors, making installation easier. The wireless solution is self-repairing; redundant mesh technology maintains communication, rerouting signals around obstructions. These analyzed dashboards provide key information to review key data points, facilitate analysis, and help clients develop energy strategies to control costs to achieve targeted energy saving.

Trane's energy solution business model is based on highly sophisticated resource integration from hardware, software, application, special knowledge, and skills, together with advanced IoT technology—in other words, an ecosystem around HVAC with all stakeholders. From clients' perspective, expected saving from energy consumption can well justify the investment; though a value co-created long-term contract is expected, due to pay back, investment may not be recovered within a short period of time. By building a long-term relationship business model, other business opportunities can also be established, including (but not limited to) repair, spare parts, and other services.

KONE Elevators (www.kone.com), headquartered in Helsinki, Finland, is one of world's leading companies providing solutions for the installation, maintenance, and modernization of elevators and escalators and the maintenance of automatic building doors. KONE is one of the top firms globally in the manufacture of evaluators and escalators, and one of the world's most innovative companies. The company's service philosophy is reflected in its trademark 'people flow', which refers to its market offering that moves people within and between buildings with the help of elevators, escalators, moving sidewalks, and automated doors. One of the company's competencies is to optimize the flow of people through sensors and simulation techniques to provide people flow information to the client and hence provide an innovative service, optimizing the flow of people through and between buildings, instead of just selling equipment (Greer, Lusch & Vargo, 2016).

KONE adopts the latest digitalization technology to develop its IoT platform service business model, using real-time data and analytics as preventive maintenance gets smarter. It also means improving customer experience through real-time transparency, or it can mean sustainable smart building, making better use of energy and resources. For users, it signifies a better, personalized experience through the whole elevator and escalator journey. The company has announced its intention to establish an independent organization focused on digitalization solutions, innovate solutions focused on people flow analysis. It is attempting to master people flow in a more effective manner, to adopt a 'digital culture' and co-create a new solution offering together with customer and partners.

The vision is to innovate a business model that creates a new revenue stream, embracing the latest digitalization technology in selling solutions based on customers' specific requirements: it is a value co-creation model offering everything the customer needs to resolve a people flow issue.

One of the projects as a practical application, the company is undergoing a new service offering with partners that applies the latest technology, the IoT, enabling devices to be installed in lifts linked to the company's remote monitoring center through the mobile network on a real-time basis. The data transmitted from lifts at remote locations will provide instant information to the cloud server. With fast cloud computing technology equipped with sophisticated data modeling, valuable information will be sent immediately to the company's remote monitoring center for the purpose of detecting any malfunction or potential control system or component failure; such an occurrence will trigger follow-up decision-making to resolve the issue either remotely (machine-to-machine context) or through phone calls or dispatching service technicians to the job site. This project will also integrate the existing company field mobility system in which all service technicians already have a smartphone device on hand, providing their daily working schedule and contents, a location positioning service, spare parts ordering, and the most critical online and offline training modules with regular updates, which will enhance their knowledge and skills with technical tips, fact sheets of malfunction root cause, and short learning modules. During the design of a proof of concept, the company applied a value co-creation design process to gather different sources of input from all its stakeholders. These stakeholders participated in the project collaboratively and were not limited simply to value-in-exchange (paying the bill in exchange for a service) or value-in-use (who will use the service). They also need to receive relevant shared information on the project in a real-life application for their own network for decision-making and actions, and this value-in-context needs to be co-created from a longer term perspective.

Case Findings

This study aims to provide guiding principles wherein a firm will consider these guidelines when it is intending to transition to a more service-oriented business model by adopting the Internet of Things. Though these guidelines are derived from theoretical studies, together with specific characteristics and the expected economic value of the IoT, we believe they provide appropriate prospects to demonstrate a disruptive technology-based business model which may itself provide leading edge or first mover advantage. However, key is how these business models can really commercialize or monetize.

The three exemplary firms selected, which are all traditional manufacturing companies providing both products and services to their clients over decades, tested the guidelines we proposed from a theoretical perspective, as summarized in Table 3.3. We noticed that all these firms recognized the criticality of the trend toward innovating a service-centric business model while producing a focused existing business model was becoming more commoditized and price competitive. The service itself can be an independent business, or it can operate together with the product to construct a solution business. It is essential to provide the right value proposition to cater for a client’s needs, helping the client to better serve its customers, a true value co-creation framework. IoT technology advancement opens up business opportunities for them to redesign their way of doing business with their clients and partners, together creating a co-existing value network and ecosystem. The winning pattern for these firms is how successfully they integrate internal and external resources, investing in both operant resources—essentially creativity, knowledge, information, and skills are the key resources—together with (mostly external) technological partners. Resource integration with substantial investment is not aiming simply to sell a product and service in one shot (value-in-exchange), but purposely aims to maintain a long-term relationship perspective with clients, hopefully creating a handshake and lock-in business model that competitors will find difficult to penetrate. Furthermore, one of IoT’s fundamental characteristics is making data collection much more efficient, mostly in a real-time manner: how these companies can utilize these profound data in a key value proposition will decide if clients are willing to pay to use the information to improve their operation or better serve their clients’ customers. All these critical elements are again aligned with the guiding principles proposed for designing a service-centric business model for the Internet of Things.

Table 3.3 Summary Applicability of Guiding Principles.

Guiding Principles	**Industrial Scientific**	**Ingersoll Rand Trane**	**KONE Elevators**
Service Centric	X	X	X
Value Co-Creation	X	X	X
Long Term Relationship Perspective	X	X	X
Capitalize Value of Information	X	X	X
Resource Integration	X	X	X
Ecosystem Business Model	X	X	X

3.7 Conclusion

The IoT technologies connecting the physical world with the world of the internet promise a number of benefits both to potential customers and to the vendors of the solutions. Despite these benefits, the adoption of these technologies is relatively modest at the current stage. The expected rapid adoption of IoT technologies depends on the stability, diversity, and productivity of the business model innovation that is being formed around these technologies. The technological advancement of the Internet of Things itself is currently helping to overcome some of the technical challenges, from standard protocol, robustness, and reliability of the wireless network to maintainability of the engine (cloud computing) for data analytical modelling, security of the entire ecosystem, data integrity and reliability, and providing anywhere and anytime access in a relatively cost effective way. Apart from technical challenges, a number of studies have begun to investigate or intend further to examine how firms can invent a new business model by effectively utilizing this advanced technology and hence create value for the entire business ecosystem.

The goal of this paper is to inspire the understanding of the IoT domain from the business model design perspective. It analyses the role that IoT has played in business models to date, and derives six critical guiding principles for designing service business models for the Internet of Things in manufacturing firms. It hopefully offers a holistic view and may serve as a means to identify new opportunities for business model innovation frameworks and theory. It has investigated related IoT business model literatures and understood their business model angles for IoT regardless of design, technical, or ecosystem lens, and illustrated them with some real-world examples from practical business case studies. These guiding principles promote an IoT service-centric business model. IoT facilitates a value co-creation business model and strives to maintain a long-term relationship business model. An IoT business model should capitalize on value of information, reinforce resource integration, and reflect the value of the ecosystem and network partners. This paper is striving that these six guiding principles serve as the foundation to commercialize a business from a managerial perspective instead of focusing only on the disruptive technology perspective, helping manufacturing firms to design a viable business model in an IoT-enabled environment.

There are many aspects apart from technology challenges on which this paper does not shed light, particularly the key challenges of each of the guidelines. For example, there is discussion still to be had on goods- and service-dominant logic, value co-creation or value proposition, the challenges of data as a revenue generator and big data business model innovation, and the challenges of managing an IoT ecosystem in terms of going for common direction: as a total ecosystem provides service value versus different goals for each of the actors in the ecosystem, building an ecosystem business model can be compared with a firm-centric business model. Each of these areas needs much deeper discussion. This paper also does not intend to go into industry- or process-specific discussions, though our research focuses on traditional manufacturing firms producing goods and provide post equipment sales service in general. Can these guidelines be generalized to all industries without boundaries? Questions remain to be answered and to be more specifically formulated.

Chapter 4 Internet of Things Business Models in Ecosystem Context – Cases of Elevator Services

Abstract: Companies increasingly have to adapt new technology and design new business models to retain their competitive advantage in highly dynamic environments. The increasing pervasiveness of the Internet of things (IoT) has offered great potential in many different areas of application to lead or complement new business models. However, business models based on largely static, single firm or historical information architectures are facing challenges in today's more dynamic environment as new ways of creating value arise across industries and between firms, clients and other stakeholders. Embracing the business ecosystem concept is now becoming critical in order to realize business opportunities or business model potential. This paper focuses on the elaboration of the business ecosystem concept in the IoT business model environment, from both academic and practitioners' perspectives, to analyse how IoT business models are connected to the underlying business ecosystem. We analyse three cases from the elevator industry to explain how different business models are employed in connection with business and IoT ecosystems, as well as their challenges and possible options to overcome these challenges.

Keywords*:* Internet of things; business ecosystem; IoT ecosystems, ecosystem business model

4.1 Introduction

Many real-world Internet of things (IoT) applications have been postulated in many industries: the domain not only covers conventional industrial sectors, but also the consuming industries of everyday life, in which IoT can bring significant improvement, even leading to new business models. IoT, also called the Internet of Everything or the Industrial Internet, is a new technological paradigm envisioned as a global network of machines and devices capable of interacting with each other (Lee & Lee, 2015). It refers to linking the objects of the real world with the virtual world, thus enabling connectivity at any time, in any place, for anything and for anyone. It enables a world in which physical objects and beings and virtual data and the environment interact with each other in the same space and time. Enterprises can utilize IoT to create and capture value by connecting devices integrated with in-house business intelligence applications, traditional enterprise resource planning and supply chain systems, business analytics and decision support systems (Bradley, Barbier & Handler, 2013). The true value of IoT lies in creating an environment in which the crucial information from any of the networked autonomous actors can be shared efficiently with others on a real-time or interval basis (Yang, Yang & Plotnick, 2013). The adoption of IoT technology is rapidly gaining momentum as technological, societal and competitive pressures push firms to innovate. IoT has the potential to disrupt industries through changing products, services and business models, just as the Internet did in the 1990s (Keskin & Kennedy, 2015).

IoT is a broad concept and a consensus has yet to be built concerning a common definition. This paper focuses on conventional manufacturing companies (using elevator services as case studies) expanding their new offering in providing IoT services to generate additional revenue as well as to improve productivity, which essentially can bring value to their clients and other stakeholders. In the IoT service domain, information is gathered from various sensors through networks, processed for information analytics and optimization in a central service (cloud computing) and finally suited to decision making and control of the targeted aspects. These services are expected to find users in a wide range of smart applications related to home, factories, energy, healthcare, logistics and maintenance and could revolutionize society. Especially, there are several initiatives aimed at promoting IoT services in the industry sector, including “Industry 4.0” in Germany, “Made in China 2025” in China, the “Industrial Internet” in the United States (US) and the “Industrial Value Chain Initiative” in Japan (Uchihira, Ishimatsu & Inoue, 2016). In particular industry 4.0 foster automation and data exchange over cyber-physical systems, internet of things, cloud computing and cognitive computing, which communicate and cooperate each other and with human in real time both internally and across organization service offered and used by actors of the value chain (Wollschlaeger, Sauter & Jasperneite, 2017). Hermann et al. proposed six design principles for Industry 4.0 implementation; they are interoperability, virtualization, decentralization, real-time capability, service orientation and modularity. which rely on full transparency of communication among physical things, physical and virtual network (Hermann, Pentek & Otto, 2016). Some examples for Industry 4.0 are machine which can predict failures and trigger maintenance processes autonomously or self-organized logistics which react to unexpected changes in production, as well as services through machine to machine interface. All these effect needs everything is interlinked with everything else, it is a fair assumption of driving force behind IoT (Sarvari et al., 2018). However, in the modern global, competitive and collaborative business environment, an IoT business model must be designed as a business ecosystem due to the fact that no firm owns content, networks, software and hardware in the same spectrum. Therefore, business model design considering the business ecosystem is required to bridge the gap between expected value and the firm’s existing core competence or innovative capability (Mäkinen, 2014).

The central elements of IoT include the concepts of the ecosystem and the business model. The business ecosystem concept was originally presented by James F. Moore in 1993 and stems from the notion that innovative businesses rely on different resources, including capital, partners, suppliers, customers, or even authoritative bodies, with which they create co-operative networks (Moore, 1993). In addition to the business ecosystem as such, there are other spectrums in the IoT ecosystem environment: there are different levels of ecosystems from the technical or process perspectives, including platforms, protocol standards, cloud computing, devices and applications related to hardware and software. The business ecosystem and IoT technological ecosystem co-evolve in combination to create a commercialized business model, leading to clients' choice concerning the platform of the ecosystem.

There is a considerable body of literature articulating that IoT will enable traditional manufacturing firms to innovate in developing new business models. This literature indicates that technological advancement and product or service innovation alone may not sustain the life of a business unless a viable and sustainable business model exists. A viable business model will play an important role when it comes to leveraging the opportunities of new technological innovation, ensuring that it matures and is cost-effective. However, business models based on largely static, firm-centric core competences or historical information architectures are facing challenges in today's dynamic environment as new ways of creating value arise across industries and between firms, clients and other stakeholders. Furthermore, adapting the established technologies of an industry to develop innovative products and services is ultimately the cornerstone for breakthrough business model development and embracing the business ecosystem concept when adopting the IoT technology ecosystem may facilitate novel applications and business models.

In this paper we aim to analyse the business model from both the business ecosystem and IoT ecosystem perspectives, specifically applied to new service IoT offering in elevators industry. The objective is to shed light on existing and potential models by discussing them in connection with the underlying ecosystems in designated domains. This study contributes to recent IoT business model studies, adopting the lens of the IoT ecosystem perspective, which advises firms to embrace the business ecosystem concept when designing new offerings in elevator industry in China based on IoT technology. We intend to:

1. Discuss the relationship between the business model and IoT ecosystem

2. Utilize elevator service case studies to illustrate the IoT business model in the ecosystem context
3. Describe the challenges of IoT business model development

This paper begins with a review of the theoretical foundations of business ecosystem and business models, we then construct a discussion of the IoT business model in ecosystem context based on different frameworks. This is followed by the use of real-world IoT business model cases as exemplars in the elevator industry to illustrate similar IoT technological application in the same industry based on different business model approaches under the ecosystem environment. Finally, we review our key findings and draw conclusions regarding the challenges of IoT business model development and possible solutions.

4.2 Theoretical Background

Research on business ecosystems and business models has gained attention in the literature. However, there is little extent work on the ecosystem business model concept and similarities and differences between various applications. In this section, we identify and discuss the relevant literature in the broader context of the business ecosystem and business model, as well as more specifically with regard to the business model within the ecosystem perspective. We show that the business model embedded in the ecosystem concept is especially well suited given the disruptive technological impact on business model design in recent years, whereas the earlier literature on the business ecosystem generally provides somewhat more multifaceted discussions.

4.2.1 Business Ecosystem

The ecosystem as an abbreviated term for the ecological system in the business context is a notion derived from the biological sciences. Just as biological ecosystems consist of a variety of interdependent species, business ecosystems analogously depict interdependent networks of organization (Mäkinen & Dedehayir, 2012). Business ecosystem theory originated in the work of Moore (1993) and illustrates that successful businesses must attract resources of all sorts, drawing in capital, partners, suppliers and customers to create cooperative networks. Such networks should under the rubric of strategic alliance, virtual organizations and the like nurture the complex business communities that bring innovations to market (Moore, 1993). In these networks, each member contributes to the ecosystem's overall wellbeing and is dependent on other members for its survival. Reciprocally, the survival and success of each member is influenced by the ecosystem as a holistic entity that is in continuous evolution (Iansiti & Levien, 2004a).

At the centre of the business ecosystem, actors in the business ecosystem co-evolve capabilities around existing or new innovations by working cooperatively as well as competitively in the creation of products and services (Moore, 1993; Lusch, 2010; Teece , 2007). Other than traditional partners, such as customers, suppliers and complementors, business ecosystems may also be seen to comprise distributors, outsourcing firms, finance providers, research institutions, regulatory authorities and standard-setting bodies, as well as to some extent competitors when their actions and feedback affect the development of the firm's own products or processes (Adner & Kapoor, 2010; Pierce, 2009). These loose networks of actors in the ecosystem, which together provide related products or services, as well as technological providers and a host of other organizations, are affected by the creation and delivery of the company's own offering (Iansiti & Levien, 2004b). If we analyse further, like an individual species in a biological ecosystem, each member of a business ecosystem ultimately shares the fate of the network as a whole, regardless of that member's apparent strength. However, biologists have observed that natural ecosystems sometimes collapse when environmental conditions change too radically and dominant combinations of species may lose their leadership. New ecosystems then establish themselves, often with previously marginal plants and animals at the centre. This applies to the business environment today when dealing with challenges from the economy, market, new innovation or technological breakthrough; there are clear parallels and profound implications (Moore, 1993; Moore, 1997).

A number of studies have shown similar constructs to describe the ecosystem and generic products and services from the ecosystem perspective, including the "industrial ecosystem" (Desrochers, 2010), "product ecosystem" (Frels, Shervani & Srivastava, 2003), "service ecosystems" (Lusch, 2010) and "technology-based ecosystem" (Santos & Eisenhardt, 2005), or from the perspective of the specific industrial segment or the firm-based, for instance the Internet ecosystem (Zacharakis, Shepherd & Coombs, 2003), Amazon's web service ecosystem (Isckia, 2009), Google's innovation ecosystem (Lyer & Davenport, 2008) and the automotive leasing ecosystem (Pierce, 2009). All these are examples of interdependent networks that centre on respective collaboration (Mäkinen & Dedehayir, 2012). The business ecosystem has the co-evolution value of being able to account for change dynamics and the strategic implications of these changes for member organizations (Moore, 1993). Through the ecosystems approach, firms can analyse either own businesses by considering their suppliers and the partners they collaborate with and at the same time assessing the strength of their competitors with respect to the ecosystems that they are able to produce. Moreover, according to Iansiti and Levien (2004), the presence of hubs makes the network robust to the removal of individual nodes, as long as the hubs remain intact. In contrast, the removal of a hub often results in a collapse of the whole network. Following the biological metaphor, it is suggested that the roles in the biological ecosystem correspond to the strategies of the firms in the business ecosystem, with the most critical roles in the business ecosystem being the roles of the so-called keystone, dominator and niche player (Iansiti & Levien, 2004a; Talvitie, 2011).

4.2.2 Ecosystem Business Models

Consensus on a common definition of the business model has yet to be reached in the management literatures (Zott, Amit & Massa, 2011). However, one early definition that has been widely influential stems from Amit and Zott (Amit & Zott, 2001): "A business model depicts the content, structure, and governance of transactions designed so as to create value through the exploitation of business opportunities". Also, a business model is an organization's approach to generating revenue at a reasonable cost and incorporates assumptions about how it will both create and capture value to benefit enterprises (Brandenburger & Stuart, 1996). Essentially, every company has a business model, whether it articulates it or not. However, complications arise with the most basic questions. What is a business model? What constitutes the firm's business model? Chesbrough (Chesbrough, 2010) suggested that a business model performs two important functions: value creation and value capture. Similarly, Teece (Teece, 2010) defined the essence of a business model as defining the manner by which the enterprise delivers value to customers, entices customers to pay for value and converts payment into profit. Pavie et al. offered a good overview of various business model concepts in their 2013 paper for the ESSEC business school; no matter what market a business organization is competing in, it will – either implicitly or explicitly – create or apply a business model. A business model can be defined as the architecture and mechanism of actual value creation by an organization (Pavie et al., 2013). All these concepts have in common a focus on the rationale for how an organization creates, delivers and captures value.

More detailed frameworks for the design and classification of business models have been developed since the early publications on the topics. Teece (Teece, 2010) defines a business model as reflecting management's hypothesis about what customers want, how they want it and how an enterprise can best meet those needs and be paid. Gassmann, Frankenberger and Csik (Gassmann, Frankenberger & Csik, 2013: Gassmann, Frankenberger & Csik, 2014a: Gassmann, Frankenberger & Csik, 2014b) employ a conceptualization that consists of four central dimensions – the who, the what, the how and the value – in the magic triangle. By answering the four associated questions and delineating 1) the target customers, 2) the value proposition for the customers, 3) the value chain behind the creation of this value and 4) the revenue model that captures the value, a business model can then be established. Based on this magic triangle, Gassmann's St. Gallen Business Model Navigator identified 55 repetitive patterns that form the core of many new business models, having looked at several hundred business model innovators. Alexander Osterwalder (Osterwalder & Pigneur, 2010) introduced the business model canvas in the Business Model Generation Handbook, offering a set of nine interdependent "building blocks", beginning with key partners and key activities, together with key resources, moving on to the value proposition to target the customer segment based on customer relationships and channels and ending with the cost structure and revenue streams defined by the other elements. This business model canvas aims to expand along with the sum of resources and activities which the company organizes and implements in order to provide a specific value for a particular target segment (Kralewski, 2016).

These frameworks developed appear to analyse the related challenges of innovating and implementing new business models in practice (Visnjic & Neely, 2011). In particular, technology can bring about disruptive business model opportunities in terms of the ability to experiment and through progressive introductions of new products or services. Systematic data collection on usage and performance is important in the development of business models (Chesbrough, 2010). From another angle, challenges have also been witnessed in emerging industries with regard to technology, application and organization. It is argued that there is the need for a new business model or novel technology to connect ecosystem stakeholders and initiate a new way of commercializing the business model and technology (Rong et al., 2015). These challenges require stakeholders to achieve interoperability between different levels of the organizations to cope with uncertainties (Gassmann et al., 2010; Rong, Shi & Yu, 2013). Therefore, it is argued that while existing business model templates and frameworks are adequate for examining the challenges faced by single existing organizations (Osterwalder & Pigneur, 2010; Sinfield et al., 2012), they are less suited to analysing the interdependent nature of growth and success among companies that are evolving in the same innovation "ecosystem" (Weiller & Neely, 2013). Traditional industrial-era business models held that competitive advantage was based on product excellence, in-house technological innovation and careful management of scarce resources and supply chains (Carbone, 2009). More recent academic research suggests the need to expand the focus in business models from a single company point of view to an ecosystem perspective (Leminen et al., 2012), particularly in the climate of increasing complexity, with more adaptive technical solutions and changes in the roles of business actors compared to the traditional way of managing partners to support firm-centric value design. Furthermore, companies are seeking new commercialized offerings, shifting the focus from industry-specific applications to applications spanning multiple industries; under such circumstances, the challenges increase substantially (Gassmann et al., 2010). Similarly, Zott and Amit (Zott & Amit, 2010) defined a business model as a system of activities dependent on each other through the focal company and the surrounding network. Adopting the established technologies of one industry to develop innovative products and services in another industry is ultimately the cornerstone of a breakthrough in a new offering in today's business society, although challenges need to be overcome. In building business models for emerging ecosystems, the most critical challenges typically are not at the firm level, but lie at the ecosystem or network level and industry interfaces (Leminen et al., 2014). Changes in industry boundaries and service architectures require the development of value design from an ecosystem business model perspective. Companies are sometimes forced to work on development within a network of partners, which include their customers or even competitors. This implies not only a lead users' approach but also encompasses an entire ecosystem as a facilitator. In the digital world, the one who brings the most developers to its platform wins (Fleisch, Weinberger & Wortmann, 2015).

4.3 Ecosystem Business Models for the Internet of Things

4.3.1 Defining the IoT Ecosystem

The essence of IoT is the interconnection of the physical world of things with the virtual world of the Internet, software, hardware and network platform, as well as the standards commonly used for enabling such interconnections; these may become the core of an IoT ecosystem. Mazheils, Luoma and Warma (Mazhelis, Luoma & Warma, 2012) define the IoT ecosystem based on different focal aspects; (i) connected devices and gateways, including the hardware platform; (ii) the connectivity between devices and the Internet; (iii) the application services built based on connectivity with the common software platform; (iv) the supporting services that are needed for provisioning, assurance and security standards. Within current IoT ecosystems, the number of different vendors providing the components of proprietary platforms, protocols and interfaces at different layers makes them barely compatible, while keeping the prices of such components high. Some of the available technologies could be seen as de facto standards, but no fully open standards have yet been applied successfully in the domain of sensor networking. This puts firms in a difficult situation in terms of managing IoT ecosystems when deploying them with a view to firms' common value.

Mejtoft (Mejtoft, 2011) depicts three layers of value co-creation in IoT, focusing on the co-evolving value-driver perspective of the IoT ecosystem: in the first layer, manufacturing and retailers can benefit from simply tracking objects; the second layer concerns the creation of value through the collection of data that can be used in both industry- and customer-driven value creation; the third layer relates to co-creative IoT partners and value creation at different levels of the IoT ecosystem, with value capture and creation as two main elements of business model constructs. Chan (Chan, 2015) present a more detailed four-layered architecture of IoT in explaining the ecosystem environment from a technical perspective: object sensing and information gathering – the use of smart devices to collect contextual information concerning the environment; information delivery – wireless technology networking; information processing – pervasive services providing big data analytics capability with mostly cloud computing; application and smart service – heterogeneous network performance and computing capability to accommodate users' requirements in support of decision making.

The major challenge for IoT projects in realizing business potential lies in the integration of multiple businesses operating in a collaborative environment. Companies should focus on analysing the business system and its stakeholders (Gambardella & McGahan, 2010). There are many innovative IoT projects that start with a rather unclear or unfocused development track. For many projects, there is no problem engaging in new pervasive information system development, but there is a problem combining this with a new value proposition in such a way that the innovative idea is clear to all stakeholders and allows their own assessment from the profitability and technological feasibility perspectives (Glova, Sabol & Vajda, 2014; Keskin, Tanrisever & Demirkan, 2016).

4.3.2 The IoT Ecosystem Business Model

Smart objects in IoT facilitate novel applications and business models; however, designing a viable business model requires the collection of data automatically and remotely from devices and turning these data into useful information then helps to solve problems and enables the development of embedded services and a revenue model (Leminen et al., 2012). The nature of IoT technology enables the pooling of resources in networks that include multiple nodes and links between the nodes. This means that there are almost endless ways to utilize information and IoT infrastructure (Bucherer & Uckelmann, 2011), Bucherer and Uckelmann further elaborate that information exchange between the nodes in an IoT network and the involvement of all stakeholders in the “win-win” information exchange are the key elements in designing an IoT business model. Therefore, the IoT business model should shift from a cost-centric approach to a value-focused perspective, i.e. from a firm-centric to an ecosystem approach. Fleisch, Weinberger and Wortmann (Fleisch, Weinberger & Wortmann, 2015) further emphasize that IoT bundles diverse technologies and systems together by combining technologies and functionalities. A complex product or service from smaller subsystems can be designed and built independently. This enables a shift in power in the steps that can be executed at the network edge, which enhances the modularization of business processes and empowers decision making in a decentralized manner.

Leminen et al. (Leminen et al., 2012) posit that the central elements of IoT include the concepts of the ecosystem and business model. A framework connecting the various types of IoT business model is built based on the underlying ecosystem; there are two principle axes, the first defining the type of ecosystem from closed and private to open networked and the other the type of customers from business to consumer. In this regard, more mature industry tends to apply a more closed ecosystem and immature industry and newcomers will apply a more open ecosystem. Equally, consumer products tend to favour a more open ecosystem in order to gain platform leadership advantage. Ju, Kim and Ahn (Ju, Kim & Ahn, 2016) also further note that IoT ecosystems are changing from closed private ecosystems to open networked ecosystems. Among the examples they use are that Car2Go services are provided to consumers through a closed private ecosystem, while products and services provided by Google and GE work on open and integrated ecosystems. Nest is trying to make the Nest learning thermostat the centre of smart homes. Home appliances, such as smart light bulbs, tend to be fragmented and controlled by separate applications. As part of an open networked ecosystem, the Nest developer program enables various home appliances, such as lights and washers, to interact with the Nest learning thermostat. By making connections between various appliances, Nest can provide consumers with a seamless and personalized experience. Integrated services reframe the products and services of companies and offer far greater value for consumers (Ju, Kim & Ahn, 2016). However, the degree of openness depends on the maturity of the ecosystem.

Rong et al. (Rong et al., 2015) developed an integrated 6C framework to improve understanding of IoT-based business ecosystems, namely context, cooperation, constructive elements, configuration, capability and change. The context concerns the environmental setting for ecosystem development, cooperation reflects the mechanisms by which the partners interact to support strategic objectives, constructive elements define the fundamental structure and supportive infrastructure of the ecosystem, configuration seeks to identify the external relationships among partners and capability investigates the key success features of a supply network from the functional view of design, production, inbound logistics and information management. Finally, each business ecosystem faces the challenge of change (Rong et al., 2015). Rong et al.'s case studies reveal that the ecosystem tends to be very open at an early stage, in which the focal firm needs more stakeholders to add value to products or the service platform. The focal firm primarily controls the product or service during the business model development stage, but then needs partners (including customers and suppliers) and other third parties to provide support or make modifications, thus refining it with more functional features in the complex IoT environment. Once the ecosystem begins to mature, the focal firm will consider the product/service as a dominant design, suggesting the development of any new business model should be adaptable via an open platform and enabling diverse solutions to allow full utilization of participants' resources and capabilities (Chan, 2015).

We argue that regardless of how sophisticated the IoT business model a company would like to deploy, it will evolve more or less differently depending on partners from both the technical and business perspectives; therefore, the core of an IoT ecosystem concerns the interconnections between the physical world of things and the virtual world of the Internet, software, hardware and cloud computing platforms, as well as the standards commonly used for enabling interconnection (Mazhelis, Luoma & Warma, 2012). From the business ecosystem perspective, we argue that the leadership of companies will have a strong influence over the co-evolutionary processes: the operation of the system cannot be understood by studying its parts detached from the entity. Thus an IoT ecosystem of co-creating actors is established: essentially, every actor in this IoT ecosystem needs a distinct business model itself to serve its clients and all actors together co-exist and share the value that the final customer is willing to pay. Therefore, firms need to reposition themselves when designing business models for IoT due to the fact that an ecosystem business model is a business model composed of value pillars anchored in ecosystems and focuses on both the firm's method of creating and capturing value and any part of the ecosystem's method of creating and capturing value (Westerlund, Leminen & Rajahonka, 2014). In summary, we conclude that a viable business model for IoT should change its focus towards an ecosystem approach to doing business and if it uses business model design tools that consider the nature of the ecosystem of the IoT rather than emphasizing an individual company's self-centred objectives, it will move towards a common ecosystem goal instead of different goals for each of the stakeholders in the ecosystem.

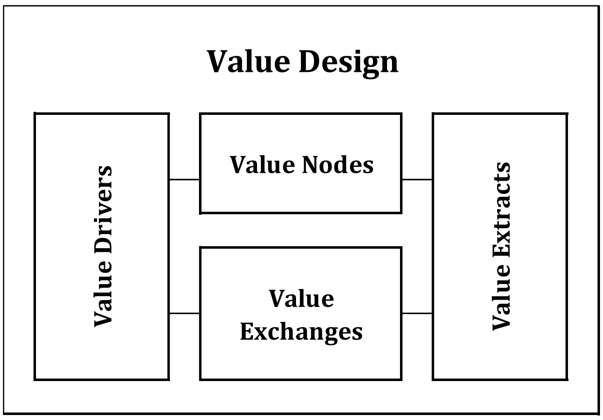
4.3.3 Proposed IoT Ecosystem Business Model Design Framework

Leminen et al. (Leminen et al., 2014) proposed an ecosystem perspective on business models to help understand possible IoT business models and challenges in building them. Their value design framework comprises four pillars: value drivers, value nodes, value exchanges and value extracts. Both a firm's business model and any part of the ecosystem business model can be described in terms of value design, a concept that illustrates how value is deliberately created and captured in an ecosystem with the four value pillars anchored in the ecosystem (Westerlund, Leminen & Rajahonka, 2014, pp. 9-11) as follows:

- Value drivers express the individual and shared motivations of diverse participants to fulfil a need to generate value, realize innovation and make money.
- Value nodes include various actors, activities or processes.
- Value exchanges are flows that describe the exchange of value through different resources, knowledge and information.
- Value extracts refer to the parts of the ecosystem that extract value. This concerns the meaningful value that can be monetized and the relevant nodes and exchanges that are required for value creation and capture. Value extracts make it possible to "zoom in" and "zoom out" in the ecosystem to focus on something beneficial for the business.

In our following case studies, we employ this four-pillar value design framework at figure 4.1 to analyse business models in the IoT ecosystem, based on multiple case studies in similar ecosystems in the same industry using IoT to offer business models in different ways.

Figure 4.1 Key pillars of a business model design tool for IoT ecosystems (Westerlund, Leminen & Rajahonka, 2014, pp. 11)



4.4 Case Studies

The qualitative analysis undertaken in this research was based on a multiple case study research approach in which three companies in the elevator industry in China were chosen. The three companies/cases selected have all adopted advanced IoT technology in their new service-oriented offering, embedding an IoT ecosystem at different levels and commercializing under new business models in a different manner. These cases represent exceptionally interesting examples that illustrate the importance of embracing the ecosystem business model from different angles, as well as the distinct challenges inherent in the IoT ecosystem business model. In investigating these three cases, we adopt the four-pillar value design framework (Figure 5.1), explained in the previous section, to analyse the value drivers anchored in the IoT ecosystem in order to create and capture value through establishing the business model.

The data for this research were collected mainly through a series of semi-structured interviews with the three companies' executives and IoT project leaders. To gain an overview of the entire IoT ecosystem business model, we also interviewed experts from related IoT vendors, including hardware and software providers, portal application developers and cloud service providers, most of them located in China. Furthermore, in within the spectrum of the Chinese elevator industry, authoritative bodies, including government bodies and industrial associations, with a strong influence on the industry and regulation were also interviewed in order to gain a broader view of the studies. In addition to interviews, secondary sources of data were accessed, including companies' public information and exemplar cases demonstrated in their public documentation and websites.

The interviews were conducted as open discussions rather than in the reactive structure of an interview style, starting from asking about participants' roles in the overall IoT design, then about their key contributions and the underlying challenges in this ecosystem, gradually moving from the technical to the more commercialized aspects that are the main drivers of business model design. The interview questions included but were not limited to: 1. What are the main value drivers of the IoT offering in elevator services? 2. Who should be the main beneficiaries in the underlying IoT ecosystem? Who should pay for it? 3. Who are the key actors and what are the key elements or processes when designing an IoT offering for elevator services? 4. What are the challenges related to the IoT ecosystem and business model that might illustrate future trends and development?

4.4.1 Case Background and Analysis

IoT has attracted the attention of actors in the technology and business communities, who are eagerly waiting for its potential finally to be unleashed. In the Chinese elevator industry, seemingly every elevator company has started to introduce IoT offerings focused on connected services for remote monitoring or advanced services. In our case studies, three companies were selected that are aggressively adopting an IoT ecosystem; they have certain commonalities and differences in terms of technology and platforms, as well as degrees of similarity and differentiation in their ecosystems. However, each company has adopted a slightly different approach to IoT business model development based on its own beliefs concerning the specific value design drivers for its clients and society.

Company A is a global leading European-based company that provides solutions for the installation, maintenance and modernization of elevators and escalators. This company has a strong presence in China. In addition to manufacturing elevator equipment in China, the company is aggressively expanding its service business by providing corrective maintenance (on-call services), preventative maintenance (regular interval services) and major repairs and retrofits, all the way up to a full replacement service at the end of the equipment's useful life cycle. The company has a very strong own equipment installation operation nationwide, which is the basis for service opportunities. Therefore, the company is aggressively looking for opportunities to expand its service offering and IoT provides an excellent match in terms of testing the new business model and gaining sustainable competitive advantage. Company A chose to work with a prestigious global IoT and cloud computing player as a major partner from the co-creation of value perspective, developing working relationships and tailoring a Chinese-specific elevator service solution together with local partners; hence, this is a joint effort on the part of the IoT ecosystem to create a new business model. The expected benefits include the generation of new revenue by providing real-time remote monitoring, establishing safety alerts, progressing towards more advanced predictive maintenance services and supplementary benefits covering own spare parts promotion and productivity improvements. Plus, the firm aims to develop a lock-in business model to maintain long-term relationships with customers as a co-creation value driver, in particular providing tailored services to building owners to protect future opportunities concerning major repairs and the full replacement of equipment. This new service offering is targeted at a particular segment, namely those customers who have installed the company's equipment (installed base), irrespective of whether they have scheduled service maintenance under the company's own service contract, or whether their elevators are maintained by other third-party service providers.

Company B is a strong Chinese elevator brand, mainly focused on equipment manufacturing. The majority of the firm's equipment is sold through a distribution channel which entails selling equipment to distributors and services and repairs subsequently being provided by the same distributors. Company B was initially not overly focused on building its own resources and capabilities to service and repair its own machines for several reasons: first, selling the equipment was profitable for a long time, but over the last two years the market price has fallen dramatically; second, China has a famous and strong tradition in building factories globally and Chinese companies have thus focused their attention on manufacturing products, which has been a sound goods-dominant logic (Vargo & Lusch, 2004a); third, the service market is fragmented in China and there is a considerable number of third-party service companies, meaning that the market is very competitive and it is difficult to make substantial profits over the short term – a clear long-term service business strategy needs to be established; finally, labour costs have been increasing over the years, but it is difficult to push service prices higher, making services unattractive from the Chinese company perspective. Nonetheless, the company still initiated an IoT offering working with local stakeholders, strategically expecting to adopt an open platform that would attract distributors to utilize this platform to better serve their customers through the basic functions of remote monitoring, safety alerts, spare parts ordering, equipment health checks and basic equipment quality diagnosis. The technology is limited to equipment design, for instance sensors and detectors built into the elevator drive, inverter and control. By installing a transmitting device, information read from the controller can be transmitted remotely through the cloud to perform remote monitoring and equipment health checks, as well as enabling standard five-party communication (voice and video) capability remotely. As an outcome, the company will have a better product portfolio to push more sales of equipment.

Company C is a well-known Chinese listed company specializing in industrial controls and drives. It is one of the major elevator component suppliers for integrated elevator control solutions, rather than being a traditional “elevator” company. Although it has a wide range of products, from controls and drives to standard industrial automation products and industrial sensors and detectors, the majority of its sales comes from providing integrated control systems to original equipment manufacturers (OEMs) of elevators, both to domestic Chinese companies and those with a global presence in China. In recent years, the firm has proactively provided industrial IoT solutions to the elevator, automobile and crane segments. The company vision is to build an industrial control and IoT standardized protocol with support from the “Made in China 2025” policy. In the elevator segment, drive and integrated control solutions are the centrepiece of elevators as a whole. The company is building a standard IoT platform together with its own control system. It is specializing to penetrate the elevator market together with its sub-contractors and service partners, particularly with regard to upgrades, full replacement and the major repair market. Its business model focuses on IoT as a central element with an open standard platform aimed at persuading customers to upgrade their elevators, while outsourcing other mechanical components (elevator machines, cars, ropes and landing doors) directly from an elevator components company. It is now very aggressive in penetrating the elevator market. The main driving value for this company is to utilize the IoT and elevator ecosystem fully in building a standard operating platform business model from an entirely different angle; although it does not produce elevators in its factories, the target is to establish itself as an industrial leading IoT platform provider.

4.4.2 The IoT Elevator Service Offering and Ecosystem

As described earlier, although these companies may adopt slightly different approaches to the IoT business model based on their own beliefs concerning the specific value design drivers for their clients and society, there are some common value drivers in promoting elevator IoT services constituting the key factors for which actors in the ecosystem are willing to pay:

- Better end-user satisfaction and fewer complaints
- Maintaining the value of assets and prolonging the useful life of equipment
- Improving public safety
- Attaining better transparency in equipment operation information

4.4.2.1 Value Drivers

In terms of value drivers, there are more specific services that each company claimed their clients should benefit from over traditional scheduled maintenance, termed corrective maintenance or reactive maintenance (reference), as follows:

- Real-time remote monitoring of elevator equipment
- Earlier fault detection and alerts on a real-time basis
- Enhanced instance service technician dispatch
- Provision of basic preventive maintenance, repairs or parts replacement through constant equipment health checks
- Offering voice or video communication at remote locations
- Provision of operation analysis and regular reports to all related parties in the business ecosystem through a mobile device portal or direct interface.
- Implementation of user portals to enable clients to understand equipment performance in order to prolong the asset life cycle

4.4.2.2 Value Nodes – IoT Ecosystem

In our case studies, the elevator IoT service offering was divided into two categories of value nodes. The IoT ecosystem is formed around commonly used IoT hardware, software, platforms and standards, based on which the definition of value nodes for actors and activities can be described as follows:

- Data collection device: installed in elevator equipment and connected directly to an integrated control box; this contains a 2G/3G/4G carrier signal that is responsible for transmitting data (including voice/video) to a data centre on a real-time or interval basis.
- Telecom carrier: an independent mobile carrier that can help transmit data through wireless form.
- Cloud services, cloud computing and Big Data analysis: once data are collected in the cloud, certain data modelling and analysis need to be performed to convert the data into useful information for further action and analysis; some partners at this point start applying artificial intelligence (AI) or cognitive capabilities.
- Shared information portal: a user-friendly portal needs to be designed to allow different shared information sets to be tailored to meet different stakeholders' requirements; the portal can be accessed directly through the cloud or through a physical data server.
- Remote monitoring centre: a centre that contains all the necessary information for decision making and follow-up actions; this centre may also be responsible for machine-to-machine (M2M) management, network management and service management. In our cases, two companies are using such centres, which also perform as 24/7 call centres in which traditional phone calls can be managed through help-desk staff.
- Mobile devices: for service technicians receiving/sending communication information through a remote monitoring centre, the centre can send a job site equipment status report, possible fraud information, advance tips for repair/maintenance of equipment, earlier spare parts ordering and regular e-learning training and safety tips. This device can also keep track of service timing records, required for ad hoc inspections and annual equipment certification issuance by the relevant authorities.
-

4.4.2.3 Value Nodes – Business Ecosystem

This defines business stakeholders, including suppliers, partners, authoritative bodies and possible competitors. In our IoT offering cases, they are the following:

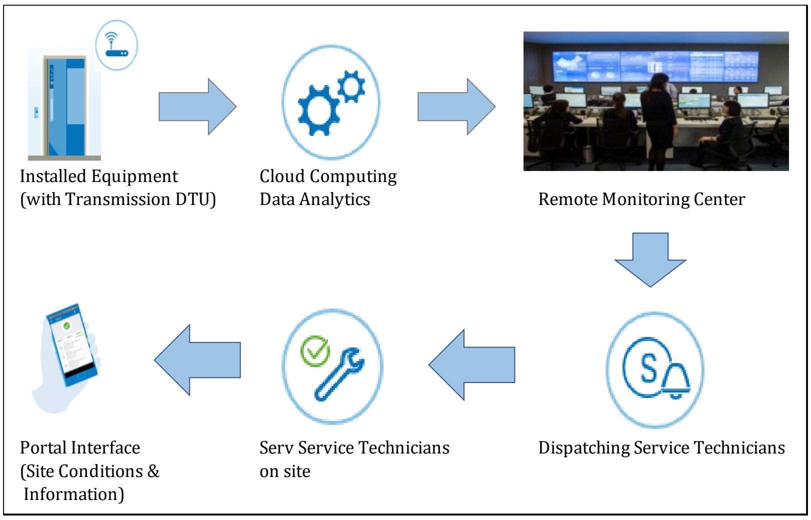
OEMs: the OEMs manufacture elevator equipment and install it at the client's site. They may or may not be the party providing a warranty and on-going regular maintenance and repair. However OEMs normally hold the main responsibility for any possible design or component default during the life span of equipment.

- Authoritative bodies: these include the General Administration of Quality, Supervision, Inspection and Quarantine (AQSIQ), which is the authority setting up quality standards, issuing certificates and regulating inspection criteria. For instance, the standard GBT24476-2017 for the "specification for internet of things for lifts, escalators and moving walks" was published together with the National Standard of the People's Republic of China and clearly defines the standards, guidelines and regulations for elevator IoT. The other semi-authoritative body is the China Elevators Association (CEA), which plays an important role as the bridge between the elevator industry and the government.
- Third-party independent service companies: independent service companies provide regular maintenance, repairs, upgrades and full replacements of equipment. Most OEMs also have their own service arm to provide on-going servicing and repairs.
- Facility management companies: these are companies that safeguard building management and ensure all equipment operates effectively and safely. In most cases they are the direct customers of OEMs and service companies, meaning that they receive the value of IoT services and pay the bills.
- End users: these are the passengers who use the lifts. The equipment has to be operated effectively and efficiently to move them from one location to the other, safely and in comfort.
- IoT solution vendors: as described in IoT ecosystem, there are different levels of IoT solution vendors, including hardware, software, cloud computing, Big Data analysis, portal design and system integration providers.

4.4.2.4 Value Exchange – flow of knowledge and information among different resources

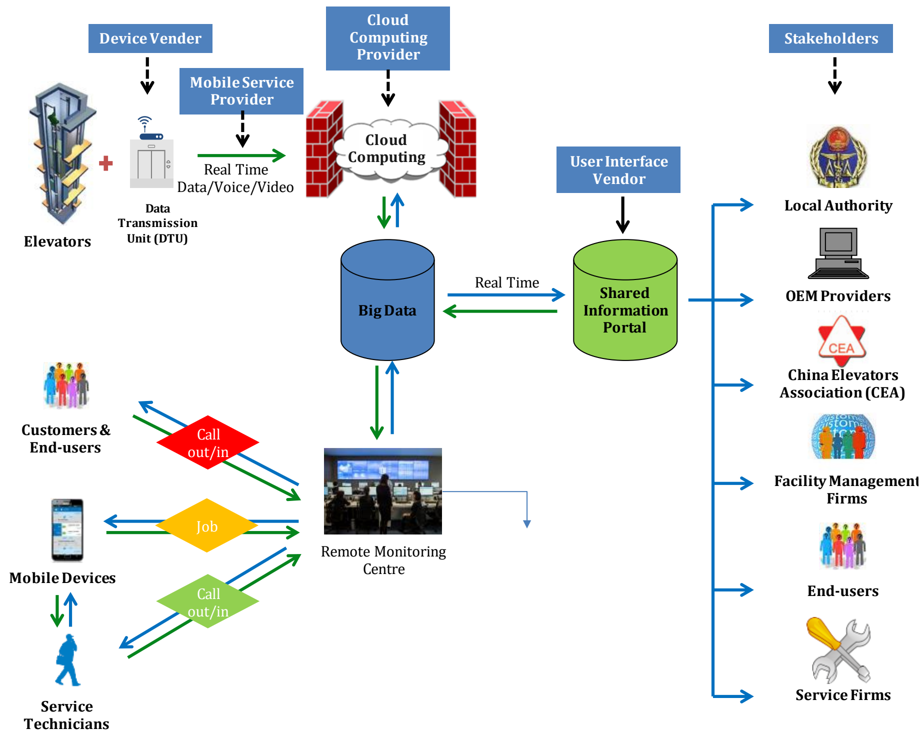
During the interviews, all three companies demonstrated a basic standard in terms of IoT offerings, as shown in Figure 4.2. Machines can communicate with machines without human intervention, i.e. between elevators and the cloud, employing cloud computing and data analysis to identify potential fraud, issue alerts and suggest corrective actions. They can then trigger follow-up actions, potentially sending service technicians on site with parts and repair tips in advance. At the same time, the user portal can have visibility over machine movement before and after the corrective actions. There are no major differences in the flow of value exchange; rather, the key component is the way in which each company deals with the data collected, utilizing data from certain identified patterns to make decisions. This relates to the major competences the company can exploit to take a leading advantage over others and the key elements of business model value drivers.

Figure 4.2 Basic elevator IoT offering activities



4.4.2.5 Value Exchange Summary: Figure 4.3 presents a summary showing the complex network of activities that needs to be co-created with different stakeholders: vendors, other service providers, customers or authoritative bodies. These stakeholders participate in the overall IoT service offering collaboratively and are not limited to just value in exchange (paying the bill in exchange for a service) or value in use (who will use the service); they also need to receive relevant shared information, mostly through real-time applications, for decision making and action in their own networks and value design needs to be co-created to ensure value can be exchanged so that all actors benefit regardless of value.

Figure 4.3 Standard elevator IoT roles and activities



4.4.3 The IoT Ecosystem Business Model: Value Extracts

Our empirical study reveals different levels of ecosystem business models. The large company is more mature and has driven the development of IoT due to its plentiful resources, benefiting from key roles in its comfort zone as well as core competences developed over decades. Thus, it tends to have a more closed ecosystem and focuses on its core competences together with strong partners in terms of technology provision to provide a closer and more sustainable business model with a view to long-term benefits. However, user-centred approaches, which mean opening up innovations and the ecosystem, should be utilized when creating IoT business models (Sinfield et al., 2012), particularly in the area of co-creative value, in order to provide tailoring to customer-specific requirements. The mid-sized or relatively small immature company has adopted a more open ecosystem with an open IoT protocol in order to create a society embracing a standard that will attract more actors to join its ecosystem, believing that this will eventually be of real benefit to clients and end users. However, there are still challenges in the ecosystem business model; rather than concerning technology, these relate to how to commercialize and make a profit if the system is open and any actors inside or outside the ecosystem can play their role and go downstream or upstream to penetrate market share.

Company A plays is a keystone actor in its ecosystem (Carbone, 2009; Nuseibah & Wolff , 2015), expecting to consolidate the industry competence around the value proposition by providing a dominant design or architecture that facilitates collaboration and aids collective innovation in the business ecosystem. It promotes customized, connected services within a system that uses the sophisticated platform of a global partner with AI capability to process data from elevator monitoring devices in the cloud, analysing and predicting equipment problems before they occur. For this solution, clients will need to pay a monthly fee, deriving the value of enabling preventive maintenance to minimize downtime and repairs, utilizing a smart solution to minimize the number of unplanned stops and maximizing the life cycle of the installed equipment. This has advantages compared with traditional calendar-based elevator maintenance, with various components serviced or parts replaced based on estimated times of wear and tear. The intention is to attain revenues and profits through better service provision and the promotion of proprietary spare parts, system upgrades, major repairs and ultimately full replacement of equipment at the end of useful life.

Company B has adopted a more open IoT ecosystem as the majority of its business is with distributors – the actors providing services to the clients. The company is fully utilizing its commercial resources (resources available in the market) and standard components to construct a simple and straightforward IoT connected service and provide this as a product feature sold together with elevators. This is a cost-effective solution which will benefit the distributors (partners) and eventually end users. The business model is more inclined towards traditional product sales, collecting additional fees from clients to acquire this service upfront on a one-time basis. One of the critical factors is how data are collected and shared.

Company C believes that data should be shared openly through the entire ecosystem, including business partners and technical partners; it is up to each of these actors to decide how to use the data for their own benefit. Company C is essentially not an elevator company, but a supplier of integrated control components to elevator OEMs. It has significant market share in providing elevator control systems to full elevator OEMs and it thus makes sense to provide an IoT solution which utilizes the control systems installed by these elevator companies. The majority of IoT devices read from standard sensors and detectors already installed in every part of the elevator system, including landing doors, machinery and signal systems; the control system is at the heart of collecting all data. With this benefit, companies just need to have a reading device attached (built in) to their control system and transmit data to the central remote monitoring service. It is intended to build an open elevator IoT platform and provide services to the entire elevator ecosystem, including manufacturers, service companies, facility management companies and authoritative bodies. The company provides the IoT transmission device free of charge as it is already built into the control system; the model is to provide tailored data modelling and analysis capability for data collected and stored in the company's data centre; in other words, the value driver is selling data and services rather than promoting hardware. The company believes with increasing amounts of data, the services provided will be of more use to each actors in the ecosystem. These services include remote monitoring, safety alerts, parts ordering, a service technician dispatch system, a friendly portal tool and preventive maintenance services. From our interviews, the firm also lobbies authorities for the use of the IoT platform as a standard interface city by city, meaning that any elevator service company wishing to do business in these cities will have to buy their service, or at least interface with the local authority safety monitoring system which is part of China's vision for smart cities.

In summary, we employ Westerlund, Leminen and Rajahonka's (Westerlund, Leminen & Rajahonka, 2014) key pillars of business model design as a tool for IoT ecosystems to illustrate the differences between these case companies in Table 4.1.

Table 4.1: Case summary of extractions in value design in the IoT ecosystem business model

Company	Type of Business Model	Value Drivers	Value Nodes	Value flows/exchanges	Value extracts
A: Global elevator player presences in China	Promote IoT offering as advanced service offering	Provide advanced elevators service and predictive maintenance over traditional maintenance	Partner with strong global IoT solution provider, customers and all level of stakeholders	Convert data into useful decision flow to stakeholders and promote customized predictive maintenance service	Provide unique advanced elevator condition base maintenance with monthly subscription charge
B: Strong elevator local player	Additional remote monitoring feature for equipment offering	Additional feature and functionality in their standard equipment to support distributors	Various IoT vendors (software and hardware), elevator distributors and authoritative bodies	IoT function attached to equipment flow	Selling equipment with build in IoT feature
C: Elevator components supplier	IoT platform provider together with integrated elevators control components	Promote data modelling and service to tailor customers service requirement	OEM elevator manufacturers, service company and authoritative bodies	An IoT open platform, centralized database, information and money exchange	Establish IoT open platform to promote data analytical service to tailor needs from clients

4.5 Challenges of the IoT Business Model in the Ecosystem Context

Based on our research on IoT business model design in the ecosystem context in three different types of elevator companies in China, we conclude that there are various opportunities and challenges in the ecosystem from both the technical (IoT ecosystem) and business (ecosystem business model) perspectives. During the interviews, we realized that to address challenges in building the ecosystem business model within the IoT ecosystem environment, it is first necessary to distinguish whether the challenges are at firm level, i.e. constituting elevator contextual factors, or at the IoT ecosystem system level, more specifically on creating value that customers will be willing to pay for from the firm's existing core competences, IoT networking or the surrounding ecosystem. We concluded that in building the IoT business model, the most critical challenges typically are not at the individual firm level, but at the ecosystem and industry interfaces.

- One of biggest challenges found in relation to IoT business models in other industries lies in how to proceed from promises to reality (Leminen et al., 2014), namely how to turn promising sounding IoT technology into a real-life business model. IoT will provide a breakthrough only if and when customers attain clear and concrete benefits and hence the business model can be monetized. In our case studies, all the companies had solid business applications attached to existing firm-centric core competences, but challenges remained in terms of ensuring clients and different level stakeholders would be willing to pay for the value they perceive as expected. The three companies approached the commercialization of IoT solutions from different angles based on their surrounding ecosystems. However, IoT is a relatively new solution and there are no definitive answers to which model gains better acceptance from customers; hence all three companies agreed that there was still a need for trial-and-error adjustment in testing market acceptance. One of the solutions to overcome this challenge is to have value design tailored to customers' specific needs based on value co-creation with stakeholders.

- IoT is moving into a relatively new area, shifting from traditional industry with a product focus to service-centric industries, of which the elevator industry is a good example. These companies have maintained their firm-centric perspective for decades or even more than 100 years and may not have expertise in IoT ecosystem technology and management. Hence, shifting their focus from the firm business model to an ecosystem business model could be a challenge for them, regardless of which commercialization strategy they employ. We argue that existing business model templates and tools are not well suited to the interdependent nature of companies that are evolving in the same ecosystem, because they have been designed to address the challenges faced by single incumbents (Fleisch, 2010). All three companies encountered challenges in terms of how to integrate the business network at the ecosystem level rather than drawing on their own firm-centred competences. Therefore, our perspective on the value design ecosystem business model becomes critical to overcome these challenges. Companies have to align each actor within the business ecosystem towards a common goal or direction, rather than each pursuing a different direction. To overcome this, common value extraction during value design becomes critical when designing the business model. The dominant actor has to be open to accepting expert views from different areas instead of insisting on its own firm-centric view.
- Both providers and customers in emerging IoT ecosystems are still seeking to identify their roles and underlying value drivers. It seems that IoT vendors in the ecosystem are becoming aware of the fact that increased networking and cooperation with multiple stakeholders, including partners, customers and end users are needed to overcome the barriers to the emerging platform. The entire value-creating network should be involved in developing customer-oriented services, not only as those who pay for it but also as related stakeholders.
- Data can be collected from the main control box in elevators with a few dozen sensors and detectors pre-installed in the standard elevator. These data are then sent to the cloud on a real-time basis and the real challenges arise when analysing and finding useful patterns in the immense volumes of data gathered. IoT is a popular buzzword, but in terms of linking data into the cloud, the prospects only become really exciting when applying some intelligence to it, otherwise the amount of data has little meaning. The single most important element of the IoT ecosystem is to ensure data flow and hence the exchange of value at different stakeholder levels. Identifying how data can be converted into useful information for further action or decision making still remains a major challenge. In particular, company A expects to advance elevator services towards a more predictive maintenance basis, which depends on the accumulation of data over time, sophisticated data modelling, plus the latest AI machine-learning technology. This capability is probably the most valuable driver in

ensuring benefits for customers and society, but we believe this still in the early stage and needs time to develop.

- One of the value drivers that all three companies identified concerned remote access to real-time data (including voice and video), so that a remote monitoring centre located hundreds of miles away can instantly detect problems, for instance trapped passengers, and manage urgent situations from a safety perspective as the top priority. This is also the most critical requirement from the authorities' lens. In reality, signal transmit over mobile access point name (APN) network for data is economic and affordable and can enable the cloud to signal an alert for any possible major system breakdown and trapped passengers. Voice over carrier costs more, but the costs can be accepted if only for urgent usage. However, for video service that may cost much more and thus real-time twenty four hours seven days video monitoring may not be feasible from the cost–benefit angle. Therefore, all three companies treat it as an optional service, based upon client's decision, until either carrier cost can be significant reduced or faster speed mobile network.
- There are also challenges in determining whether the standardization of the service interface is needed for an elevator IoT platform, although China has published a new standard (GBT24476-2017) in this regard. However, customers' needs are becoming increasingly heterogeneous (Leminen et al., 2014) and value co-creation differentiating services tailored to customer-specific requirements is critical for the business model. Moreover, the elevator industry is typically a business-to-business (B2B) field, rather than focusing on consumer products. The question then is whether a standardized IoT platform and service is critical to differentiate the business model. Companies A and C have taken a totally different stance on open or closed networks, each having its own angle in terms of the business model. In a niche industry, it is arguable whether the trend towards open platforms and platform providers will eventually win, as proposed by the literature (Leminen et al., 2012).

4.6 Conclusion

This paper explores the way in which firms nurture the business ecosystem to deal with the emerging IoT ecosystem business model. Three implications are highlighted in our empirical study as underlying ecosystem business models in the IoT field. First, IoT in general is inspiring a wealth of new business models, which frequently involve diverse partners and increasingly cross-industry ecosystems (Turber et al., 2014). Thus, innovations in this area predominantly present an ecosystem and cross-industry orientation in contrast to the traditional industry-specific incremental innovation. Therefore, we argue that existing methods of business modelling are not sufficient in addressing the IoT ecosystem. We suggest that firms have to shift their thinking from the single firm business model of innovation to the ecosystem business model when innovating new offerings in the IoT field.

Second, through case study expert interviews and the literatures review, we realized the most critical element of the IoT business model concerns data analytic capability, especially moving from relational data modelling to AI cognitive capability, this particularly critical to our cases in elevators service segment. Data are collected on a real-time basis and modelling methods are improving all the time, so the more data collected, the better services can be defined. These capabilities heavily rely on working with both technical and busienss ecosystem over traditional firm centric core competence. The analytics engine is self-learning, so the various kinds of connected services will definitely come into play to a greater extent in the future. Elevators IoT service business model is turning from selling traditional maintenance services to selling safety, right comfort together guaranteeing minimal downtime, this is an interesting vision for IoT elevator services and further research with practical experiment is needed to accommodate future trend.

Third, all these companies have adopted the IoT ecosystem to provide service-oriented solutions to clients and other stakeholders, including enabling the remote monitoring of the operation of elevators, shortening the dispatch time of service technicians on site and providing predictive maintenance, which can alert operators to the potential malfunction or failure of components in advance in order to reduce the damage of downtime, as well as facilitating instant spare parts replenishment. All these value drivers are mutual and co-created; this not only involves the company and clients, but also different levels of the IoT ecosystem and multiple stakeholders, including authoritative bodies, from the business perspective by linking company and clients at both the M2M level and the business relationship level. This entails both human and machine learning among stakeholders to ensure the continuous improvement of value for all stakeholders in the ecosystem; in this regard, deeper service- and customer-oriented thinking are required.

Chapter 5 Shifting paradigm to service-dominant logic via Internet-of-Things with applications in the elevators industry

Abstract: The purpose of this paper is to investigate how latest technology Internet-of-Things (IoT) can enable/facilitate traditional manufacturing firms shifting to more service-centered business perspective. Service-dominant (S-D) logic has emerged to provide the right perspective, vocabulary and assumptions on which to build a service-centered alternative to the traditional goods-dominant (G-D) paradigm for understanding economic exchange and value creation and has been identified as an appropriate philosophical foundation for the development of service science (Maglio & Spohrer, 2008; Maglio, Vargo & Caswell, 2009). S-D logic is in its current state of development is conceptual and few empirical studies exist to test such a logic realized in real business applications. On the other hand, IoT is a novel paradigm recently envisioned as a global network of machines and devices capable of interacting with each other to reach desired business goals in the real world. However, there is considerable research on IoT technical specifications but less elaboration on real business applications. This paper aims to describe IoT as a critical vehicle when manufacturing firms desire to transit to a more S-D and value co-creation business model, with an in-depth real business case study in the elevators industry. This paper aims: (1) to explain the distinction between G-D logic and S-D logic and its implication for manufacturing firms, (2) to examine how IoT can facilitate the transition from key S-D logic managerial implication perspective and (3) to conduct a case study in a new service offering of an elevator service business when transition to more S-D mindset by adoption of IoT, the purpose aims to examine whether the underlying technology can bring different ways of thinking when deploying a new industrial service offering.

Keywords: service science; service-dominant logic; goods-dominant logic; Internet of Things; value co-creation

5.1 Introduction

A new competitive environment for manufacturing and service industries has been forcing a change in the way manufacturing enterprises are developed. The service sector is gradually taking the main stage of the global economy, manufacturing firms, and particularly industrial goods manufacturers, are also adopting a more proactive service strategy and embedding it into their overall company strategy. Over the last two decades, a number of researchers and practitioners have studied a variety of conceptual frameworks or theories for service operation in manufacturing firms, a shift from a central focus on the supply and movement of tangible products for manufacturing; a broader focus on partnerships, relationships, networks and value creation is evident (Lusch, Vargo, & Tanniru, 2010).

As firms attempt to remap their offerings from goods to services, interdisciplinary and cross-disciplinary approaches are required to understand how services should be designed, delivered and supported. Among many subsets of service operations research, a fundamental shift in the worldview has been proposed to match the analogous shift in the economy: from goods-dominant (G-D) logic to service-dominant (S-D) logic (Spohrer et al., 2008; Vargo & Lusch, 2004a). This suggests that firms may need to redirect the production and marketing strategies that they have adopted for manufactured goods by adjusting them to the distinguishing characteristics of services. To distinguish the conceptualization in services, S-D logic defines services as the application of competencies for the benefit of another party; it basically shifts the thinking of the traditional view on value in terms of operand resources – tangible, static resources that require some action to make them valuable – to operant resources – intangible, dynamic resources, shared information, knowledge and skills that differentiate the competitive advantage.

Internet of Things (IoT) is a new technology paradigm envisioned as a global network of machines and devices capable of interacting with each other. The IoT is recognized as one of the most important areas of future technology and is gaining vast attention from a wide range of industries (Lee & Lee, 2015). Many of studies and researchers attempt to examine how the true value of IoT for enterprise can be realized, and what benefits that firms can gain when they design new product/service offering into real-life business applications. The same discussions have also taken place concerning what S-D logic actually means to service operation in traditional industrial goods manufacturing and how firms can really apply this conceptual worldview to business applications. In this paper, researchers take a subjective view that attempting to fully engage the key resources to gain competitive advantage is the most crucial element of firms making service-centric transition, and which companies may be able to engage the latest technology IoT to facilitate the transition that acts as a key agent to promote shared information, knowledge and skills enhancement and hence to embrace value co-creation. This paper aims to contribute to the effort of the traditional manufacturing firms in embracing IoT when attempting to transit to S-D logic. The paper is organized as follows: (1) explains the distinction between G-D logic and S-D logic and its implication for manufacturing firms, (2) examines how IoT can facilitate the transition from the key S-D logic managerial implication perspective, and finally (3) conducts an in-depth case study of a new service solution of an elevator service business that desired transition to the S-D model by the adoption of IoT – to examine whether the underlying technology can bring together different ways of thinking when deploying a new industrial service offering. This single case study format consists of two sections: the initial stage is to develop a service offering proof of concept by experimenting with value co-creation with all the stakeholders among collaborative networks; once a proof of concept has been established, further studies will carry out a two-year longitudinal case study to monitor this service offering implementation in a real-life business model, enabling us to present our findings in a more assembled and responsible manner. In this paper, the focus will be limited to the first phase of proof of concept development.

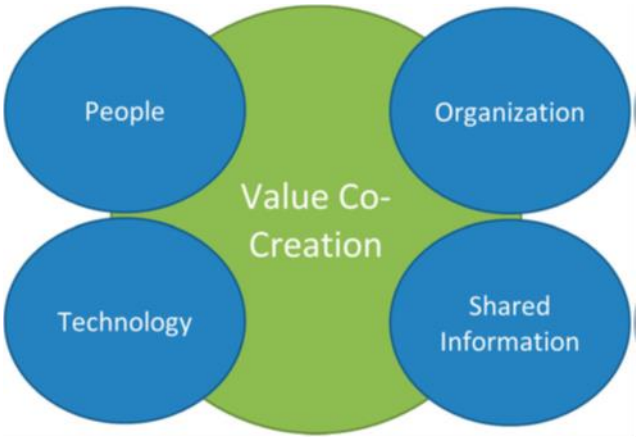
5.2 Shifting Paradigm to S-D Logic

Service science has grown into a global initiative involving hundreds of organizations and people who have begun to create service innovation roadmaps and to invest in expanding the body of knowledge about service systems and networks (Bishop et al., 2008). Service science is the study of service systems, aiming to create a basis for systematic service solution development, and combines organization and human understanding with business and technological understanding to categorize and explain the many types of service systems that exist, as well as determine how service systems interact and evolve to co-create value (Maglio & Spohrer, 2008).

The conceptual framework of service science embraces all the key elements and guidelines for service system design and helps us to understand that a service is the application of competences for the benefit of others (Vargo & Lusch, 2004a). We are now moving to a more knowledge-intensive and customized form of service, depending more on client participation and input, whether through clients providing labour or property or through information obtained via organizational or technological value chains (Sampson & Froehle, 2006). Maglio and Spohrer (2008) concluded that service systems are defined as value-co-creation configurations of people, technology, organizations and shared information that create and deliver value to customers, providers and other stakeholders (Maglio & Spohrer, 2008), as shown in Figure 5.1.

To elaborate the central paradigm of service science further, Maglio and Spohrer claimed that S-D logic provides just the right perspective, vocabulary and assumptions on which to build a theory or service systems, their configurations and their modes of interaction (Maglio & Spohrer, 2008). S-D logic is a service-centred alternative to the traditional G-D paradigm for understanding economic exchange and value creation and has been identified as an appropriate philosophical foundation for the development of service science (Maglio et al., 2009).

Figure 5.1. Service systems defined as configuration of value co-creation.

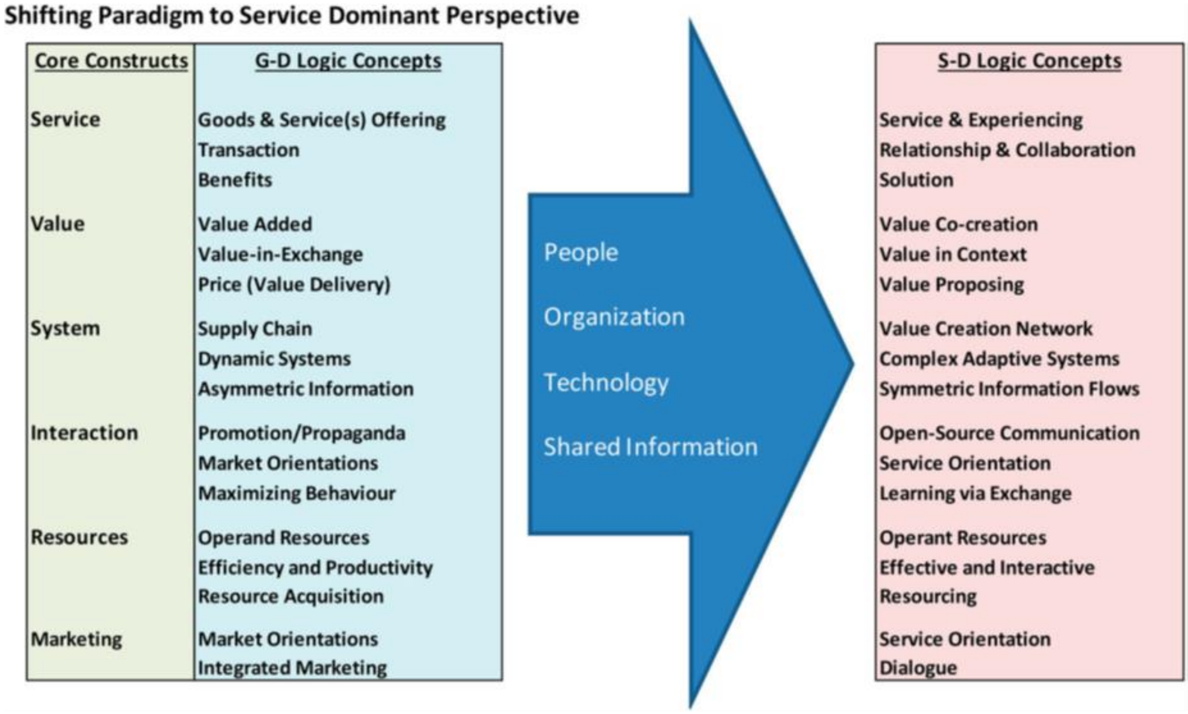


Traditional G-D logic provides a view of economic exchange and value creation that focuses on the production and distribution of goods and considers services as special types of goods with undesirable qualities (e.g. intangible, perishable products) or added value to tangible products (e.g. after-sales services) (Vargo, Lusch & Akaka, 2010). This traditional view of economic exchange, concentrating on manufacturing and distribution activities, considers values to be exchanged between a firm and its customers (Vargo & Lusch, 2004a).

G-D logic views the primary focus on firms as the production of output to be exchanged with customers. G-D logic considers value created by a firm through production and value-added activities, such as distribution and sales. As the economy grew towards services, which are an intangible aspect of exchange, services were recognized as an add-on to the tangible good and did not fit well with the G-D basis of exchange. This stems from an increasing number of service offerings that cannot be categorized as goods and therefore are considered to be services (Vargo et al., 2010). These led service scientists to become concerned with the efficient production of intangible goods rather than the effective creation of value through services (Lusch, Vargo & Wessels, 2008).

S-D logic proposes an alternative perspective for the study of economic exchange, which actually involves more foundational notions of real value (applied to specialized knowledge) and value-in-use than G-D logic. As discussed in earlier sections, service systems are defined as value-co-creation configurations of people, technology, organization and shared information that create and deliver value to customers, providers and other stakeholders. More precisely, it defines a service as value co-creation and value as change that people prefer and realize as a result of their communication, planning or other purposeful and knowledge-intensive interactions (Spohrer & Maglio, 2010). The framework proposed illustrates that the key resources necessary to transform the paradigmatic logic from goods to services are people, organization, technology and shared information, as shown in Figure 4.2. These resources indicated by the central arrow in Figure 5.2 are the key participating actors able to transform to the S-D logic;

Figure 5.2. Shifting paradigm to S-D logic conceptual framework.



5.2.1 Value Co-Creation

The fundamental concept of service science and S-D logic is that value is co-created; discussing value co-creation in more detail in this section is unavoidable. Traditional manufacturing firms define their services as focusing on providing valuable (e.g. innovative) product and service offerings to customers, emphasizing efficient transitional capability (supply chain) to pass the benefit to customers in exchange for the benefit from the other end. The S-D logic's conceptualization of value co-creation exceeds simply inviting the customer to participate in production or design processes (Vargo & Lusch, 2008). It suggests that there can be no value without the customer incorporating the firm offering into her or his own life.

Although in the original S-D logic article, coproduction was used instead of co-creation to represent this integrative meaning (Vargo & Lusch, 2004a), after considerable debate and clarification, co-creation of value has been used to convey the customer's collaborative role in value creation while mere customer participation in the development of a firm's offering has been identified as coproduction in S-D logic. Therefore, customer participation in the value creation process suggests a larger, more extended venue of value creation than the firm or firm–customer interaction because it implies that neither the firm nor the customer has adequate resources to create value, either independently or interactively, in isolation (Vargo & Akaka, 2009). It points to a network-within-network conceptualization of relationships that converge on value creation through a web of resource integration.

5.2.2 Tangible to Intangible

The tangible and intangible concept was brought to research attention from resource-based view; it highlights the importance of resources and capabilities in supporting organizational survival, growth and overall effectiveness (Wernerfelt, 1984). Organizations build upon and exploit the pool of resources they can access to, including both tangible and intangible. Physical resources are typically tangible and consist of plant and equipment, raw materials, financial instrument and information technology. Organizational and human resources are mainly intangible resources, including planning, controlling, coordination and management systems from organizational resource, and experience, judgement, insights and social relationship of employees from human resource (Barney, 1991). The shift from tangible to intangible in organizations focuses on the solution that the customer is seeking. In the traditional business-to-business (B2B) market, it is called solution selling. In almost all industries today, companies continually promote themselves as selling not just a product but a solution, regardless of their business (Vargo & Lusch, 2011). When the focus becomes the solution, which may contain either tangible or intangible elements or both, what firms learn is that the tangible content cost of the product becomes smaller and the brand rises in value and importance; the tangible content is only the appliance used for the more important and more enduring experience (Vargo & Lusch, 2004b).

5.2.3 Operand to Operant Resources

S-D logic establishes the primacy of operant resources, defined as those that act upon other resources to create benefit, such as knowledge, competence, experience and so on, over G-D logic's focus on operand resources, which must be acted on to be beneficial, such as natural resources, goods and money (Constantin & Lusch, 1994; Vargo & Akaka, 2009). That is, operant resources, such as knowledge and skills, are the underlying source of value to sustain a competitive advantage over others; this fundamentally transforms the traditional thinking that value occurs in exchange for operand resources. It is suggested that the integration of operand and operant resources is fundamental to the co-creation of value under S-D logic (Ballantyne, Williams & Aitken, 2011).

5.2.4 Value-in-Exchange to Value-in-Context

Value is phenomenological and contextually derived by the service beneficiary. S-D logic proposes that value is not created until the beneficiaries of the service (value-in-use), often the customers, integrate and apply the resource of the service provided with other resources, in their own context, together with the available resources, including those from other service systems (value-in-context). It is different from the traditional G-D concept in which value is created at the point of exchange, for instance at the time when goods are exchanged for money (value-in-exchange), and it is beneficial for both parties. In S-D terminology, these service systems are characterized as “resource integrators”. Thus, the co-creation of value incorporates the integration and application of resources from service providers, including resources among the network, by the service beneficiaries (Vargo, 2011). Hence, value is always contextually beneficiary specific; always determined by the beneficiaries.

Value-in-context highlights the importance of time and place dimensions and network relationships as the key variables in the creation and determination of value. Thus, value-in-context is uniquely derived at a given place and time and is phenomenologically determined based on the existing resources, accessibility to other integrated resources and circumstances (Vargo & Akaka, 2009).

5.2.5 Asymmetric to Symmetric Shared Information

S-D logic suggests that all exchanges should be symmetric; symmetry is defined as transparent shared information among all the actors in the network. It fundamentally implies that (1) one does not mislead customers, employees or partners by not sharing “relevant” information that could enable them to make better informed choices and (2) all exchanges or trading partners are treated equitably (Lusch, Vargo & Wessels, 2008).

In an increasingly global economy, information sharing in a more symmetric way is essential because the system will drive out organizations that are not trustworthy. Organizations must promote the symmetric flow of information both across firms and customers and within the firm, in which different departments and divisions can be internal customers and suppliers of one another (Lusch & Vargo, 2008). In summary, this argues for truth telling as a business partner concept in the service business and does not imply that all information needs to be fully transparent to all the related stakeholders.

5.2.6 Managerial Implications for Practitioners

We understand that the paradigms are difficult to changes but leaders in firms do have choice to make. In recent decades, leaders of many successful organizations have institutionalized a new mindset that is grounded in S-D logic. It argues that a service perspective can and in being used by all types organizations, including manufacturing as well as service (Greer, Lusch, & Vargo, 2016). S-D logic despite being a mindset and perspective on service perspective and it is argued rather than a theory (Kowalkowski, 2010), it offers few normative guidelines or managerial implications for practitioners (Lusch & Vargo, 2006), from these guidelines, it is possible to provide recommendations for mangers to adopt for designing new offering or engineering the process, these guidelines are:

- The firm should strive for transparency and make all information symmetric in the exchange process with customers. Since the customer is someone to collaborate with, anything other than complete truthfulness will not work.
- The firm should develop relationships with customers and maintain a long-term perspective. Firms should thus always look out to support and protect customers' interests as well as long-term well-being.
- The firm should view goods as transmitters of the operant resources; they are intermediate "products" that are used by other operant resources (customers) as appliances in the value-creation process. Firms should integrate resources to foster innovation by focusing on selling service flows.
- The firm should support and make investments in the development of specialized skills and knowledge that is the fountainhead of economic growth.

5.3 On Internet of Things

5.3.1 Fundamental Attributes

The IoT, also called the Internet of Everything or the Industrial Internet, is a new technology paradigm envisioned as a global network of machines and devices capable of interacting with each other (Lee & Lee, 2015). It refers to linking the objects of the real world with the virtual world, thus enabling connectivity at any time in any place, for anything and for anyone. It enables a world in which physical objects and beings, as well as virtual data and the environment, interact with each other in the same space and time. Enterprises can utilize IoT to create and capture value by connecting devices with integration with in-house business intelligence applications, traditional ERP and supply chain systems, business analytics and decision support systems (Bradley, Barbier & Handler, 2013).

The concept of "things" in the network infrastructure refers to any real or virtual participating actors, such as physical devices, human beings, virtual data and intelligent application agents. The true value of the IoT is to create an environment in which the crucial information from any of the networked autonomous actors can be efficiently shared with others in a real-time or interval basis (Yang, Yang & Plotnick, 2013). The adoption of IoT technology is rapidly gaining momentum, as technological, societal and competitive pressures push firms to innovate. IoT has the potential to disrupt industries through changing products, services and business model just as the Internet did in the 1990s (Keskin & Kennedy, 2015).

Fundamental attributes of the IoT technology are summarized as (i) IoT is a global and real-time solution, (ii) IoT is mainly wireless oriented and able to collect and exchange data, (iii) IoT has the ability of remote monitoring the environment and tracking objects and (iv) IoT is able to provide comprehensive data analysis about its surrounding environments (Yang, Yang & Plotnick, 2013). From the technology perspective, few technologies are widely used for the deployment of successful IoT-based products and service, including but not limited to machine-to-machine interface, radio frequency identification (RFID), wireless sensor network (WSN), microcontrollers, location technology, middleware, cloud computing, big data analysis and IoT application software (Lee & Lee, 2015; Whitmore, Agarwal & Xu, 2015). Based on the technology trend and literatures review, we identified that IoT can enhance firms' value from various enterprise applications, based on the assumption of key IoT fundamental attribute with technology. They monitor and control big data and business analytics, information sharing and collaboration, improve efficiency with speed, facilitate decision-making and enhance knowledge accumulation, as summarized in Table 5.1

Table 5.1 Summary of IoT attributes, technology and business values

IoT Key Attributes	IoT Key Technologies	Values from IoT Technology and Application
IoT is a global and real time solution	Machine-to-Machine Interfaces	Monitoring and Control
IoT is mainly wireless oriented and able to collect and exchange data	Protocols of Electronic Communication	Big Data and Business Analytics
IoT has the ability of remotely monitoring the environment and tracking objects	Microcontrollers	Information Sharing and Collaboration
IoT is able to provide comprehensive data analysis about its surrounding environment	Intelligent Sensors and Actuators	Improve Efficiency with Speed
	Wireless Sensor Network (WSN)	Facilitate Decision Making
	Radio frequency identification (RFID)	Enhance Knowledge Accumulation
	Location Technology	
	Cloud Computing	
	Data Analysis and Diagnosis	
	IoT Application Software	

5.3.2. In Practical Business Applications

IoT has provided opportunity for traditional manufacturing firms to redesign their production flow for supply chain management, including productivity improvement, warehouse management or logistic tracking monitoring for quality insurance. For example, specific application of IoT in fresh agricultural products starts from supply chain management to ensure freshness of product, tracking source of product for food security, up to building management information for agricultural products process control (Gu & Jing, 2011). Another example is a new type of stock management based on IoT to manage traditional goods demand, purchasing, replenishment and delivery in a more robust ways, not only for internal product and control improvement but also for not missing revenue opportunity (Ding, 2013; Xie & Wang, 2007). From the service industry IoT technology which builds machine-to-machine interaction can be perfectly applied to various service operations enabling WSNs that consist of distributed autonomous sensor-equipped devices to monitor the physical or environmental condition at remote location. Information transmission from remote location at the interval or real-time basis can then incorporated to internal ERP systems and decision-making in order to diagnose the status of a product or equipment, such as its location, temperature, movement or even spare parts utilization status (Atzori, Iera & Morabito, 2010). Further integration with cloud computing and user-friendly mobile application can trigger follow-up service decision for better, timely and quality of services rendered; it was described as device-to-device, device-to-human and finally human-to-human interaction service context in a reliable and robust manner (Lee & Lee, 2015).

5.3.3 IoT Facilitates Goods to Service Transition

As traditional manufacturing firms move from goods to service in order to gain competitive advantage, it is interpreted that firms not only sell equipment they produce but also offer after-sales service, from either equipment selling to trigger service, a “push” strategy, or from providing quality service and hence win equipment or parts opportunity at either replacement or repairing instances. Through integration with IoT hardware and software, it offers opportunity also for the product and service integration industry, to redesign their business models conscientiously to serve customers in a more efficient and effective manner. For instance, service operations such as those carried out in the elevators industry can potentially perform real-time remote monitoring and control, together with big data analytical capability, provide decision-making information to better serve their customer, at the same time collaborate with other stakeholders, including the public end-users and authorities. Building management systems aims at efficiently managing building facilities, HVAC (heating, ventilation and air conditioning), lighting control, power systems, security monitoring, and life safety systems in order to conserve energy, save operation cost and improve safety and security. By adopting IoT on cloud, the building management system at either single building or group of buildings (campus or compound of office and residential building) can be managed through remote monitoring, control and upgrade in a real-time robust way (Li et al., 2013). Another example is that a proposed product service system uses web technologies to provide services and support aerospace maintenance, repair and overhaul services, which can easily be accessed by distributed users through the Internet in real time for regular delivery (Zhu et al., 2012).

5.4 IoT Enables the S-D Transition

This section will illustrate how firms can initiate transition towards S-D perspective by adopting the IoT technology. It attempts to elaborate how IoT can facilitate or expedite the transition in a more efficient and effective manner. As the IoT enables connection between technicians, suppliers, customers and other stakeholders, we are now beginning to see these connections that characterize business and society by using the Internet to increase collaboration. We applied S-D logic managerial implication of normative guidelines to examine if IoT can play a critical role to help the firms when transition to more S-D logic, these guidelines again are symmetrical information exchange with stakeholders, maintain long-term perspective with customers, innovation from focusing on service flow and investment in knowledge and skills. We can now examine how influential relationship can be built upon S-D logic normative guidelines and IoT fundamental characteristics.

5.4.1 Symmetrical Information Exchange

The amount of studies of asymmetrical information exchange shows that balanced knowledge sharing and symmetrical information exchange are critical for successful value constellations and propositions (Mascarenhas, Kesavan & Bernacchi, 2007). Shared information is one of critical elements for value co-creation; it is fully aligned with one of fundamental elements of IoT, which makes information movement more transparent and more efficient. By utilizing the latest technology, device at remote location can transmit information through mobile wireless into firms' data centre, which can do such as remote monitoring, situational awareness and data modelling for further decision-making. Information can also be converted to useful dataset in order to share with stakeholders who should include internal and external customers, partnering suppliers and authoritative bodies to establish true collaboration and openness (Kowalkowski, 2010). For some of industrial products in emergency management community, timing of information sharing is even more critical with a rapid pace of response operations and decision-making support are important factors for minimizing property damage and even people's injury or fatality (Yang, Yang & Plotnick, 2013).

5.4.2. Strive for Long-Term Perspective Business

S-D logic orientation emphasizes the ability to participate in co-creating superior lifetime value-in-use for the customer (Kowalkowski & Ballantyne, 2009) and to derive an equitable part of that value is vital. As focus on lifetime value implies that goods can be only sold one time at the point of value-in-exchange which is static, but services can be sold multiple or unlimited times in the dynamic form of time span is the value that co-exist by maintaining a long-term relationship with customers or stakeholders: the concept of balanced centricity (Gummesson, 2008).

IoT by linking the device at customer's premise and sending signal back to the centralized data centre through the mobile network by itself is the way to build the connecting relationship at least from machine-to-machine context (Sampson, 2010), how further relationship establishment from machine-to-machine, machine-to-person and person–to-person context is defined by the business model firms deploy. For example, industrial equipment including diesel engines, elevators, central air-conditioning or industrial machinery the providers already built in sensors and devices in equipment delivered to customer premises. All these devices will record the machine operation status, including operational efficiency, temperature, malfunction or fault detection signals. By adopting the IoT technology, signal is now able to be transmitted to equipment providers or independent data central at either interval or real-time basis; with customers' agreement, firms can provide remote monitoring/diagnosis, online upgrade, remote control and repair, up to fast response by dispatching technician to job site for repairing or replacing components to minimize customer damage due to machine downtime. This is a more efficient way to build customer relationship by providing better service and a lock-in business model. It is in a way helps maintaining longer term business relationship, as well as building a hand-shaking lock for customers not easy to jump ship, unless poor service is rendered or information from IoT is not effectively used.

5.4.3 Opportunity for Service Innovation from Focus on Service Flow

Under the S-D logic-based proposed guidelines, the key stakeholders including customers and suppliers are potential part of the co-innovation process. There are opportunities to co-design new service offered by working with different levels of suppliers and customers, including both active and passive customers (Ramirez & Mannervik, 2008). For example, by replacing traditional barcode tags with RFID technology along with remote monitoring capability, new data with more detail and timely intervention will make service offering possible to understand both customers and machines' behaviour. Therefore, when developing new product and service offering, or upgrading the existing offering, firms should consider how new information and communication technology can be integrated into the system to enable better collection of customer usage data (Kowalkowski, 2010); here IoT can be one of solutions from service co-innovation perspective.

5.4.4 Investment in Knowledge and Skills

S-D logic guidelines emphasize that firm should have the ability to propose a competitive value proposition to convince customers that firm is committed to the offering. When designing a new offering, firm (or firm's engineers) should have knowledge to understand customers' needs plus sufficient skills to really implement the offering (Kowalkowski, Brehmer & Kindstrom, 2009). The knowledge and skill need continuous accumulation and updating through either from internal capability building and external acquisition from both customers and suppliers. For instance, feedback loops from service personnel are important in order to design offering that is not only easy to assemble in the manufacturing plant but also should be easy to install or future maintenance in the field. In more sophisticated industrial equipment, the skills of professional service technician is the key to improve the level of customer satisfaction and hence to secure business at a long-term perspective.

Through technology, it is possible to collect enormous amount of data. By accumulating these data, database can hence be established to further categorize and analyse; with cloud computing and big data analysis capability, firms can work with professional vendors building sophisticated stimulation models to analyse customer behaviour pattern for the purpose of better offering design, or can be used for internal product quality or process improvement. In addition to new offering design, investments in specialized service-related skills and knowledge will become even more important, as they are mostly people-related professional and soft skills. The database aggregated from collection of information can provide excellent training materials for product and service engineers on how they can produce improved product or provide better field service. The ability to handle flexible and result-oriented business models coping up with dynamic and changing customer demands is critical and should be complemented with these new tools. For instance, an elevators company can quickly provide service or safety tips through pushing information into each technician’s personal smartphone or tablet, a quick learning on-the-go will improve technician skills in a more effective and efficient way, instead of traditional class room training.

5.5 A Case Study

5.5.1 Research Methodology

After illustrating the potential benefits of adopting IoT when manufacturing firms attempt transition to the S-D logic paradigm, an in-depth case study was conducted in order to construct an interpretation from the real business applications, as well as potentially bringing inevitable benefits to the real world when deploying IoT-related technology. This case study aimed to describe and analyse S-D logic-oriented solutions in a new service offering – an IoT project/offering in the elevators and escalators (E&E) service business in China. The concept of S-D logic has been discussed and debated for a few years; a few studies reported real case studies on real-world applications (Kuppelwieser & Finsterwalder, 2016) as well as a framework applicable to manufacturing firms. An empirical study is therefore appropriate to bring out some opportunities and challenges that occur when traditional manufacturing firms adopt the S-D paradigm to design and implement new service solutions.

The data collected for this research were obtained from a number of sources. First, information was collected through participatory observation in which the researcher worked with a global elevator company in China, participating in developing the elevators IoT solution for the company; therefore, it was possible to obtain case study related information from direct or indirect interactions with other stakeholders. This not only enables insights to be gained into their perspectives but also facilitates access to data, including a variety of strategic and operational meetings, documentation, meeting minutes and presentations. Second, in addition to accessing perspectives and concrete information from the elevator firm directly, 12 semi-structured interviews were conducted with individuals from the China elevators association (CEA), a property/facility management company, a third-party service company, a property developer and end-users. The interview length varied but interviews typically lasted for about one hour. The objective was to gain insights into this contemporary phenomenon (Yin, 2011b) and to understand what value can be co-created from these stakeholders towards IoT offering. Third, the researcher was also closely involved in work with a service system integrator from an external consultant company (vendor) that helps to develop hardware and cloud computing solutions, as well as a software company that is contracted to develop a user interface (UI) application to facilitate more friendly and effective shared information.

As mentioned in the Introduction section, the single case study consisted of two phases. In this paper, the research focused only on the first phase, which consisted the development of the proof of concept based on the key elements of S-D perspective. Further research will cover the second-phase implementation, which will take another 18–24 months during which the researcher will gain a richer set of data and a deeper understanding of the research outcome evaluation and research phenomena through observation of the case study environment over periods.

5.5.2 The Company and Service Offering

The company is a global leading European-based company that provides solutions for the installation, maintenance and modernization of E&E. This company has a strong presence in China; in addition to manufacturing equipment in China, the company is aggressively expanding its service business by providing corrective maintenance (on-call service), preventative maintenance (regular-interval service), major repair and retrofit and up to full replacement service until the end of the equipment's useful life cycle. While continuing to sell significant amount of equipment annually, the service is growing by more than 25% per annum. Due to the fact that all these installed and operational lifts are geographically dispersed nationwide, the company is now operating more than 500 service depots (service offices) in China. With this significant scale of service operation, the company acts as an independent service organization nationwide, with more than 8000 full-time professional and skillful employees, the majority being front-end service technicians located in these service depots to provide direct services for lifts in operation across China. The company is aggressively looking for opportunity to shift its business model from product focus to service focus in China, it is not only a pure business model shift but also a perspective/mindset shift, and therefore an IoT project is established to test if the value co-creation mindset can be accepted by market and hence gaining sustainable competitive advantage.

5.5.3 The IoT Project

The company is undergoing a new service offering project that applies the latest technology, the IoT, enabling devices to be installed in lifts linking to the company's remote monitoring centre through the mobile network on a real-time basis. The data transmitted from lifts at remote locations will provide instant information to the cloud server. With fast cloud computing technology equipped with statistical analysis modelling, valuable information will be sent immediately to the company's remote monitoring centre for the purpose of detecting any malfunction or potential control system or component failure; these will trigger follow-up decision-making to resolve the issues either remotely (machine-to-machine context) or through phone calls or dispatching service technicians to the job site. This project will also integrate the existing company field mobility system in which all service technicians already have a smartphone device on hand providing their daily working schedule and contents, a GPS location service, spare parts ordering and the most critical online and offline training modules with regular updates, which will enhance their knowledge and skills with technical tips, fact sheets of malfunction root cause and short learning modules.

During designing a proof of concept, the company applied a value-co-creation design process to gather different sources of input from all its stakeholders. The company conducted interviews from June to December 2015 with respondents from such entities as the local authority, the CEA, clients (property/facility management company), end-users (passengers), third-party service firms, venders, including remote transmission device providers, system integration providers, a UI software company, a mobile and cloud computing company and a big data company and, finally, a few experienced service technicians and field supervisors. The proof of concept is now being finalized, as illustrated in Figure 5.3, which shows the complex network of value that needs to be co-created with different stakeholders, regardless of whether they are vendors, other service providers, customers or authoritative bodies. These stakeholders participated in the project collaboratively and are not limited to just value-in-exchange (paying the bill in exchange for a service) or value-in-use (who will use the service); they also need to receive relevant shared information on the project in a real-life application, for their own network for decision-making and actions, and this value-in-context needs to be co-created from a longer term perspective. In summary, the proof of concept is aligned with the framework that was discussed in Section 4.2 which shows that the key resources necessary to enable the transition to S-D logic are people, organization, technology and shared information.

5.6 Case Findings and Discussions

5.6.1 IoT Support Building Long-Term Perspective Business Model

As illustrated in Figure 5.4, elevators business itself is a long-term business, though the business initiated by equipment selling, service still dominates the entire business cycle during equipment’s useful life, from a long-term perspective. As all components have their limitation based on their useful life, particularly for E&E, which run for almost twenty-four hours every day, certain components and functions could deteriorate over time and need to be replaced. Other than regular spare parts replacement, most lifts need a major retrofit after a certain number of years of operation, representing a major business from the service or manufacturing firm’s perspective; this business includes major repairs, system upgrades and modernization. Eventually, lifts need to be fully replaced with new equipment when they have been operating for more than 15–20 years. This type of business evidentially requires a more professional service combination with technology, experience, knowledge and skill from professional technicians due to the complexity of the system within the limitation of the external environment (critical downtime management).

Figure 5.3 Proof of concept of the IoT project (AQSIQ, General Administration of Quality Supervision, Inspection and Quarantine; CEA, China elevators association).

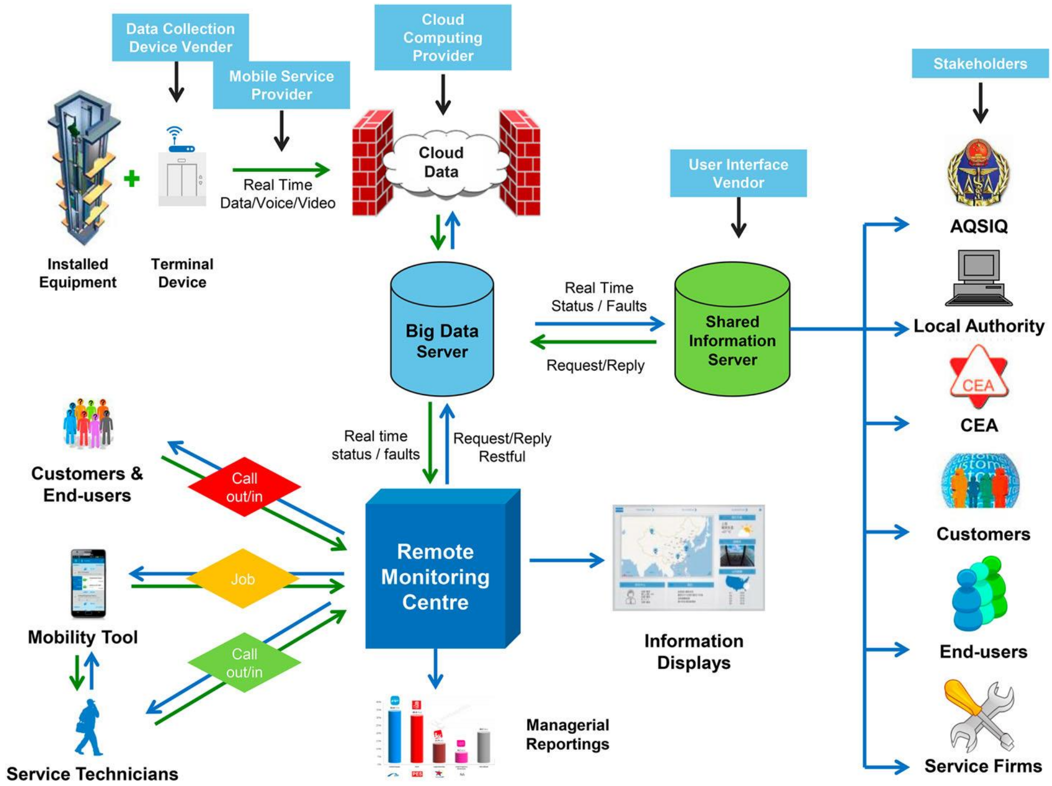
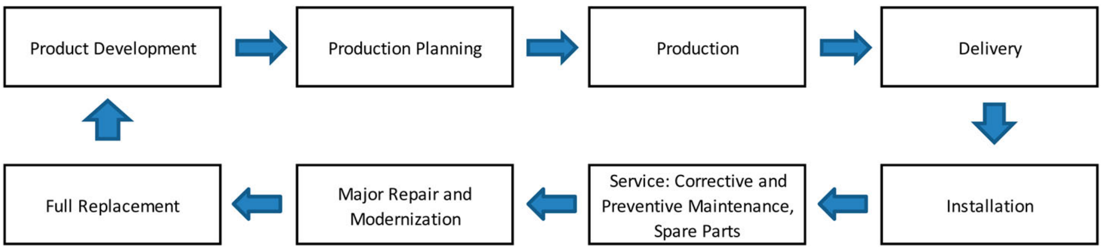


Figure 5.4 Standard lifts business cycle



S-D logic suggests that firms should strive to develop relationships with customers and should take a long-term perspective. This guideline means that the ability to participate in co-creating superior lifetime value-in-use for the customers (Kowalkowski & Ballantyne, 2009) and to derive an equitable part of that value is vital. A focus on lifetime value implies that firms need to apply a holistic perspective to value creation and customer relationships and not only view the entire product and service sales as separate and static. Applied to the case that we studied, the new IoT service offering provides remote monitoring and hence safeguard customers' equipment as well as providing timely information analysis for customer better justify their investment and for them to better service their customers is to set-up a bridge establish a long-term relationship connecting customers with other stakeholders and more important to their customers who are the end-users using the elevators, at the same time as giving safety and comfort from authoritative bodies' perspective. It can be interpreted that the emphasis is not limited to value-in-exchange but more importantly includes value-in-use, as well as other values in different contexts. The case aligns with and supports S-D logic from the long-term perspective, and the traditional view in manufacturing firms that new product features and design drive the requirement for services needs to be revised.

5.6.2 IoT Enhances Value Co-Creation

S-D logic implies that "producing" should be transformed into "resourcing". Resourcing allows value creation through collaborative value co-creation, involving not only the providers and the beneficiary but also all the parties in the value creation network (Lusch, Vargo & Wessels, 2008). Goods remain one of the important provisions in S-D logic, but they are seen as the vehicles for resource transmission rather than containers of value. Findings from the case studied, the new generation of service offering in traditional manufacturing firms has transformed from the simple person-to-person after-sales professional encounter context of services to a more sophisticated multi-channel context with enhanced technology (Glushko, 2010). None of the key resources that we identified in the framework, from people to organization, technology, shared information and processes, can be excluded at any stage of the network to achieve a good quality of service and hence provide value to all the stakeholders. This resource contains both tangible and intangible service provision; fundamentally, this is what lies behind the service-oriented architecture.

5.6.3 IoT Reinforce the Investment in Knowledge and Skills

As pointed out by Vargo and Lusch (2004a), microscopic actions begin with the division of labour. Physical and mental skills are the two basic operant resources that all individuals possess, as well as knowledge and skills, which are the two fundamental resources necessary to generate a competitive advantage. The sources of advantage are the operant resources that firms deploy, comprising assets such as networks, innovation and facilities that can be traded and valued; more important are the capabilities enabling these assets to be deployed advantageously. The capabilities apply firms' knowledge and skills to the core processes of the business; they need to be activated by resource enablers, such as people, organizations, technology and shared information. This investment includes investing in people by acquisition, retention and upgrading (training and coaching), investing in organizational capabilities by adopting an adaptive organization, investing in technology by using the latest information technology (IoT, cloud computing, mobile technology and big data analytics) and investing in process improvement (Six Sigma, lean manufacturing, total quality management, balanced scorecard and business re-engineering processes). These investments must be aligned with the strategic theme that gives direction to the firm and sets strategic priorities so that they work in concert to deliver superior relational value.

The new service offering in the case study utilizing the IoT project is a combination of investments in people, organization, technology and processes, moving information faster to accumulate knowledge from the customer end both to trigger faster service on-site or remotely and to provide useful feedback to the manufacturing end. This feedback loop from the service job site is important to design equipment that not only improves the quality and promotes a longer useful life but also is easy to replace in the field service. This can advance the study of condition-based maintenance, which moves towards predictive maintenance from traditional corrective and preventive maintenance; however it is not included in this paper. One of the critical elements of the IoT project also enables a direct linkage between big data at the remote monitoring centre and the service technicians' mobile device; ideally, critical equipment faults or failure information will appear on the screen together with technical tips on how to repair the equipment or which component parts are needed at the job site. These will keep front-end service technicians' knowledge to accumulate at an almost instant pace; furthermore, mobile devices will push daily repair tips and short offline training courses to enhance service technicians' skills and knowledge as part of the company's long-term investment in knowledge.

5.6.4 IoT Promotes Shared Information

One of the critical guidelines proposed by S-D logic is that firms should be transparent and make all information symmetric in the exchange process. Because the customer is someone to collaborate with, anything other than complete truthfulness will not work (Kowalkowski, 2011; Lusch & Vargo, 2006). In our view, shared information is a perspective that does not have to be totally symmetric. Information should be exchanged based on a criticality and sufficiency basis with all the collaborative stakeholders instead of only between buyer and seller. In this IoT case, information will need to be shared with different levels of stakeholders, for instance central and local safety authorities are only concerned with safety-related information, one example being that trapped passengers need to be rescued within thirty minutes based on the safety code of Standing Committee of National People Council (June 2013) People's Republic of China Special Equipment Safety Law. Service firms may require more information, including potential components/parts that need to be replaced or any site visits that need to be arranged based on the equipment operation status. Customers such as facility management companies need real-time video and voice information due to their position as the party that actually monitors the elevators' status on a real-time basis. At the passenger level, they probably only care about whether the elevators are running smoothly and safely.

Our argument is that shared information should be transparent and sufficient: whether or not it is symmetric or asymmetric is only a perspective discussion. From another angle of the equation, with regard to innovation, the view of S-D logic is that information symmetry is essential (Lusch, Vargo & Malter, 2006); while there are professional standards about fully informing clients and not misleading customers or stakeholders, entrepreneurship and innovation are based on information asymmetry. In other words, complete information discourse has the potential to reduce the perceived value offered to the customer (Theoharakis & Sajtos, 2007). This is particularly critical to manufacturing firms, in which continuing to drive innovation in all aspects from product to technology, process, tools or marketing approach is crucial for firms to keep their competitive advantage. Thus, keeping information totally symmetric somehow damages firms' benefit from protecting continuous investment in innovation capability resources. From the customer perspective, the positioning of products is in itself an act of creating a monopoly in customers' minds and is to a great extent an effort to create informational asymmetry in some cases. Using an example from the case studied, raw data collection from the real-time mobile network needs to be evaluated by big data analytics to distribute appropriate information on the right level to various actors in the network. Many actors are involved in the collaborative network, and loading a huge amount of data purely symmetrically to all the parties may not be appropriate. That the data need to be screened and categorized to address the party of key concern is probably justified. Therefore, we can try to strike a right balance between the symmetric and the asymmetric perspective for information sharing.

5.7 Conclusion

In summary, from a theoretical point of view, this paper examines that applying S-D logic as a market orientation in traditional manufacturing firms means that the traditional goods sales and after-sales services and solutions are no longer discrete functions, and this elevates the strategic importance of the lifetime value of the customer relationship, regardless of the combination of services and goods (Kowalkowski & Ballantyne, 2009). An increase in interdisciplinary collaboration would be highly beneficial for the concept's theoretical and practical advancement, as well as for dealing with the transformation of traditional manufacturing firms to adopt S-D logic (Kuppelwieser & Finsterwalder, 2016). The IoT technology has many positive impacts or possibly a driving force on designing product and service offering by redefining a more innovate service flow. The literature review together with the case study supports collaborated technology and shared information to enable perspective shifting. This has implications for organizations, which are required not only to integrate products and services as a solution business but also, more importantly, to shift their mindset towards S-D logic in combination with adopting advanced technology.

Interviews with industrial experts at manufacturing and service firms, as well as regulators resulted in the common consensus that shifting from an equipment-centric to S-D business model is required for keeping sustainable competitive advantage in the market. However, there are physical and mindset challenges, physical challenges being mostly the shortage in knowledge and skilled people, plus investment in technology. To this extend, S-D logic may be able to provide right perspective to the company re-thinking their strategy and hence invest resource at the right stance. In the case study, IoT project is a service offering that the company began adopting value co-creation mindset, utilizing most of required resourcing including people, organization and shared information together with collaborative technology stakeholders and partners. This project provides a good opportunity for researchers to examine the key components both product to service integration and possible transition to adopting S-D logic key concepts.

From practitioners' point of view, this paper offers a real application on how a leading global manufacturing adopts S-D logic by utilizing IoT into its new service offering project. As we showed that IoT playing a critical enabler role, it is no longer a theoretical study from the technical perspective; more and more firms are either already implemented or in the process of prototyping testing IoT in real-world business applications. We anticipate that research on the IoT technology will continue to evolve providing better service offering and solution over the next decade, as IoT getting more mature and dynamic, firms regardless S-D or G-D should benefit from this technology in order to transform their business model in a more timely, dynamic and predictive manner. As indicated by one of industry leaders interview, IoT can increase more insight and control – enabled by connected sensors together with handheld application, which transforms the business workflow from reactive to predictive, possible moving up from predictive to proactive. Though investment is obvious, mutual benefits will pass through not just firms and its collaborative stakeholders, but also down to every field technician they hired. With mobile phone application carries data from remote centre, front-end technician in the field now have everything at their fingertips to diagnose, solve and prevent issues, making their works easier, as well as making customers equipment having a better experience at right comfort, and more important safer. By adopting IoT technology, the traditional manufacturing firm is now able to not only focus on selling equipment but also innovating to selling service flow, which creates a long term value co-creation business model with its clients and ecosystem.

Chapter 6 Internet of Things Enabling Condition-Based Maintenance in Elevators Service

Abstract: This study demonstrates how Internet of Things (IoT) technology can enable highly distributed elevator equipment servicing by using remote-monitoring technology to facilitate a shift from traditional corrective maintenance (CM) and time-based maintenance (TBM) to more predictive, condition-based maintenance (CBM) in order to achieve various benefits. Literature review indicates that CBM has advantages over conventional CM and TBM from a theoretical perspective, but it depends on continuous monitoring enhancement via advanced Internet of things technology. An in-depth case study was carried out to provide practical evidence that IoT enables elevator firms to achieve CBM. From a theoretical perspective CBM of elevators makes business sense. The challenges lie in data collection, data analysis and decision making in real world business contexts. The main findings of this study suggest that CBM can be commercialized via IoT in the case of elevators and would improve the safety and reliability of equipment. It would thus make sense from technological, process and economic perspectives. Our longitudinal real-world case study demonstrates a practical way of making CBM of elevators widespread. Integrating IoT and other advanced technology would improve the safety and reliability of elevator equipment, prolong its useful life, minimize inconvenience and business interruptions due to equipment downtime and reduce or eliminate major repairs, thus greatly reducing maintenance costs. In summary, the main contribution of this paper lies in the empirical demonstration of the benefits and challenges of CBM via IoT relative to conventional CM and TBM in the case of elevators. We believe this study is timely and will be valuable to firms working on similar research or commercialization strategies.

Keywords Internet of things, time-based maintenance, corrective maintenance, condition-based maintenance

6.1 Introduction

Elevators are a common form of infrastructure and are widely used by the general public in everyday life. Continued maintenance after installation is critical to high operational reliability. As the reliability of elevators is critical to the safety of people moving from one place to another, maintenance strategy is an important part of the overall strategy for ensuring the reliability, safety, and efficiency of elevator systems during long periods of continuous use (Niu et al., 2008). From the customer's perspective the two most critical objectives of elevator maintenance are ensuring safety and reliability; the other objectives include prolonging the useful life of equipment, minimizing inconvenience or business interruptions due to equipment downtime, reducing or eliminating major repairs and identifying the probability of fault occurrence and troubleshooting (repair or replacement).

Conventionally, there are two types of elevator maintenance strategy: Corrective maintenance (CM), also called reactive maintenance or breakdown maintenance; this involves sending service technicians to elevator sites to make repairs once a fault or failure has been reported. Preventive maintenance (PM), the main objective of PM is to carry out basic maintenance, repair, and replacement of components so as to avoid unexpected failure during normal operations (Duffuaa et al., 2001; Bengtsson, 2004). The most common approach of PM is known as time-based maintenance (TBM) or predetermined or scheduled maintenance; under this strategy service technicians are dispatched regularly to elevator sites to carry out maintenance operations (Mann, Saxena & Knapp, 1995). TBM can generally be performed using modularized procedures based on the recommendations of the original equipment manufacturer (OEM), which will be based on sophisticated scientific and statistical analysis of historic and design data, as well as on exploiting the knowledge accumulated by skilled technicians during long service. In most cases TBM is performed at regular time intervals (Sheu, Griffith & Nakagawa, 1995).

The elevator industry has also explored the other type of PM strategy, one can use information about the condition of a component/system to improve the diagnosis and prognosis of failures in order to reduce maintenance-related costs. This is known as condition-based maintenance (CBM) and the fundamental objective is to reduce downtime and set-up costs (Jardine, Lin & Banjevic, 2006; Peng, Dong & Zuo, 2010). CBM of complex engineering has attracted considerable attention from researchers over the past few decades. At the heart of CBM is the condition monitoring process, in which signals are continuously monitored using certain types of sensor or other appropriate indicators (Campos, 2009). The key assumption behind condition monitoring is that 99% of equipment failures are preceded by certain signs, conditions, or indications that a failure is going to occur (Bloch & Geitner, 1983). This implies that maintenance activities can be performed only when needed or just before failure incurred (Anderson & Rasmussen, 1999). CBM is already used in many real world contexts in aviation, oil-gas refineries, energy, the semiconductor industry, and other fields where there is high investment in heavy engineering equipment. Investment in CBM in contexts where there is heavy and costly equipment is a case worthy of special attention (Peng, Dong & Zuo, 2010; Hameed, Ahn & Cho, 2010; Hernandez & Labib, 2017). It is not usually feasible to implement CBM in relatively light engineering systems due to limitations of technology and the high cost of collecting real-time data. Elevator equipment is widely installed at distributed locations and there is variation in site conditions and frequency of use. Deploying CBM without an efficient, effective, and economic continuous monitoring mechanism would be a challenge, so mainstream methods of maintaining the various components used in the elevator industry still entail intensive use of manpower.

Over the last few decades the growth of technology has brought about great changes in maintenance functions (Ahmad & Kamaruddin, 2012a). Nowadays the development of advanced sensors and Internet of Things (IoT) technology has made the remote acquisition of condition data much more efficient and economic, which makes the business case for CBM more attractive than it was before. There have been proposals for many real world IoT applications in many industries. The domain covers not just conventional industrial sectors, but also the consumer industries of everyday life, to which IoT can bring significant improvements, even new business models (Lai, Jackson & Jiang, 2016). IoT is a broad term that is commonly applied to a new technological paradigm that envisions a global network of machines and devices capable of interacting with each other (Lee & Lee, 2015). In parallel with the very rapid advances in the relevant technology a common language has developed to describe the fundamental attributes of IoT technology, which links real world objects with the virtual world. This has enabled global and real-time - mainly wireless oriented - solutions to problems of data collection and exchange. The IoT has the capacity to provide remote monitoring of an environment, track objects, and ultimately carry out comprehensive analysis of data on the surrounding environment (Yang, Yang & Plotnick, 2013). Thus the IoT could prove the ultimate solution for the elevator industry's maintenance needs, implemented in the form of a CBM strategy. The advantage of adopting IoT in elevator CBM is not limited to allowing more economical real-time, remote monitoring; IoT-based CBM could also offer rapid data analysis, which would enable decisions about maintenance to be taken quickly and on the basis of real-time information about the condition of the equipment through use of advanced cloud computing.

The existing studies of CBM often focus on simulations or statistical models that could be used to coordinate maintenance of components under a CBM policy; there has been little research on scalable ways of coordinating the maintenance of the multiple components of complex infrastructure equipment. In particular, there is a lack of practical research on implementation of CBM using advanced technology in industries such as the elevator industry. The aim of this paper was to explore the potential benefits of CBM underpinned by IoT technology for a highly distributed elevator service, as well as analyzing how IoT could be used to realize CBM and identifying the main benefits relative to conventional CM and TBM. The main contributions of this paper are one, a discussion of existing and potential approaches to maintenance in relation to CBM and IoT in designated domains and two, further investigation of how IoT can be used in a real world case - elevator servicing - to implement effective and efficient CBM. Ultimately we hope to develop guidance for the elevator industry to enable it to embrace CBM strategies and design maintenance services based on IoT technology.

This paper begins with a review of the theoretical foundations of various approaches to maintenance, including CBM, and maintenance strategies used in the elevator industry. We then describe an in-depth case study of the use of IoT to enable CBM in the elevator industry, followed by an illustration of the benefits of CBM relative to conventional TBM. Finally, we review the key findings of the case study and the challenges raised and propose ways of addressing these challenges, which leads us to identify issues to be addressed in further research.

6.2 Theoretical Background

This section describes and analyzes existing theories and previous research on IoT, CBM and the intersection of the two in order to place the research in context and give the reader an overview of related research.

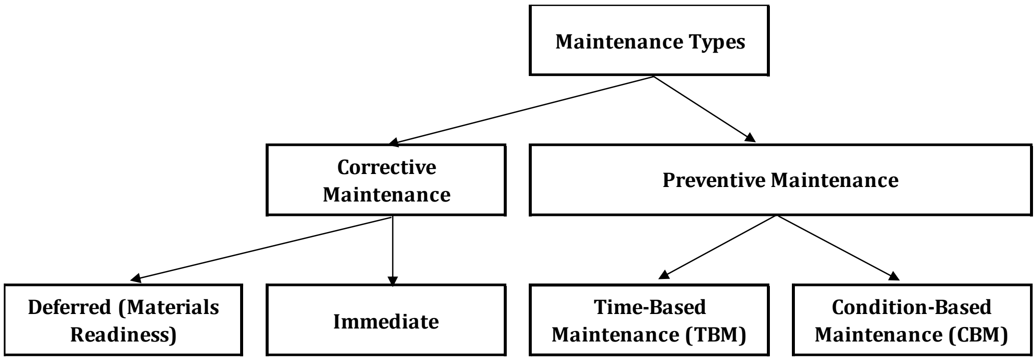
6.2.1 Maintenance Types

The most commonly used of the various definitions of maintenance is that of the European Standard SS-EN 13306:2001 for Maintenance Terminology, approved by the European Committee of Standardization. This defines maintenance as a “combination of all technical, administrative, and managerial actions during the life cycle of an item intended to retain in it, or restore it to, a state in which it can perform the required function.” In general, maintenance strategies can be broadly classified as corrective maintenance (CM) and preventive maintenance (PM) (Duffuaa et al., 2001). CM is a strategy that is used to restore equipment to full functioning after it has failed, and is also known as reactive maintenance or on-call service (Blanchard, Verm & Peterson, 1995). CM can for some situation be deferred in time if the consequences of a fault do not affect the comprehensive function of equipment or services, this deferred corrective maintenance can instead be planned to be executed at a time more appropriate for productivity capacity. Faults or breakdowns have direct affective on system downtime, or that are hazardous to safety, or other specific maintenance rules, must without delay be maintained (Bengtsson, 2004). It is argued that this strategy leads to long periods of machine downtime and high maintenance costs due to sudden failures (Tsang, 1995). PM is an alternative to CM; it involves carrying out maintenance activities before equipment fails. The main objectives of PM are to reduce the frequency of equipment failure and thus reduce failure and maintenance costs and machine downtime as well as increasing project quality and improving productivity (Usher, Kamal & Syed, 1998; Lofsten, 1999).

PM involves maintaining, repairing and replacing components in order to avoid unexpected failures during normal operations. The objective of any PM strategy is to minimize the total cost of inspection and repair and to minimize loss of productivity and business interruptions due to equipment downtime. There are typically two approaches to PM. The traditional approach is to perform maintenance at scheduled intervals (TBM), selected on the basis of statistical analyses of equipment failure and reliability; this is also known as period-based maintenance (Yam et al., 2001). With sophisticated, statistical, reliability-based analysis total cost is minimized by establishing a static, statistically “optimal” maintenance schedule, replacing or overhaul equipment or components at scheduled intervals (Lawrence, Saxena & Knapp, 1995). A number of studies have focused on optimizing this kind of PM schedule to reduce costs whilst ensuring that normal operations are not interrupted and service quality is maintained (Yamashina & Otani, 2001a). The second approach involves sensor-based monitoring of the condition of equipment in order to predict when machine failure or malfunction is likely to occur. The maintenance schedule is no longer static or fixed; the objective of CBM is to perform maintenance when needed. The principle of CBM is that one can use information about the condition of a component/system to improve the diagnosis and prediction of failures and thus reduce maintenance-related costs by reducing downtime and set-up costs (Jardine, Lin & Banjevic, 2006; Peng, Dong & Zuo, 2010). Summary of maintenance types illustrated at figure 6.1.

A few critical terms commonly used in relation to maintenance strategies need to be clarified. Asset malfunction conditions are described as “faults” and “failures,” as these two terms are closely related and can be misused, the International Standards Organization (ISO) has provided clear definitions of failures and faults in machines (Hitchcock, 2006): “An engineering asset has a fault if any of its components or subsystems has a behavior or condition that is below its designated level, but the asset can still perform its principal functions”, whereas “An engineering asset suffers from a failure when it can no longer accomplish one or several of its required principal functions.” The terms “diagnostics” and “prognostics” describe two important aspects of a maintenance program. Diagnostics deals with fault/failure detection, identification and isolation. Fault/failure detection is a task which indicates when something is going wrong in the monitored system; fault/failure isolation involves locating the component that is faulty; fault/failure identification involves determine the nature of the fault/failure once it has been detected. Prognostics deals with predicting fault/failures before they occur. Fault/failure prediction involves determining whether a fault/failure is impending and estimating the probability that it will materialize and the time at which it will do so (Jardine, Lin & Banjevic, 2006; Bengtsson & Jackson, 2004).

Figure 6.1: Summary of maintenance types



6.2.2 Condition-based Maintenance (CBM)

CBM has been a research topic since 1975. It was introduced as more economical, more effective alternative to traditional maintenance strategies. Due to the massive advances in information technology there is now much more research being done into this area. Compared with traditional TBM and CM, CBM is more beneficial and realistic (Ahmad & Kamaruddin, 2012b). Preventive strategies are now mainstream in the servicing of industrial products and machinery; they are gradually replacing CM strategies, also called reactive or unplanned maintenance strategies. Because it is recognized that CM strategies are more expensive, PM strategy has been recognized as an attractive alternative (Gertsbakh, 1977). A PM strategy involves undertaking regular, planned maintenance before failure occurs thus avoiding the costs of unexpected failures (Jayaswal, Wadhwani & Mulchandani, 2008). According to the literature maintenance services must deal with three major problems: 1. Planning maintenance work for durable assets in a complex operational environment; 2. The need to reduce the high cost of labor and spare parts; 3. The need to avoid the risk of catastrophic failure and eliminate unplanned forced outages of equipment or systems (Tse & Atherton, 1999). Maintenance based on the actual condition of assets has been introduced as an alternative to CM and as a PM strategy that addresses these three problems.

The formal definition of CBM given in the BS3811 British Standard Glossary of Maintenance Management Terms in Terotechnology in 1993 is that it is a method used to reduce the uncertainty of maintenance activities, and involves carrying out maintenance activities according to need as indicated by the condition of the equipment. The key assumption of CBM is derived from modeling of the deterioration process and is that 99% of equipment failures are preceded by certain signs, conditions, or indications that a failure is going to occur (Bloch & Geitner, 1983). Thus, CBM assumes that there are indicators that can be used to detect and quantify the possible failure of equipment before it actually occurs. Prognostic parameters provide an indication of potential problems and instantly detect faults that would cause the equipment or component to deviate from the acceptable level of performance (Yam et al., 2001). There is probably little argument about the definition of CBM; however there is a considerable body of research demonstrating the different ways in which it can be applied in real-world cases. CBM is most commonly implemented in the form of a maintenance program that makes recommendations about maintenance based on the information collected through continuous or interval-based monitoring of the condition of equipment, either by local wired connections or remotely over a wide area or mobile network. According to Jardine, Lin & Banjevic, 2006, CBM consists of three main components/steps: data acquisition, data processing, and maintenance decision making. There are amount of literatures articulate each of these three major components under CBM related discussions. For instance, data acquisition is now a popular IoT research area, Hashemian and Bean (2011) categorized CBM into three sub-groups based on the data acquisition: (1) existing sensor-based maintenance techniques; (2) test-sensor-based maintenance techniques; (3) test signal-based maintenance techniques.. Data processing research deals with statistical analysis and scientific data modeling and has recently expanded to include analysis of ‘big data’, cloud computing, and machine learning. Decision making research now mainly involves human behavioral science, integrated with work on machine learning, organizational behavior, and decision support systems (Sheu, Griffith & Nakagawa, 1995; 2004; Tallam et al., 2007).

Over the past few decades researchers have paid considerable attention to CBM of complex engineering systems. Studies have been undertaken in many industries and real-world implementations have been in use for many years, in areas such as aviation, oil-gas refineries, energy, the semiconductor industry, and other fields with high investment in heavy engineering equipment (Ahmad & Kamaruddin, 2012a). The main reason why CBM cannot be deployed more broadly is the investment required to enable the collection of data through continuous performance monitoring. At the heart of CBM is the condition-monitoring process, and CBM requires robust analysis of reliability and financial maintenance data (Ellis, 2008), such that signals are continuously monitored using certain types of sensors or other appropriate indicators (Campos, 2009). The development of advanced sensors and IoT technology means that nowadays the remote acquisition of condition data is much more efficient and economical, which makes the business case for

CBM more attractive than it was before. We can thus expect to see CBM more widely deployed in many industries, together with other advanced technologies.

6.2.3 IoT enabling CBM in Service Business

Service companies are constantly seeking to develop better maintenance strategies with a view to improving productivity and optimizing maintenance planning. As we saw above, CBM is considered a more productive and lower cost maintenance strategy from theoretical perspective, and the underlying assumption of CBM is to understand equipment or each of components' useful life and predictive faults and failure under real conditions basis, and thus can reduce downtime and set-up costs (Jardine et al., 2006; Peng et al., 2010). Over the past few decades CBM has attracted considerable attentions from researchers interested in potential applications in complex engineering systems. Studies have been conducted in many industries and real world applications of CBM have existed for years, however the field of application has been limited to heavy engineering equipment, such as in aviation, oil-gas refineries, energy, the semiconductor industry, and other fields where there is high investment in engineering equipment (Andersen & Rasmussen, 1999; Jardine, Lin & Banjevic, 2006; Peng, Dong & Zuo, 2010). As noted in the introductory section, the heart of CBM is the condition-monitoring process, in which signals are continuously monitored using certain types of sensors or other appropriate indicators (Campos, 2009). However it may not be feasible to all equipment due to the fact that heavy first time and on-going cost is associated to continuous monitoring and particularly in real-time basis. Hence it is likely that only a limited number of critical components will be subject to continuous condition monitoring. CM and TBM may still be the optimal way of maintaining the rest of the components (Alsyouf, 2009).

Many real world IoT applications have been postulated in many industries: The domain not only covers conventional industrial sectors, but also the consuming industry of everyday life, in which IoT can bring significant improvements, even leading to new business models. In parallel with the rapid development of the relevant technology a common language has developed to describe the fundamental attributes of IoT technology, which can be summarized as (i) IoT is a global and real-time solution, (ii) IoT is mainly wireless oriented and can be used to collect and exchange data, (iii) IoT has the ability to monitor environments and track objects from remote locations and (iv) IoT can provide comprehensive analysis of data about the surrounding environment (Yang, Yang & Plotnick, 2013). Based on trends in technology and previous research we concluded that IoT can enhance firms' value from different perspective, they are enhancing situational awareness, improving navigation control and automation, reinforce monitoring and control, improving the speed and efficiency of decision-making by tracking behavior, optimizing resource planning, enabling information sharing and collaboration, up to more complex autonomous system and decision support (Chui, Löffler & Roberts, 2010: Lai, Jackson & Jiang, 2016).

Thus, the development of advanced sensors and IoT technology enable the remote acquisition of condition data much more efficient and economical nowadays, which makes the business case for CBM more attractive than it was before, IoT could prove the best way of implementing CBM strategies. The advantages of adopting IoT for CBM are not limited to the opportunity for more economical real-time, remote monitoring; they include the capacity for rapid data analysis, which allows maintenance decisions to be made quickly and on the basis of real-time information about the condition of equipment provided by advanced cloud computing. Furthermore, IoT technology might allow firms to promote integrated product and service operations—for instance, wireless sensor networks or remote monitoring systems that consist of distributed autonomous sensor-equipped devices that monitor physical or environmental conditions and can cooperate with internal systems to monitor the real-time status of a product or equipment, including variables such as its location, temperature, movement or even component utilization in order to facilitate better maintenance (Atzori, Iera & Morabito, 2010). The true value of IoT for enterprises will be realized when connected devices are able to integrate with in-house business intelligence applications, traditional enterprise resource planning (ERP), and supply chain systems, collecting big data and business analytics for other decision support systems (Bradley, Barbier & Handler, 2013).

Amount of literatures has shown the increasing trend of embracing IoT with CBM at both scholarly and practitioner’s discussion. For instance, embedded devices that carry out real time monitoring of temperature and thermal humidity could significantly improve the performance and prognostic capability of the dairy and agricultural industries. Experimental studies have produced positive results and have led to real world applications (Kedari et al, 2018). Thanks to the continual development of IoT technology, CBM theory is beginning to be used in equipment safety management. An example of equipment bearing condition maintenance was given to illustrate the feasibility and the result shows that the IoT-based safety management for equipment condition maintenance is scientific and feasible; it can facilitate the management of equipment maintenance and prolong the safe service life of equipment (Song, Wu & Wang, 2011). Rymaszewska, Helo and Gunasekaran (2017) sought to address how servitization can utilize IoT, which has the potential to usher in unprecedented innovation in product-service systems. An analysis of successful implementations of IoT in power generator manufacturing showed that CBM can be used in larger projects to improve the reliability of the machinery; whilst this may increase the company's maintenance business somewhat, the main value proposition is for the end customer in the form of lower ownership costs (Rymaszewska, Helo & Gunasekaran, 2017). In Kwon et al. (2016) broad discussions on how prognostics and system health management can enable discipline that used sensors to access the heath of system, diagnoses anomalous behavior and ultimately predicts the remaining useful performance over the life of assets.

Our research deals with use of IoT to enable CBM in the elevator industry. Although there have been many proposals to apply CBM to elevator servicing over the decades, it was Lin, Hsu and Rajamani (2002) who published the first simulation of CBM in the elevator service field. Lawrence, Saxena and Knapp (1995) proposed CBM over statistical-based maintenance in the elevator industry. Lee et al. (2006) demonstrated CBM using one of the main elevator manufacturers as a case study. They implemented continuous monitoring of braking systems and the acceleration and deceleration of elevators to ensure the elevators met high safety standards in high-rise buildings. The idea was to use product degradation information extracted using online sensing techniques to minimize system downtime to assess the risk of failure. CBM of elevators has recently taken off, thanks to the rapid maturation of condition-monitoring equipment. The cost of collecting data has declined rapidly, at the same time as signal processing and sophisticated data modeling and analysis have become much faster thanks to cloud computing. In addition, measurement units are shrinking in size, and the reliability and durability of monitoring equipment in harsh environments are improving. All these factors mean the climate is now ripe for adoption of condition-based elevator maintenance.

6.3 Methodology

The study is a single, in-depth case study of a company operating in the elevator industry in China. We have been investigating this company for more than three years and have published related research (Lai et al., 2016; Lai et al., 2018b). Our motivation for continuing to study the same company is that it enables us to carry out in-depth research on certain phenomena in a real-life context. The company has adopted the most advanced IoT technology, together with sophisticated data modeling, and has the potential to build upon machine learning and artificial intelligence into a new commercialized service-oriented offering, embedding a CBM strategy under a new business model. This case is an exceptionally interesting illustration of the importance of integrating technology and CBM in elevator maintenance, as well as the specific challenges inherent in IoT and CBM. Here we describe the continuation of our research: further analyzing of how IoT facilitates implementation of CBM in elevator servicing. We also highlight the main benefits of CBM relative to conventional CM and TBM using two years of real world data collected from more than six hundred installations at different sites operating under different conditions using the company's IoT connected service.

The data for this research were obtained from a number of sources. First, information was collected through participatory observation, which involved one of researchers working with a global elevator company in China, participating in developing an IoT solution for the company. This meant that it was possible to obtain case study information through direct or indirect interactions with other stakeholders and gave us insight into the perspective of various stakeholders. However, we were only able to review the outcome of data analysis instead of raw data in order to be free on competing of interests. We believe that is sufficient from qualitative research perspective as external interpreters. Second, publicly available information was collected from the company, including exemplary CBM cases described in its public documentation and on its website. Third, seven semi-structured interviews were conducted with company leaders involved in the IoT project, including service operations executives, an IoT project manager, the service innovation director, a sourcing manager and service maintenance managers located at various sites. The interviews varied in length but typically lasted one hour. Interviews were conducted at various stages of the project: proof of concept, practical implementation, when customer feedback became available and when the outcomes of implementations were evaluated. The objective was to gain an understanding of in-depth contemporary phenomenon, in particular the conceptual design framework and outcomes of execution. Fourth, we conducted three additional interviews with various IoT vendors from a digitalization consultancy who help to integrate IoT resources, a software company that designs user interfaces for coordinating data analysis and maintenance actions and a global partner providing cloud computing services who provided statistical analysis and cognitive data modeling. Finally, we were able to review the outcomes of the analytical modeling, which encompassed more than six hundred installed IoT units running range from one to two years' timeframe.

The interviews were conducted as open-ended discussions, rather than in formal question and answer style. The interviewer began by asking about the participant's role in the overall project design, then about his or her main contribution and the progress of the project, then gradually moved the discussion from the technical aspects of the project to the commercial factors driving business model value and the underlying challenges. The interview questions included the following, 'What are the main drivers of the value of the IoT offering in elevator maintenance from the client's perspective?'; 'How do the outcomes of CBM compare with those of traditional CM and TBM models and what are the challenges of CBM?'; 'Are your clients happy with this service offering in general?' What is the value you or your clients perceived versus the monetary value paying?'; 'What do you see as the main challenges in condition-based elevator maintenance and IoT technology and how do you see these fields developing in the future?

6.4 Case Description

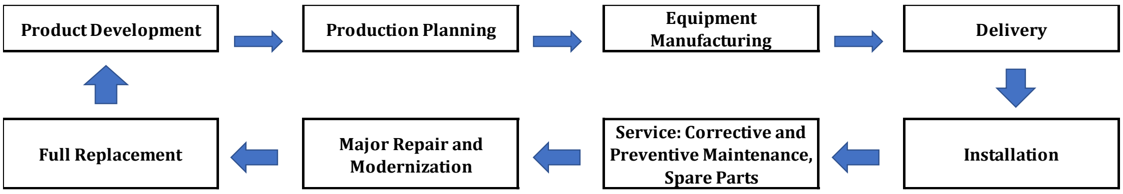
In this section we describe the case study in greater detail, based on the market assessment, documentation review, direct observation and outcome of interviews. These various sources of data reveal the company's strategy and managerial implications to IoT-CBM offerings, as well as their proposed method of creating value internally, for customers and for other stakeholders. We start by describing the company and case background, then the general process of elevator maintenance in theory, and finally its IoT offering and the value the company hopes to create through its use of IoT technology.

6.4.1 Case Background

The company we studied is a leading global company based in Europe that provides solutions for the installation, maintenance and modernization of elevators and escalators. It has a strong presence in China. In addition to manufacturing elevator equipment in China, the company is aggressively expanding its service business by providing CM, TBM, major repairs, retrofits and full replacement service at the end of an installation's useful life (see Figure 6.2). The company installs a lot of its own equipment nationwide, providing a platform for attracting customers to its service offers. Therefore company has an incentive to seek opportunities aggressively in order to expand its service offering for higher revenue from external, and internally improving service productivity and lowering the cost. As such, company provides a standard maintenance service, covering basic maintenance and labor, and a comprehensive maintenance service, covering basic maintenance plus repairs and spare parts. The company's new offering is connected services based on a CBM approach, which customers can purchase in addition to either the standard or comprehensive service package. CM, TBM and CBM can co-exist; they are not mutually exclusive. In addition to offering connected services directly, under its own name, the company is also offering open IoT platform to partnering with independent service companies who are interested in using the connected service to enhance their own service offerings.

IoT provides an excellent match in terms of realized CBM, as well as testing the new business model and gaining sustainable competitive advantage. The company chose to work with a prestigious global player in IoT and cloud computing as a major partner from the co-creation of value perspective, as well as working with local partners to tailor an elevator service solution specifically for the Chinese context. Thus the project represents a joint effort embrace busienss ecosystem in IoT context. The expected benefits include the generation of new revenue from a real-time remote monitoring service, establishing safety alerts, progress towards a more advanced, predictive maintenance services and supplementary benefits such as being able to promote own-brand spare parts and productivity improvements. In addition the company aims to develop a lock-in business model through value co-creation efforts to maintain long-term relationships with customers. Specifically, it hopes to offer tailored services to building owners that will tie them to the company for major repairs and the full replacement of equipment. This new service offering will be targeted at a particular segment, namely those customers that have installed the company's equipment (installed base), irrespective of whether they have scheduled service contract with the company or use a third party to service the equipment.

Figure 6.2: Life cycle of the elevator business



6.4.2 Elevators Maintenance

As described at introduction section, elevators are a common form of infrastructure encountered by the general public in everyday life. After-sales service is crucial to the operational reliability of elevators (Yamashina & Otani, 2001b). As public safety is concerned, maintenance strategy is an important part of an elevator system: it must ensure that the elevators operate safely, reliably and efficiently throughout long periods of continuous usage (Niu et al., 2008). Operational safety and reliability are paramount for the owners of buildings where elevator systems are installed, the facility management company, the tenants and the visitors who use them (Park & Yang, 2010). There are various key objectives of elevator maintenance from the customer perspective:

- Improve safety and reliability;

- prolong useful life;
- minimize inconvenience or business interruptions due to equipment downtime;
- reduce or eliminate the cost of major repairs;
- identify the probability of fault occurrence and troubleshoot issues (repair or replacement).

Conventionally, elevator maintenance operations are mainly carried out by maintenance personnel dispatched regularly to each site. Scheduled maintenance, which is normally carried out at least once a month, can be categorized into two types: (i) basic maintenance, comprising works common to all elevators, including cleaning, lubrication and retightening - these are routine tasks and vary little from one piece of equipment to another; (ii) preventative maintenance, where the tasks vary greatly depending on the parts to be maintained and the work required (Imark & Ozkirim, 1999; Luk, Tsang & Leung, 1997). Preventative maintenance is common throughout the world and may be time- or condition-based. It has been argued that standard TBM is mostly based on OEM recommendations, which may not be relevant if the objective is to minimize operational costs whilst maximizing machine performance (Ahmad & Kamaruddin, 2012a), particularly given that there is variation in installation environments and frequency of usage. This variation means that tailored maintenance schedules are necessary. Moreover, machine designers often have little experience of dealing with machine failures and are less able to make recommendations for preventing failure than the people who operate and maintain them (Labib, 2004). Furthermore, it is possible that OEMs and service providers have a hidden agenda which involves using frequent CM to maximize revenue from provision of replacement parts (Labib, 2004; Tam, Chan & Price, 2006). Because of the problems inherent in conventional TBM and CM strategies it is now recommended that CBM be used to complement these two maintenance strategy in the elevator industry.

6.4.3 The IoT Elevators Service Offering

IoT has attracted the attention of actors in the technology and business communities, who eagerly await the unleashing of its full potential. All companies operating in the Chinese elevator industry, whether global or local players, have started to introduce IoT offerings in the past two to three years. Their offerings have been focused on connected services that enable remote monitoring and have been oriented towards improving existing time-based maintenance strategy. All the companies used connected services in a slightly different way, based on their specific objectives. Some provide connected services to fulfill basic public safety requirements, others use an IoT platform to attract medium or small elevator companies that lack the capacity or capital investment (Lai, Jackson & Jiang, 2018b). And the global players are seeking to provide a brand new offering that incorporates a more predictive CBM service to embrace increasingly demanding customer needs and having a longer term business model opportunity.

In our case company, the new offering is intended to increase end-user satisfaction and reduce complaints, by maintaining the value of assets, prolonging the useful life of equipment, improving public safety and making the operation of equipment more transparent by providing more information. This is summarized in Figure 6.3.

Figure 6.3: Summary of benefits offered by IoT

Customer Benefits	**Operational Benefits**	**Business Model Benefits**
1) Safety enhancement	**1) Optimized maintenance planning**	**1) Long-term customer relationship**
2) Less business interruption	**2) Reduce call out rate - minimize unplanned visit**	**2) Value co-creation with customers**
3) Prolong assets useful life	**3) Preventive repairs**	**3) Differentiation**
4) Planned/scheduled down time	**4) Optimized maintenance planning**	**4) Improve quality and reliability**
5) Asset management - total cost of ownership	**5) Increase customer satisfaction**	**5) New value creation through additional service offering**
6) Analytical information on people flow	**6) Improve communication through professional information**	

There are more specific services that the company claimed their clients and stakeholders should benefit from over the traditional maintenance strategy:

- Real-time remote monitoring of elevator equipment.
- Earlier fault detection and real-time alerts.
- Enhanced, faster service from technicians.
- Basic PM, repairs or parts replacement that is based on continuous equipment checks and performance monitoring.
- Voice or video communication at remote locations.
- Operational analysis and regular reports to all stakeholders, including authorities, through a mobile device portal or direct interface.
- User portals that enable clients to understand equipment performance and thus prolong the useful life of assets.

In basic concept of this offering, machines (elevators and escalators) can communicate with other machines without human intervention, thus cloud computing and data analysis can be used to identify situation in which machine failure is likely and issue alerts to a remote monitoring center, as shown in Figure 6.4. Follow-up actions can then to triggered, including dispatching service technicians to the site with parts and repair tips in advance of a failure actually occurring. The user portal allows the client and other stakeholders to inspect machines before and after the repair or replacement actions.

When it was working on a proof of concept design the company used a value-co-creation design process to gather input from all its stakeholders. The purpose was to ensure the project would deliver value for all the stakeholders; for instance the local authority expected an IoT-CBM connected service to be able to pass information quickly and hence allow trapped passengers to be rescued quickly as well as reducing the frequency of other safety incidents. CBM can mean more reliable lifts, which has benefits for public safety. The China Elevators Association (CEA) believes that IoT-CBM can increase transparency and improve overall lifts assets management; this should lead to further policy improvements. Property/facility management companies would be interested in how the IoT-CBM service could improve elevator reliability and prolong useful life, as well as direct and indirect ways in which it would allow them to enhance their customers (end-users) satisfaction. All the players in the IoT ecosystem - remote transmission device providers, system integration providers, user-interface (UI) software companies, cloud computing and data modeling companies - have their own business considerations or business models and so creating a project which allows them to move in the same direction and work towards the same goal was one of the biggest challenges, according to the company executives we interviewed. Figure 6.5 depicts the complex network of activities making up the IoT ecosystem, which need to be coordinated amongst the various stakeholders (vendors, other service providers, customers and authorities).

Figure 6.4: Basic elevator IoT offering activities

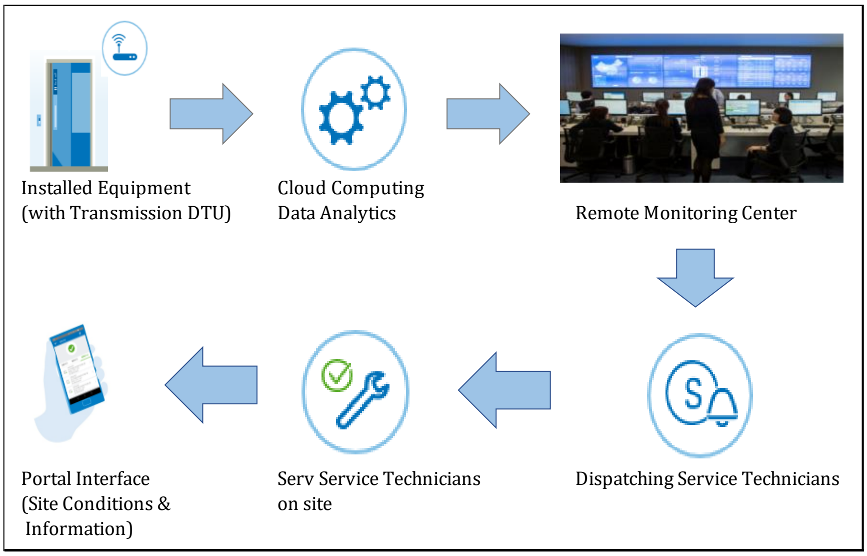
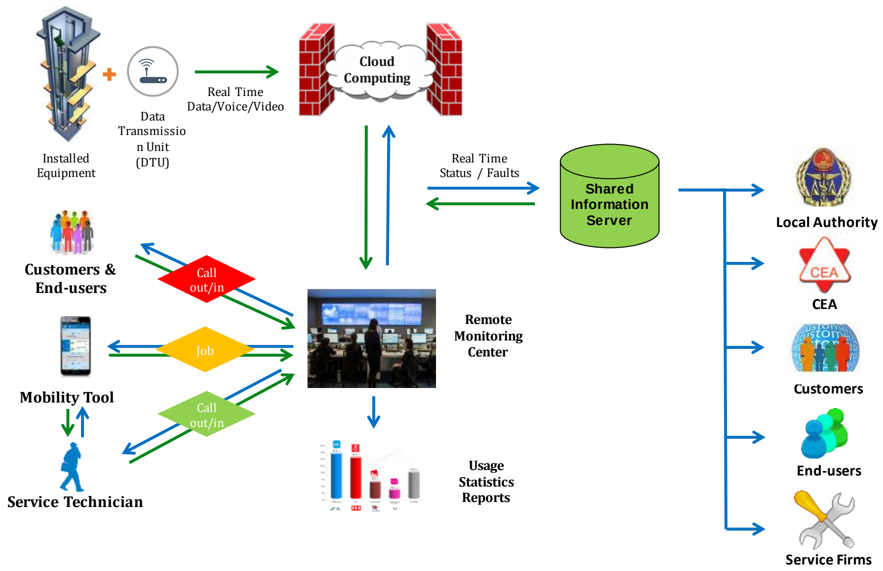


Figure 6.5: IoT-CBM service structure and its ecosystem



6.5 Case Analysis

In the previous sections we have described the various maintenance strategies, CBM, and the principles, general processes involved in IoT-CBM operations as well as the commercial considerations. We have also provided background to the case study and the set out the main objectives of the new service offering, which is the subject of this study. Thereby, information deriving from multiple research methods, we illustrate in greater detail how IoT can enable CBM in elevator servicing employing the case from an elevator maintenance perspective, drawing on the three main elements of maintenance strategy (Jardine, Lin & Banjevic, 2006): data collection, data analysis/modeling, and the decision process. We also analyze the differences between CBM and traditional CM or TBM and discuss their relative merits.

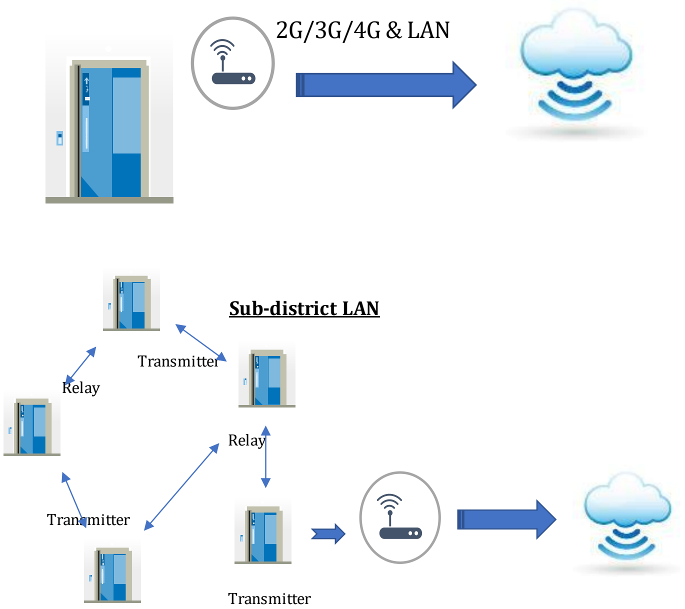
6.5.1 Data Collection

Data collection is the most important task in any maintenance operation and is always the most challenging (Waeyenbergh & Pintelon, 2002). There is always a timing effect concerning dataset, regardless of whether one is measuring failure data, operational information, or other predictive parameters. This means that the parameters of interest always include timing, in seconds, minutes, hours, days, or some other unit of time. Our case study data reveals that only very limited information can be collected using CM, because extensive data are only collected after equipment failure. Nevertheless it is still possible to obtain a limited historical data by downloading data from the control system attached at equipment. In conventional, preventive TBM, maintenance is performed at specified intervals or during call-outs for repair. Data can be collected at every visit, but the dataset will still comprise interval data rather than continuous data. Moreover, there are two fundamental problems with TBM data collection: first, the data may not always be available or possible inaccurate due to incorrect recording of sensory effects. Second, a considerable amount of time is required to collect sufficient data points for predictive analysis; in fact the useful life of certain components may not be long enough to allow sufficient data to be collected. As we have already noted, TBM mostly relies on OEM recommendations and experienced technicians' knowledge of what is required to prevent failures. Each elevator installation may be subject to different environmental factors, the quality of installations may vary based on site conditions, and all these factors can affect the operation of equipment and follow up maintenance. Therefore, CBM is introduced to provide a more effective and efficient way of handling this variability than traditional TBM or CM. CBM requires continuous data and until recently continuous performance monitoring was expensive. Nowadays, advanced information technology, such as IoT, sensory equipment and cloud computing, has made such monitoring much more economically justifiable in the case of highly distributed equipment such as elevators and escalators and is ideal for supporting a CBM strategy.

The IoT system used in our case study can monitor up to two hundred critical elevators parameters in real time and more than one hundred escalator parameters. These parameters include door operations, numbers of starts, stopping accuracy, operating direction (up or down), vibration and noise, braking distance, step chain speed and tension (escalators), deceleration time, and many mechanical and engineering statistics, the critical parameters measured shown in figure 6.6 for elevators and escalators respectively. A smart data transmission unit (DTU) that can be attached to the control system for each elevator has been installed. This can collect real-time data and transmit them to the cloud at up to two hundred times in a second in three ways: (1) the installation site can be equipped with a wired or wireless local area network (LAN); (2) the site can be connected through an Access Point Name (APN) using a 2G/3G/4G mobile network signal and data can then be transmitted through the mobile network to the cloud; (3) if neither the mobile network or LAN is available or the mobile signal is too weak, a sub-district network can be introduced. Access to the Internet is enabled by wireless LAN (WLAN) and DTUs via a network of wireless transmitters and wireless relays. A sub-district local network consists of ≤ 50 elevators or escalators, which are then connected directly to the Internet through DTU, with only one data flow for each group of up to fifty elevators. This is the most cost-effective solution if there is a high density of elevators in a building or a group of buildings, such as subway stations, shopping malls, schools, groups of residential buildings etc. Figure 6.7 illustrates the different methods of uploading data to the cloud.

Figure 6.6: Critical parameters measured for both elevators and escalators

Figure 6.7: Methods of uploading data to the cloud

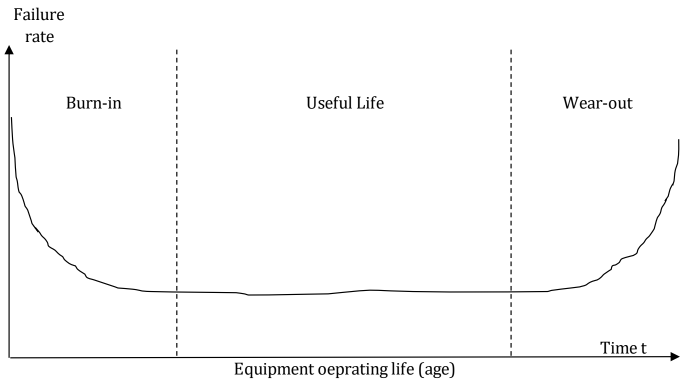


Data security is ensured because the connections between the cloud and elevator sensors are encrypted and required authentication. When working with cloud partners the company adopts secure software development methods for working in embedded systems and for software development.

6.5.2 Data Analysis/Modeling

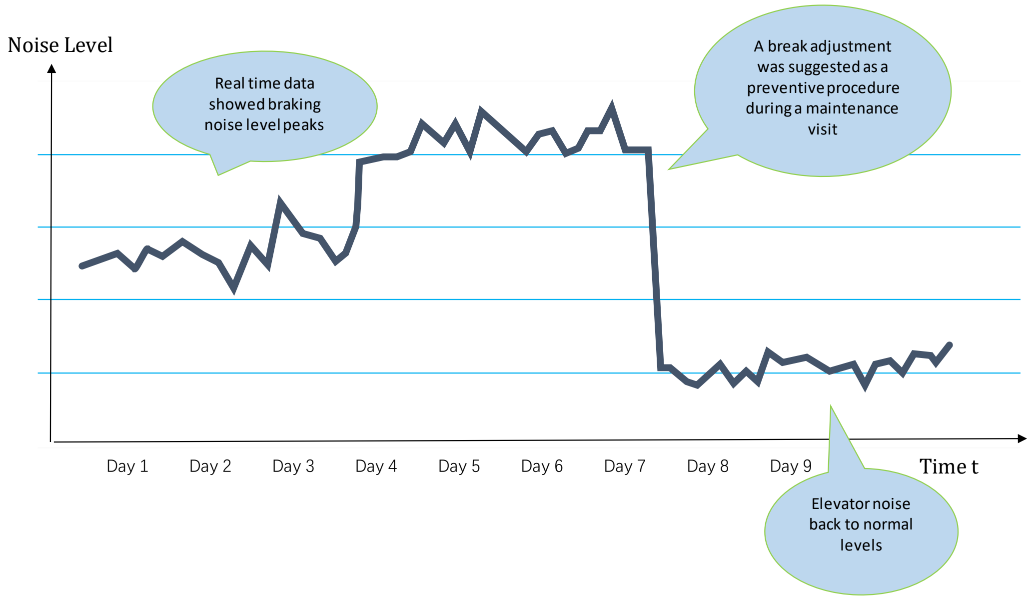
Data analysis is the process by which data about the condition of equipment are cleaned and used in calculations and modeling to generate information that can be used to formulate action plans and take decisions. This is also a common theme in TBM concerning elevators the company analyzes data on the timing of failure to uncover trends and identify predictors of failure based on data gathered during scheduled repairs or component replacement. Maintenance decisions are based on failure time analysis, which assumes that the failure behavior of the equipment is predictable. This assumption is based on reliability theory with respect to the Weibull distribution and bathtub curve assumption, as shown in Figure 6.8 (Ebeling, 1997; Hameed, Ahn & Cho, 2010). The Weibull distribution is a life distribution that is widely used in reliability analysis. It is very flexible and can, with an appropriate choice of parameters, be used to model many types of failure behavior (Hameed, Ahn & Cho, 2010). The bathtub curve assumes that the rate of failure of equipment decreases during the early part of the life cycle (burn-in), becomes near-constant (useful life), and then increases towards the end of life cycle (wear-out), until failure actually occurs. As elevators are complex multiple component systems the OEM will specify a design lifetime for all the critical components based on multiple reliability distribution theories and this information can be used to formulate a maintenance strategy. The design lifetime is the time within selected duty that the product fulfills its intend performance with defined reliability range, when design lifetime exceeds, component's performance starts to fall into wear-out phase. Furthermore, equipment designed lifetime matches to intended market conditions, customer segments and it align with corresponding elevator equipment solutions and processes. For instance, safety gear designed for thirteen years in standard duty load and not much different among low duty to heavy duty. The design lifetime of drive belts of landing doors is more variable, ranging from eight years under standard duty to four years under heavy duty. The reliability of traveling cable has even wider variation, ranging from twenty-five years under standard use to four years under extra-heavy duty. All these design lifetimes provide basic assumption to formulate standard and planned maintenance. However, because elevators are installed in dispersed and different environments with varied installation quality and operating conditions. These varied conditions influence the useful life of standard components, the assumptions on which design lifetimes are based may not always apply in practice. Trend analysis or statistical modeling cannot assume constant operating conditions (Mann, Saxena & Knapp, 1995). Constant operation conditions may not represent the actual conditions of the equipment during real operations, and therefore preventative maintenance still relies on the knowledge and decision-making of skilled and experienced service technicians undertaking regular periodic maintenance. Expert interviews also revealed that in the elevator and escalator industry it is standard to offer a one-year comprehensive warranty covering labor and materials; this allows owners to avoid the financial risks associated with possible early burn out of components or initial commissioning phase adjustment to site conditions.

Figure 6.8: Bathtub curve



CBM is based on the principle that it is possible to determine the condition of equipment by analyzing up-to-date data on certain parameters. In our case, we observed that cloud computing partners, using sophisticated data modeling together with machine learning and AI systems, are capable of analyzing various forms of data collected from the cloud, including acoustic data (noise), numerical values, temperatures, waveforms and multi-dimensional engineering data. In addition to data analysis modeling and machine learning enablement, noise of data needs to be eliminated or minimized during the analytic process, as well as considering OEM recommendations and expert knowledge. Ultimately, data can be converted into useful information that can be used in subsequent decision making. Figure 6.9 illustrates an example that by analyzing the continuous data tracking for elevator breaking noise can have early detection for predictive actions to minimize the occurrence of faults or failure.

Figure 6.9: PM – Braking noise adjustment



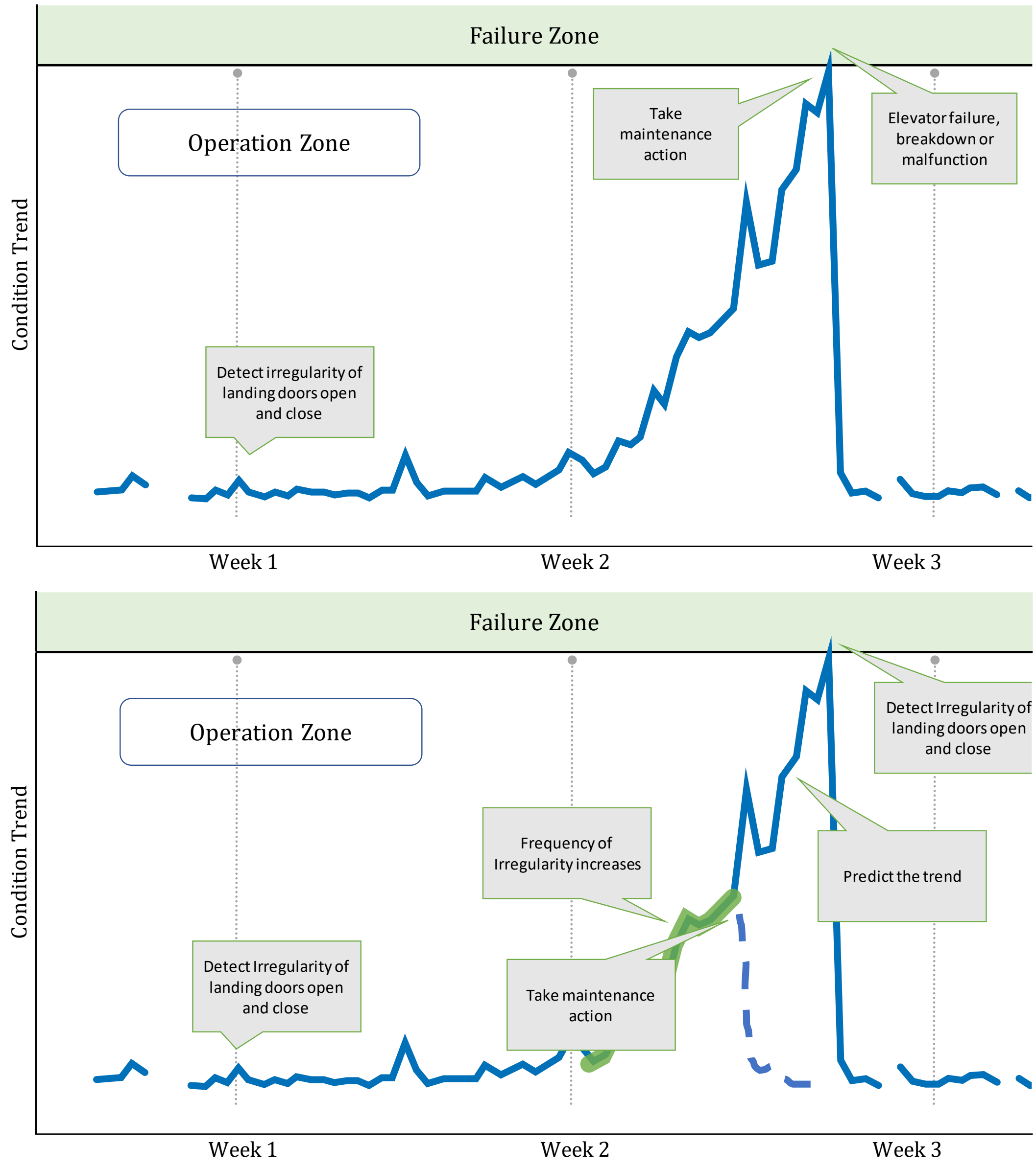
6.5.3 Decision-making Actions

The decision process consists of using information obtained from analytical modeling or intelligent predictive decision support systems to take decisions about maintenance. The main objective is to avoid machine failure causing an interruption to business or a safety incident, whilst also minimizing unplanned maintenance, which is undesirable from the service firm's perspective.

In preventive maintenance fundamental in theory aims to optimize planned maintenance and minimize the frequency of maintenance intervals, at the same time achieving the avoidance of machine downtime, reducing maintenance costs, and prolonging the useful life of the asset. However, as discussed earlier, the service firm may having hidden agenda to increase revenue by replacing spare parts more frequently. Because elevators are used daily by the general public safety is critical and so maintenance decisions are governed by two principles. First, they must comply with mandatory regulations. For instance, in China (Special Equipment Safety Supervision Regulation, State Council Order No. 549 2009; Lift Maintenance Regulation, 2017) bi-monthly maintenance checks are mandatory although a few cities are already considering whether this requirement could be relaxed where real-time monitoring and CBM are in place. Second, there is a need to consider OEM recommendations, which are based on historical failure data and statistical simulations, plus the knowledge of experienced and skilled engineers. There are pre-defined, standard, modular elevator and escalator maintenance procedures, which vary from company to company based on the company's understanding of the different types of manufacturing equipment design and installation quality, such as basic inspection modules, door operator modules, landing door modules, machinery modules, control panel modules, and signalization modules, inter alia, all have to be examined on every standard maintenance visit or every other visit, depending on the planned maintenance schedule, as well as during occasional unplanned, urgent call-outs for repairs or component replacement. All these maintenance decisions not only affect the cost of maintenance directly, they also affect the final price the end customer is charged for a service package. Most companies offer several service packages at different prices: standard maintenance, comprehensive maintenance (covering both labor and material), and call-out maintenance (charges based on the work carried out).

In CBM maintenance in our case, decision making, particularly concerning prognostics, can be accomplished through deterioration modeling, using both current condition evaluation-based (CCEB) and future condition prediction-based (FCPB) methods. Thus, we use one of install elevator real cases as an example (see Figure 6.9), representing a typical CCEB situation. Real-time monitoring detected an increase in the background noise level and although this does not affect the normal operation of the equipment, the decision-making system nevertheless suggested that adjustments should be made at the next regular maintenance visit, based on these data. Another example of CCEB is shown in the upper box of Figure 6.10. The condition monitoring system detects unusual opening and closing of the elevator doors; the system continues to track the irregularity and evaluates when to trigger maintenance action, system has to analyze the condition either reparable or irreparable before maintenance action can be carried out when necessary or planned. The lower box of Figure 6.10 illustrates a system for calculating the frequency of unusual door opening and closing; the monitoring system also predicts the trend in this system behavior, in this instance it predicts that there is a high probability of breakdown in the next few days. This would be risky for passengers, so the system immediately triggers planned maintenance action designed to avoid the predicted safety incident. This is an example of the FCPB approach. The limitation of CCEB is that there may not be sufficient time for planned maintenance if the evaluation shows that the equipment has already reached or exceeded the failure threshold; on the other hand, the limitation of FCPB is that predictions of the trend are based solely on the most up-to-date dataset, and thus observing a clean dataset based on the real condition in real time is mandated, otherwise unplanned maintenance will be carried even more frequently than the pre-determined TBM level if the data noise is deemed unacceptable. However, the challenge lies in the real world there will be noise in the data when unforeseen external forces, such as passengers forcing doors open when the elevator is still running, or touching the stop button when an escalator is running in normal conditions, trigger instantaneous failure signals.

Figure 6.10: Current condition evaluation-based (CCEB) and future condition prediction-based (FCPB) elevator maintenance



6.5.4 Comparison of Corrective, Time-based and Condition-based Maintenance

In this section we use two real elevator system cases to compare CBM based on an IoT-based remote monitoring service with conventional CM and TBM. The data-based prognostic capabilities of the new CBM service allow detection of faults or failures via an IoT-based remote monitoring system, which should - in theory - mean a more efficient and effective response to site conditions than conventional, labor-intensive approaches to maintenance.

Figure 6.11 depicts a case of an elevator fault or failure at an installation unit. Under the traditional approach the customer will react by calling the elevator hotline as soon as possible and the service company call center will respond by sending a service technician to the site. Usually customers have insufficient knowledge to describe clearly what components and parts of the system have failed or malfunctioned. The service technician has to travel to the site, carrying diagnostic tools, and assess the condition of the system on site, then report back by mobile phone, requesting the delivery of spare parts to the site. A service technician visits later to carry out repairs.

CBM with an IoT connected service would provide a much better service. The remote system would detect the failure almost in real time and without human intervention. The system would then trigger maintenance action, either urgent or deferred, based on the actual operating condition of the equipment. Detailed machine information would be sent simultaneously to the service technician’s hand-held device and the spare parts delivery center. Because the spare parts will be available when the technician arrives on site the technician will be able to carry out repairs straight away. The system is different from traditional CM in being based on analysis of data by a smart system rather than diagnosis by a human technician. It is thus more efficient and effective, and equipment can be returned to normal operation more rapidly. By the same token, the cost of maintenance is much lower from the service firm’s perspective.

Figure 6.11: IoT-CBM vs. CM

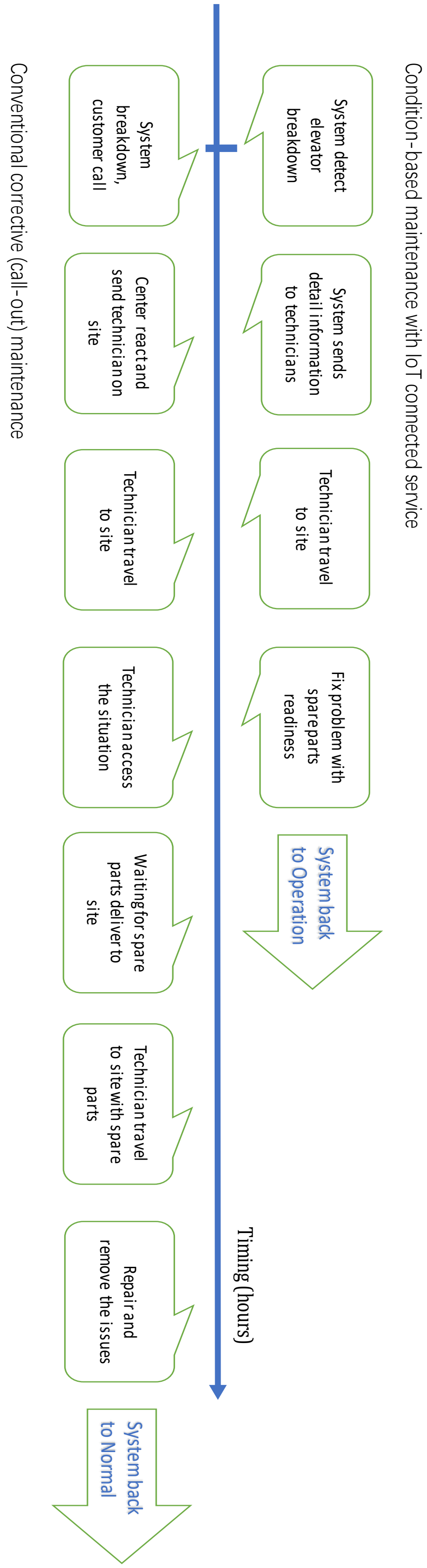
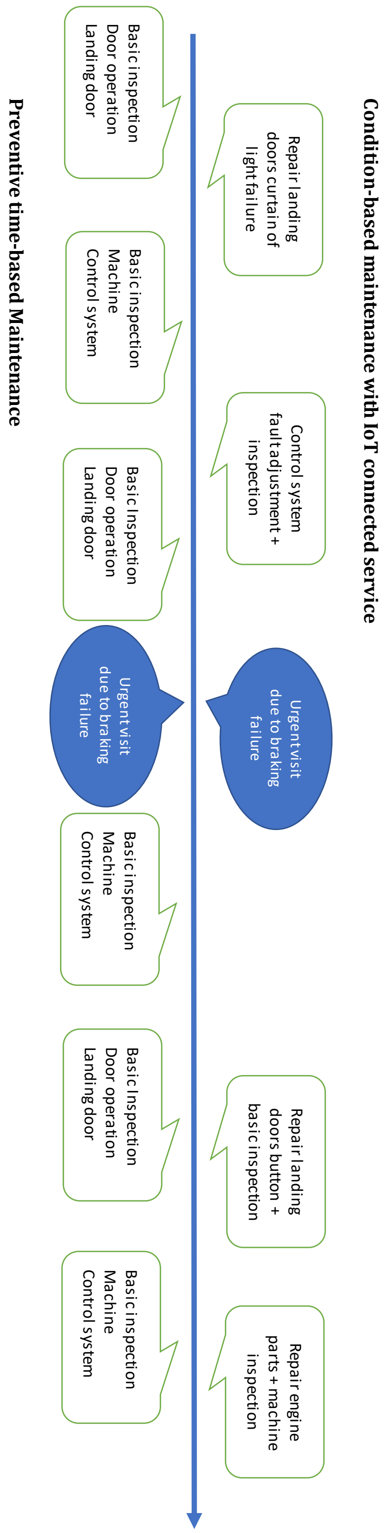


Figure 6.12 demonstrates the advantages of CBM over TBM. Essentially, CBM triggers maintenance actions based on up-to-date information about the actual condition of

equipment, whereas TBM involves carrying out maintenance actions according to a predetermined schedule. Under both systems a breakdown triggers an urgent visit, but under CBM the visit will be more productive. If clients adopt CBM then service technicians' visits will be determined by the operational condition of the installation, but they will carry out routine inspections when they do visit, thus reducing the overall cost of maintenance and making the running of equipment more effective. In summary, CBM is more data-driven which exploits a solution addressing targeted and tailored actions based on the real needs of operational equipment.

Figure 6.12: IoT-CBM vs. TBM



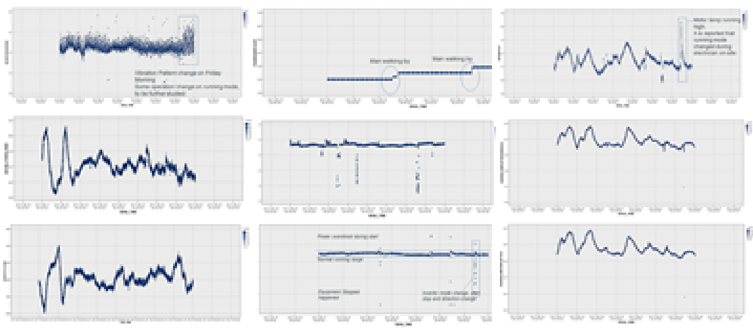
6.6 Case managerial implications and challenges

The research presented in this paper explores the potential benefits of CBM underpinned by IoT technology for a highly distributed elevator service. Interviews and empirical observations suggested that there are also a number of challenges to be tackled. The aim of this section is to discuss what the case study suggests are the main challenges of IoT-CBM applications, as well as the managerial implication for options to overcome these challenges.

- Maintenance optimization. Our case study reveals that CBM has advantages over conventional CM and TBM when it comes to elevator maintenance. However, our interview data suggest that the various maintenance strategies are not mutually exclusive: CBM is an optional service that companies can adopt and it is becoming more economically feasible to use the IoT technology on which CBM relies in business contexts. We argue, therefore, that CBM and TBM can be complementary rather than alternative services, for the purpose of resource optimization. For example, Figure 6.9 shows that although analysis of real-time data indicates an increasing noise level, the increase is not sufficient to trigger immediate maintenance action. It is therefore sufficient to notify the service technician via his or her portable device that a braking adjustment is needed on the next scheduled maintenance visit. The managerial implication is that CBM should be considered carefully and not regarded as a panacea; managers seem keen to use CBM alongside other maintenance strategies in order to optimize overall resource use.
- Data integrity. CBM relies on the availability of valid, clean datasets; without such data the analyses on which decisions about maintenance are based cannot be undertaken. CBM requires both structure and anomalous patterns in the data to the failure mode and make connection to the underlying physical equipment, data needs to be screened to avoid spurious patterns of correlations. Unfortunately, there is no such thing as a clean dataset and so dealing with noise and outliers is the biggest challenge to implementing CBM in real-world conditions. Elevators are used in everyday life in multiple locations and situations; not every elevator operates in a clean, well-organized and safe environment. Analysis of data and direct observation indicates that passengers frequently use elevators or on escalators in unforeseen ways, for example forcing doors open or closed, damaging buttons, running in the opposite direction on escalators, overloading equipment, damaging it with extraneous objects, pouring water into electrical parts etc.. All these unpredictable actions will cause unusual signals in data and they are difficult to identify using remote monitoring systems. As far as possible these data must be eliminated from statistical modeling, otherwise the predictions underlying recommendations for PM, particularly predictions about components’ useful life, will be inaccurate and hence lead to inappropriate recommendations for maintenance activity. Figure 6.13 illustrate the concept that the case study company is working with partners to find ways in which cognitive and machine learning systems can identify these outliers; it is hoped that eventually self-

learning systems will be developed and predictions about the future condition of equipment will become more accurate.

Figure 6.13: Analyzing data integrity



- Data acquisition. Real time data collection is one of the value drivers of elevator CBM, these dataset could will include both voice and video in addition to text data. However it is important to consider the cost–benefit justification for twenty four hours seven days “real-time” monitoring of all data formats. For instance, if passengers are trapped inside an elevator the system must treat this as high priority and trigger an urgent reaction, because of the public safety implications. Under this safety related incident, real-time video monitoring could be the utmost solution with complement other maintenance strategy. In reality, transmitting text format signals via mobile access points (APN) is affordable, and can enable the cloud to alert the service center to a possible major system breakdown, transmitting voice data costs more, but the costs may be acceptable in urgent cases. Video services may cost much more at current stage and so real-time 24/7 video monitoring may not be cost-effective or financially viable unless there is a local WiFi network available. Hence company treat voice and video as an optional connected service and is up to customers to decide based on specific needs and local network condition. There is an implication that ultimately technology development may enable faster mobile networks becoming available or carrier costs are significantly lower
- Data availability. The challenges of collecting data in real time are probably less critical, if data is available. Measuring the condition of equipment in real time to support decision-making remains a particular challenge if needed data is not available at current setup. The expert interviews we carried out revealed that the best way to determine what data needs to be collected by experimenting continuously, finding more patterns through data modeling, learning from failures or faults not detected by existing models and implementing corrections on the fly. As an example, in traditional time-based elevator maintenance the technician needs to carry tools to measure when the elevator balancing rope needs to be replaced, as well as have the experience and

knowledge to use them and interpret the results. Teams are now analyzing installing a few more sensors in the shaft to measure steel balancing rope tension would allow a remote monitoring center to infer the condition of the rope. It implied that as IoT-CBM gets alone the way, more and more data must be obtained with additional sensors installed. As another example, installing infrared sensors in elevator cage makes it possible to identify the number of passengers in the car cage on a continuous basis and these data can be used to analyze the flow of people and elevator usage and to determine whether there are passengers inside the cage in the event of power outage. Additionally, by installing additional counter sensors on an escalator, it enables measuring the number of people and establishing the load on the escalator; at the same time it provided additional people flow analysis so that the client could understand the dynamics of escalator traffic and use this information to redesign the transportation flow. All these examples reveal that when there are insufficient data currently, by obtaining more data, CBM can learn and thus handle more situations concerning the actual conditions of equipment, and become more adequate for commercialized application.

- Data analysis/modeling. Data can be collected from the main control box in elevators with a few dozen sensors and detectors pre-installed in the standard elevator. These data are transmitted to the cloud in real time, but the challenge is to identify useful patterns in the immense volumes of data gathered. The concept of an IoT has become popular, but it only becomes really exciting when some intelligence is applied to the process of linking data computing and analyzing in the cloud. The single most important element of CBM is converting data into information that can be used to in decision-making and this remains a major challenge. Taken from our interview, company expect to advance elevator services toward a more predictive basis, which depends on the accumulation of data over time, sophisticated data modeling, and the latest AI machine-learning technology. This capability is probably the most valuable driver in IoT-CBM, but we believe this still in the early stage and needs time to develop.
- Investment in knowledge and skill. IoT makes CBM of elevators possible, however company believes from promise to fully CBM still ahead of road to go, the main limiting factor is a lack of human capital to develop, validate and maintain the models necessary for prognostics. These models require not only conventional industry specific engineering and innovation competence, but also expertise in IoT technology, data modeling, machine learning and artificial intelligence, which the company currently lacks. From workforce perspective, they also require a suite of new skills for which the current service fleet is not necessarily ready. As CBM would make some basic service technicians' skills redundant as diagnoses would be carried out by machines, some decision making and data analysis could well be done better by machines than by

humans. As such, one of managerial implications is to invest new suite of knowledge and skills under IoT-CBM environment.

- Business model perspective. One of biggest challenges for IoT business models in other industries has been realizing the potential business value of IoT in real life contexts (Leminen et al., 2014). IoT will provide a breakthrough if and only if it provides customers with clear benefits, so that business models can be monetized (Leminen et al., 2012). In our elevator CBM case, the company had solid business applications linked to its core competences; the challenge was convincing clients and other stakeholders of the added value, so that they would be willing to pay for the new service. During our interviews customers constantly asked "Is this new offering really for my benefit or is it for your company's benefit?", "The money I already pay for your service should include high quality and safety standards, so why should I pay more?" and "If this will improve your productivity why not pass on some or all of the savings to me?" Companies may approach the commercialization of IoT solutions from different perspectives, depending on the environment in which they operate. IoT is a relatively new technology and at present there is no way of telling which model will achieve the greatest customer acceptance. This is why the case company believed that there was still a need for trial-and-error adjustment in testing market acceptance. The managerial implication for overcoming this challenge was to have value design tailored to customers' specific needs based on value co-creation with customers or other stakeholders (Lai et al., 2018b).
- Ecosystem perspective. IoT is moving into a new phase, shifting from being used in traditional industries, with a product focus, to service-centric industries, of which the elevator service industry is a good example. The company has maintained its firm-centric perspective for decades, and may not have expertise in IoT ecosystem technology and management so shifting from a company-based business model to an ecosystem business model could be a challenge, regardless of which commercialization strategy is employed (Lai et al., 2018a). We argue that one of the main challenges the company encountered was integrating the business network at the ecosystem level rather than drawing on its own firm-centered competences. It is critical to the business model that the company is able to ensure that all the actors within the business ecosystem share a common goal from value design perspective.

6.7 Conclusion

IoT is changing our world and has great potential as a digital disruptor. It could have a huge impact on the physical world, improving operations and reducing costs, creating new products and business models and driving engagement and customer experience. Recent advances in IoT technology have provided economic and effective ways for industry to move towards continuous performance monitoring solutions. Performance monitoring, particularly on a real-time basis, is the key element in the shift from conventional TBM to CBM. The main factor limiting implementation of CBM is that the required monitoring system is too sophisticated to be implemented or too expensive. Hence CBM has had very limited application so far, specifically it has been used in aviation, oil-gas refineries, the energy sector, the semiconductor industry and other sectors where there is high investment in heavy engineering equipment. In these sectors it is worth investing in expensive performance monitoring systems because CBM helps to maintain equipment in good condition and prolongs its useful life.

Elevator equipment is installed in millions of dispersed locations and is used by many people in everyday life. Maintenance is critical to ensure the equipment operates smoothly and safely. From a theoretical perceptive, adopting CBM is more realistic and beneficial than TBM or CM in elevator servicing. However, in the business environment it is both difficult and expensive to implement CBM for elevator servicing due to challenges of collecting continuous data for predictive modeling cost-effectively. Nonetheless, the spread of IoT has the potential to make continuous monitoring much more feasible and affordable than it was decades ago.

In this paper, we illustrate the potential benefits and advantages of CBM underpinned by IoT technology for a highly distributed elevator service over TBM and CM through empirical commercial demonstrations. We conclude that CBM is no longer confined to the realms of theory and academic research; thanks to technological advances it can now be implemented in a commercial environment. The elevators service industry used to focus on field service offerings but is now shifting to analytics and new types of experience, with a win-win situation for all related stakeholders. It is finding better ways to deliver, operate, communicate and tailor its services to customers, with the aim of ensuring greater safety and comfort. We have discussed various challenges and limitations relating to data collection, data integrity, data analysis and modeling. There is scope for further research in these areas and into the development of CBM business models and ecosystems from both scholarly and practical perspectives. Our main conclusion is that IoT-based CBM will have significant influence on the implementation of elevator equipment maintenance realizability assessment, prediction, risk mitigation and will ultimately lead to the creation of new business opportunities and business models. We remain positive and will continue research in the elevator servicing sector, with a view to contributing further to practical and academic knowledge.

Chapter 7: The Thesis's Contributions

The contribution of this thesis derives from the different studies presented in the four papers in journal format. This chapter presents a summary of these contributions in each of the papers as well as a summary from the perspective of the overall thesis.

7.1 Paper 1 (Chapter 3) – Designing Service Business Models for the Internet of Things: Aspects from Manufacturing Firms (Lai, Jackson & Jiang, 2018a)

This paper aims to explore the main criteria or guiding principles to follow when manufacturing firms attempt to design their service model based on the IoT. The objective of the paper is thus to answer the first research question. The paper is developed based on a content analysis of a literature review of a number of studies related to the business model of the IoT in general as well as the value of the IoT that may generate new business opportunities. The literature is gathered through a review of databases of journal articles and conference proceedings, hard copies of journals and conference proceedings, books and the Internet.

A viable business model will play an important role when it comes to leveraging the opportunities arising if new technology innovates, matures and is cost-effective – but how will the IoT provide these many business opportunities? What are the main differences between designing IoT business models and designing conventional firm-centric core competence-based business models? Furthermore, what are the critical guidelines to follow when developing service business models for the IoT if theoretically they could be in a different spectrum from the traditional business model? In this paper, these questions are addressed and the researcher's input and recommendations are provided from both the theoretical and the practical perspective. The aim is to analyse the critical guiding principles when designing an IoT business model in manufacturing firms, in which it is argued that there should be a business model containing service centrism, value co-creation, resource integration, a business ecosystem and capitalised value of information and eventually a business model from the perspective of maintaining long-term relationships. This paper's contribution lies in the fact that these guiding principles can be generalised to other traditional manufacturing firms adopting the IoT for their new service business model deliveries. These design guiding principles contribute to the establishment of the framework of design guidelines for IoT business models in this thesis, presented in Figure 1.1.

Finally, this paper also describes three exemplary real-world practical applications showing how legitimate manufacturing companies develop their new service-centric business models based on IoT technology. These cases are mainly produced from interviews with company leaders as well as public information. Though they are not particularly in-depth case studies, the purpose is to give ideas to the audience that these guiding principles can be applied in these cases at the conceptual level and hence test the managerial implications proposed.

7.2 Paper 2 (Chapter 4) – Internet of Things Business Models in the Ecosystem Context – Cases of Elevator Services (Lai, Jackson & Jiang, 2018b)

The objective of this paper is to elaborate the criticality of ecosystem business model design from a conceptual perspective in relation to the conventional firm-centric business model framework and their similarities and differences based on the underlying IoT technology. The conclusions drawn from this study address the research question of how a business model for the IoT can be designed in the ecosystem concept. Notwithstanding the benefits of business model design in the ecosystem domain, it contributes to the rethinking from practitioners' perspective to transform businesses' adoption of advanced technology and gain commercial and competitive advantages.

The aim of this paper was to analyse the business model from both the business ecosystem and the IoT ecosystem perspective, specifically applied to new IoT service offerings in the elevator industry. The objective is to shed light on the existing and potential models by discussing them in connection with the underlying ecosystems in the designated domains. This study contributes to the recent IoT business model studies, adopting the IoT ecosystem perspective, which advises firms to embrace the business ecosystem concept when designing new offerings in the elevator industry based on IoT technology.

7.3 Paper 3 (Chapter 5) – Shifting the Paradigm to Service-Dominant Logic via the Internet of Things with Applications in the Elevator Industry (Lai, Jackson & Jiang, 2016)

The objective of this paper is to expand the elaboration of the framework of IoT business model design guidelines, in particular from the perspective of service-centric transition, resource integration, value co-creation and long-term relationships, as well as addressing the research question asking how the IoT can enable elevator companies to transition from G-D to S-D logic in a new service offering. This thesis's contextual scope focuses on elevator services; therefore, this paper provides a combined literature review and in-depth single case study to describe how and why the IoT can enable an elevator service company to transition from a G-D equipment focus to a S-D business mode via IoT technology.

In this paper, the researchers take a subjective view that attempts to engage the key resources fully to gain a competitive advantage, which is a crucial element of firms' service-centric transition, and companies may be able to engage the latest IoT technology to facilitate the transition that acts as a key agent to promote shared information, knowledge and skills enhancement and hence to embrace value co-creation. This paper hence contributes to the effort of traditional manufacturing firms to embrace the IoT when attempting to transit to S-D logic via value co-creation and resource integration with the aim of maintaining business models involving a long-term relationship with stakeholders; hereby, a new elevator service offering is introduced to exemplify the applicability in the business context.

7.4 Paper 4 (Chapter 6) – The Internet of Things Enabling Condition-Based Maintenance in Elevator Services (Lai, Jiang & Jackson, 2019)

The objective of this paper is to illustrate and highlight important aspects of the value of information in the guiding principles for IoT business model design. CBM is recognised as a beneficial solution for services, and it relies on efficient data collection and effective data analysis and hence generates meaningful decision making for maintenance strategies. This paper presents a study to demonstrate how IoT technology can enable highly distributed elevator equipment services through remote monitoring technology to facilitate elevator maintenance's shift from traditional corrective maintenance (CM) and time-based maintenance (TBM) to more predictive CBM to achieve various benefits. It also aims to address the fourth research question on how the IoT can enable elevator companies to achieve data-driven CBM.

The literature indicates the benefits of CBM over conventional CM and TBM from the theoretical perspective. CBM from the theoretical perspective makes business sense regarding elevator maintenance; the challenges lie in data collection, data analysis and the decision-making process when applied to real-world business applications. The main findings of this study suggest that CBM can be executed and commercialised to enhance elevator maintenance in terms of improving the safety and reliability of the equipment, from the technology, process and economical solution perspectives, and meeting the need for continuous monitoring via advanced IoT technology in elevator services. The main contribution of this paper lies in providing empirical evidence of the benefits and challenges of CBM via the IoT over conventional CM and TBM in elevator maintenance. It is believed that this study is timely and valuable for firms working on similar research or commercialisation strategies.

7.5 Summary of the Thesis's Contributions

Each of the papers is an independent and identically publishable article; some of the papers discuss viewpoints that perhaps overlap or are repeated though from different angles. The consolidated contribution of this thesis from paper 1 to paper 4 (chapters 3 to 6) is to demonstrate how industrial goods manufacturing firms design their service business model by adopting IoT technology using cases of elevator services. It is intended to prove that fundamentally technical advancement itself might generate opportunities, but a viable business model finally needs to be realised in commercialisation.

From the academic perspective, this thesis aimed to contribute to the establishment of a framework of design guidelines, as shown in Figure 1.1, from different theoretical concepts to shed light on IoT business model design using mainly the case study research method. Paper 1 contributes the key elements of the design guidelines; paper 2 focuses on an illustration of the need for an ecosystem as the main umbrella of the business model design guidelines using three comparable case studies; paper 3 uses a single case study to demonstrate the theoretical transition from G-D to S-D logic with inherent value co-creation, a long-term relationship perspective and resource integration; and paper 4 shows that the capitalised value of information from the IoT can enable CBM from theory to reality.

In addition, through the practitioner lens, practical applications applying these theoretical design guidelines explain the service transition, value co-creation, ecosystem and capitalised value of information in detail, demonstrating the rationalisation when designing an IoT business model. Specifically, the elevator industry is chosen to use the same case, linking chapter 4 and chapter 5, to illustrate how and why it will work in real-world elevator service applications. Finally, paper 4 in chapter 6 uses the same case, linking paper 1 to paper 4; in a longitudinal investigation of connected IoT service offerings from proof of concept to real-world commercialisation, the main contribution is to prove the criticality of information in performing more beneficial CBM for both firms and related stakeholders through a practical commercialisation study. Thus, this framework of design guidelines is valid in a commercialised business model and benefits stakeholders in such a way that the design guiding principles can be generalised and replicated in similar industries. In summary, the contribution of this thesis is a novel business model conceptual framework of design guidelines for IoT applications that is grounded both in the literature and in interviews and case studies among IoT application companies and IoT professionals.

Chapter 8: Conclusions and Future Research

The IoT is changing our world and has great potential as a digital disruptor. It could have a huge impact on the physical world, improving operations and reducing costs, creating new products and business models and driving engagement and customer experience. Recent advances in IoT technology have provided economic and effective ways for industries to move towards not only continuous performance-monitoring solutions but also other advanced solutions that enable disruptive business model opportunities. Not everything will be different in the digital world in the IoT environment; this thesis indicates that large traditional companies can outcompete the fast-moving digital world if they embrace different ways of thinking and find ways to make it their business model.

Elevator equipment is installed in millions of dispersed locations and is used by many people in their everyday life. Elevators' overall servicing is critical to ensure that the equipment operates smoothly and safely. The elevator service industry used to focus on field service offerings but is now shifting towards analytics and new types of experience with the help of advanced technology, producing a win-win situation for all the related stakeholders. It is finding better ways to deliver, operate, communicate and tailor its services to customers, with the aim of ensuring greater safety and comfort.

The objective of this thesis is to investigate the key criteria when designing business models underpinned by IoT technology in manufacturing firms with a conventional product focus. The research specifically focuses on the elevator industry as its major contextual scope. The objective is broken down into one main research question and three subsequent research questions that are answered through four different research projects and reported in four separate papers. The conclusions of these research questions can be summed up as conclusions for the overall objective of this thesis. In the following, there will be a discussion of the findings and conclusions obtained in relation to the four research questions.

8.1 Conclusion RQ1: How Can Manufacturing Firms Design Business Models for the Internet of Things?

This is quite a broad question, set as the main research question for the entire thesis; the contextual scope is limited to conventional goods-centric manufacturing firms' attempt to design service-centric business models via the latest IoT technology, here using the elevator industry as the main case study.

The IoT technologies connecting the physical world with the world of the Internet promise a number of benefits to both potential customers and vendors of the solutions. Despite these benefits, the adoption of these technologies is relatively modest at the current stage. The expected rapid adoption of IoT technologies depends on the stability, diversity and productivity of the business model innovation that is being formed around these technologies. The technological advancement of the IoT itself is currently helping to overcome some of the technical challenges; apart from the technical challenges, a number of studies have begun to investigate or intend to examine further how firms can invent a new business model by effectively this advanced technology utilising and hence creating value for the entire business ecosystem.

To sum up the answers addressing this research question, it inspires our understanding of the IoT domain from the business model design perspective. The thesis analyses the role that the IoT has played in business models to date and derives six critical guiding principles for designing service business models for the IoT in manufacturing firms. It hopefully offers a holistic overview and may serve as a means to identify new opportunities for business model innovation frameworks and theory. It investigates the related IoT business model literature and understands the business model angles for the IoT, regardless of whether the design, technical or ecosystem lens is used, describing them with real-world examples from practical business case studies. These guiding principles promote an IoT service-centric business model. The IoT facilitates a value co-creation business model and strives to maintain a long-term relationship business model. An IoT business model should capitalise on the value of information, reinforce resource integration and reflect the value of the ecosystem and network partners. The research concludes that these six guiding principles serve as the foundation to commercialise a business from a managerial perspective instead of focusing only on the disruptive technology perspective, helping manufacturing firms to design a viable business model in an IoT-enabled environment.

8.2 Conclusion RQ2: How Can Business Models Be Designed for the Internet of Things in the Ecosystem Concept in Elevator Services?

Paper 2 explores the way in which firms nurture the business ecosystem to deal with the emerging IoT ecosystem business model. Three implications are highlighted in the empirical study as underlying ecosystem business models in the IoT field. First, the IoT in general is inspiring a wealth of new business models, which frequently involve diverse partners and increasingly cross-industry ecosystems. Thus, innovations in this area predominantly present an ecosystem and cross-industry orientation in contrast to the traditional industry-specific incremental innovation. Therefore, it is argued that the existing methods of business modelling are not sufficient to address the IoT ecosystem. This paper suggests that firms have to shift their thinking from the single-firm business model of innovation to the ecosystem business model when innovating new offerings in the IoT field.

Second, through the case study's expert interviews and the literature review, the critical element of the IoT business model concerning data analytic capability is realised, especially moving from relational data modelling to AI and cognitive capability, which are particularly important to the cases in the elevator service segment. Data are collected on a real-time basis and modelling methods are improving all the time, so the more data are collected, the better the services can be defined. These capabilities rely heavily on working with both technical and business ecosystems over traditional firm-centric core competences. The analytics engine is self-learning, so the various kinds of connected services will definitely come into play to a greater extent in the future. The elevator IoT service business model is turning from selling traditional maintenance services to selling safety and comfort together with guarantees of minimal downtime; this is an interesting vision for IoT elevator services, and further research with practical experiments is needed to accommodate future trends.

Third, all these companies have adopted the IoT ecosystem to provide service-oriented solutions to clients and other stakeholders, including enabling remote monitoring of the operation of elevators, shortening the dispatch time of service technicians to the site and providing predictive maintenance, which can alert operators to the potential malfunction or failure of components in advance to reduce the downtime damage as well as facilitating instant spare part replenishment. All these value drivers are mutual and co-created; they involve not only the company and clients but also different levels of the IoT ecosystem and multiple stakeholders, including authoritative bodies from the business perspective, by linking company and clients at both the machine-to-machine level and the business relationship level. This entails both human and machine learning among stakeholders to ensure the continuous improvement of value for all the stakeholders in the ecosystem; in this regard, deeper service- and customer-oriented thinking is required.

8.3 Conclusion RQ3: How Can the Internet of Things Enable an Elevator Company to Transition from Goods-Dominant to Service-Dominant Logic?

In summary, from a theoretical point of view, applying S-D logic as a market orientation in traditional manufacturing firms means that the traditional goods sales and after-sales services and solutions are no longer discrete functions, and this elevates the strategic importance of the lifetime value of the customer relationship, regardless of the combination of services and goods. An increase in interdisciplinary collaboration would be highly beneficial for the concept's theoretical and practical advancement as well as for dealing with the transformation of traditional manufacturing firms into more service-centric organisations. IoT technology has many positive impacts and may be a driving force in designing product and service offerings by defining a more innovative service flow. The literature review, together with the case study in paper 3, supports collaborative IoT technology to enable perspective shifting. This has implications for organisations, which are required not only to integrate products and services as a business solution but also, more importantly, to shift their mindset towards S-D logic in combination with adopting advanced technology.

From practitioners' point of view, paper 2 in chapter 4 offers a real application relating how a leading global manufacturer has adopted S-D logic by utilising the IoT in its new service offering project. As it is shown that the IoT plays the role of a critical enabler, it is no longer a theoretical study from the technical perspective; more and more firms have either already implemented or are in the process of prototype testing of the IoT in real-world business applications. It is anticipated that research on IoT technology will continue to evolve, providing better service offerings and solutions over the next decade, as the IoT becomes more mature and dynamic. Firms, regardless of whether they are S-D or G-D, should benefit from this technology to transform their business model in a more timely, dynamic and predictive manner. As indicated by one of the industry leaders in an interview, the IoT can increase insight and control, enabled by connected sensors together with handheld applications, which can transform the business workflow from reactive to predictive and possibly from predictive to proactive. Though investment is obvious, mutual benefits will pass not just through firms and their collaborative stakeholders but also to every field technician whom they hire. By adopting IoT technology, traditional manufacturing firms are now able to focus not only on selling equipment but also on innovating in the sales service flow, which produces a long-term value co-creation business model with their clients and ecosystem.

8.4 Conclusion RQ4: How Can the Internet of Things Enable an Elevator Service to Achieve Data-Driven, Condition-Based Maintenance?

Elevator equipment is installed in millions of dispersed locations and is used by many people in everyday life. Maintenance is critical to ensure that the equipment operates smoothly and safely. From a theoretical perceptive, adopting CBM is more realistic and beneficial than adopting TBM or CM in elevator servicing. However, in the business environment, it is both difficult and expensive to implement CBM for elevator servicing due to the challenges of cost-effectively collecting continuous data for predictive modelling. Nonetheless, the spread of the IoT has the potential to make continuous monitoring much more feasible and affordable than it was decades ago.

Paper 4 illustrates the potential benefits and advantages of CBM underpinned by IoT technology for a highly distributed elevator service over TBM and CM through empirical commercial demonstrations. It is concluded that CBM is no longer confined to the realms of theory and academic research; thanks to technological advances, it can now be implemented in a commercial environment. The elevator service industry used to focus on field service offerings but is now shifting to analytics and new types of experience, with a win-win situation for all related stakeholders. It is finding better ways to deliver, operate, communicate and tailor its services to customers, with the aim of ensuring greater safety and comfort. The paper also discusses various challenges and limitations relating to data collection, data integrity, data analysis and modelling. There is scope for further research in these areas and in the development of CBM business models and ecosystems from both scholarly and practical perspectives. The main conclusion concerning the research question is that IoT-based CBM will have a significant influence on the implementation of elevator equipment maintenance's realisability assessment, prediction and risk mitigation and will ultimately lead to the creation of new business opportunities and business models.

8.5 Limitations

IoT-enabled business models have been introduced in many areas and could be used for virtually any product, process or service industry. In this thesis, research is only undertaken in relation to the manufacturing industry and uses elevator firms as the main case study; these have traditionally engaged in both equipment and after-sales service business and are attempting to adopt IoT technology to initiate new service offering opportunities. Therefore, this thesis focuses on manufacturing companies' transition from an equipment focus to a service focus offering; software, e-business, ordinary professional service industries and so on are excluded from this project.

The case studies that are performed within the project focus on elevator companies in China, regardless of whether they are prestigious global brands, local Chinese elevator companies or elevator component suppliers, are all about equipment manufacturing companies and have a presence in the Chinese market. Paper 3 (chapter 5) and paper 4 (Chapter 6) focus on a single case study, which is the same global player headquartered in Europe and with a strong presence in China. In paper 1, three exemplary cases act as a reference to demonstrate the testing of the IoT business model framework developed by the project. One of the cases is the same case study as that in papers 2 to 4. Paper 2 contains a comparison among three elevator-related companies based on the value node framework, applying the same contextual scope of research. That means that this thesis focuses mainly on the elevator industry, and there is a possibility to generalise the outcome to industries with a similar business pattern, such as aircraft engines, central air conditioning, heavy industrial equipment and others. Furthermore, this thesis does not intend to enter into product-, service- or process-specific discussions, though the research focuses on traditional manufacturing firms producing goods and selling a service in general. Therefore, there is a limitation regarding whether these design guidelines can be generalised to all industries without boundaries.

Technological advancement progresses rapidly, for instance in the IoT, AI, big data or blockchain areas. This research project acknowledges that these continuous developments on the technical side may have a further impact on this study of business applications from the elevator service point of view. However, the study does not have the objective of investigating the possible impacts of these specific future technical advancements on the research; the project is formulated in a limited way to approach the specific problem statement in a more comprehensive manner.

Reliability is achieved by demonstrating that a study can be performed on a later occasion with the same results. The assumption of reliability is that, if a later researcher follows exactly the same procedure as described by an earlier investigator and conducts the same case study all over again, the later investigator should arrive at the same findings and conclusions (Yin, 2014). In this thesis, investigating the prevailing latest technology for IoT business model design, it is understood that technology advances rapidly and that new technology can replace old technology at a lower cost at any time. Similar to a business model, it is constantly changing due to the fact that the best way of developing a business model is to experiment in the real world and make corrections along the way, which has been part of the studies in real dynamic markets and real business applications. However, this is not to say that replications are not possible, particularly in relation to the proposed design guidelines, the service transition framework and the concept of CBM implementation. One of the most important aspects in achieving reliability is to document the procedures that a case study has followed. In this research, project reliability is addressed by documenting all the data collection routines – the interview questions, interview results, documentation, direct observation and reviewed literature. The researcher's intention in this thesis is to investigate a modern phenomenon and provide recommendations for practical implications, without the expectation that case studies will produce the same results in every single way. As the researcher is directly involved in IoT business model design in real cases, it is difficult to remain completely objective, as the case company and the researcher's personal views are bound to affect the interpretation of the results.

8.6 Future Research

There are ample research gaps related to IoT business models, as discussed in each of the papers' sections on challenges and limitations. These gaps can be summarized as follows. Firstly, there is little research on IoT business models, particularly regarding business applications. Secondly, generic business model research frameworks face challenges, as IoT fields are often context and concept specific. Thirdly, IoT research always bundles together not only technologies but also a very wide range of diverse industrial applications and business elements. Fourthly, the existing literature presents the way in which business models are used within a single company and not across networks of companies. Finally, there is little academic research on the successful commercialisation of IoT business models. Therefore, all these challenges provide space for further research from both the scholarly and the practitioner perspective. Furthermore, there are many aspects apart from technological challenges on which this thesis does not shed light. Therefore, the recommendations for future research are as follows.

Delve deeper into resource integration. The Internet of Things makes it possible to incorporate and interact with customers in any phase of the value creation process; thus, when a specific IoT technology is integrated with both tangible and intangible or internal and external resources, value is determined uniquely and phenomenologically. How does the IoT specifically contribute to the reconfiguration of resources and services to create a new relational network facilitating customer participation in value creation by interaction with smart objects and embedded sensors? Furthermore, how do such technologies enable access to and adaptation, selection and integration of resources in a continuous process of value co-creation? These open questions remained to be answered, as this thesis does not investigate these areas in greater depth.

Advance to value co-creation. The fundamentals of the Internet of Things lie within the idea that smart objects can think intelligently for themselves. This part of the value creation process is all about taking advantage of the possibilities and using the Internet of Things as a co-creative partner in the same manner that co-creative collaborative projects are managed today between people using technology as an enabler. When given the possibility to co-create in harmony with connected things, both in parallel and independently, greater flexibility in the development process will be achieved. Essentially, the concepts of value co-creation and collaboration, along with the emerging Internet of Things, have been highlighted and reinforced as important trends for future business model development; further studies can determine how these developments can provide profound scholarly activities in the future.

Building value on data. One of the main research opportunities is the availability of unprecedented amounts of data generated from all types of IoT artifacts, which, if properly regulated and managed, can lead to unprecedented insights into business model design and even human behaviours in our increasingly complex digitalised world in which everything is interconnected. Scholars should try to assemble large-scale, ultra-rich data sets from the pervasive digitalization, using data to analyse social and economic activities, the transition to using data to analyse new business opportunities and even determining how to sell data as a key revenue generator in big data business model studies. These areas can be the focus of further studies and can be made available in the public domain to support more systematic scholarly activities.

Beyond the contextual industry ecosystem. There is a need for research that reveals the embedded structures and creates a comprehensive understanding of IoT ecosystem business models as well as depicting the rules of diverse IoT actors and the dynamics of mega-ecosystems, in which different industries and clusters are integrated into a large ecosystem (Leminen et al., 2012). This remains a challenge for future research, which will need to deal with business models that are context specific and should be studied with an emphasis on both generic business model configuration and the specific design framework of the IoT containing ecosystem business models.

Several open questions in this thesis remain to be answered. As a researcher focusing on the elevator-related industry sector, I maintain a positive outlook and will continue to conduct research on the IoT or digitalisation servicing innovation, with a view to contributing further to practical and academic knowledge.

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Appendix A: Cover Page of Published Papers

Paper 1 (chapter 3): Lai, C. T. A., Jackson, P. R. & Jiang W. (2018a). Designing Service Business Models for the Internet of Things: Aspects from Manufacturing Firms. American Journal of Management Science and Engineering, 3(2), pp. 7-22. Doi: 10.11648/j.ajmse.20180302.11

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Designing Service Business Models for the Internet of Things: Aspects from Manufacturing Firms

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Abstract: The increasing pervasiveness of the Internet of Things (IoT) has offered a wealth of business model opportunities. Many conventional product-based companies are seeking to increase their competitiveness by moving toward a service-based business model where IoT can bring tremendous opportunities. These traditional product-sales manufacturing firms are required to look at business models beyond their conventional product-focused, firm-centric core competence business model innovation and respond to fast changing digitalization dynamics focused on promoting service-centric solution availability instead of physical products. However, studies and literatures have not yet provided profound and actionable approaches to service business models in IoT-driven environments for manufacturing firms. This research aims to fill the gap and elaborate the guiding principle for designing service business models for the Internet of Things in manufacturing firms. The guiding principles are derived from illustration of value of the Internet of Things and systemic review of academic literatures focusing on IoT business models. Exemplary real-world IoT service business models cases are demonstrating the applicability of the proposed guiding principles. Evaluation of the applicability of guiding principles pertaining to the emerging context of IoT business model can enable researchers and practitioners to visualize and analyze service business model design in a structured and actionable way.

Keywords: Business Model, Internet of Things, Business Ecosystem, Value Co-creation, Service-Dominant Logic

1. Introduction

Many real world Internet of Things (IoT) applications have been postulated in many industries: the domain not only covers conventional industrial sectors, but also the consuming industry of everyday life, where IoT can bring significant improvement, even leading to new business models. However, the business model based on today's largely static or historical information architectures is facing challenges as new ways of creating value arise between firms, clients, and other stakeholders—in other words, an ecosystem business model instead of a firm-centric business model. In durable goods industrial sectors, selling products is no longer simply goods exchange for their monetary value—for example, paying by usage or by performance is now a common option. In the consumer industry, customer purchasing behavior under a dynamic environment is based on situational preference and analyzing customer behavior is more difficult based on today's general customer survey; for example, firms need to adjust by means of dynamic pricing to attract customer purchasing desirability based on real time data analysis of specific customers and locations, or, in the industrial service industry, providing a real-time remote monitoring service to tailor customers' specific needs becomes more critical and necessary. By providing additional service through precise analysis evolved with the use of a multitude of sensors, firms can help to monitor and manage their clients' purchasing behaviors, operating equipment or manufacturing processes more precisely, raising efficiency and productivity, and hence creating more revenue opportunities. In certain situations, operating environments can be monitored continuously for hazardous environments where objects can take predictive corrective action to avoid

Paper 2 (chapter 4): Lai, C. T. A., Jackson P. R. & Jiang W. (2018b). Internet of Things Business Models in Ecosystem Context-Cases of Elevator Services. International Journal of Computer and Software Engineering, vol. 3(2):135, pp. 1-12. doi: https://doi.org/10.15344/2456-4451/2018/135

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Internet of Things Business Models in Ecosystem Context-Cases of Elevator Services

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Abstract

Companies increasingly have to adapt new technology and design new business models to retain their competitive advantage in highly dynamic environments. The increasing pervasiveness of the Internet of things (IoT) has offered great potential in many different areas of application to lead or complement new business models. However, business models based on largely static, single firm or historical information architectures are facing challenges in today's more dynamic environment as new ways of creating value arise across industries and between firms, clients and other stakeholders. Embracing the business ecosystem concept is now becoming critical in order to realize business opportunities or business model potential. This paper focuses on the elaboration of the business ecosystem concept in the IoT business model environment, from both academic and practitioners' perspectives, to analyse how IoT business models are connected to the underlying business ecosystem. We analyse three cases from the elevator industry to explain how different business models are employed in connection with business and IoT ecosystems, as well as their challenges and possible options to overcome these challenges.

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Internet of things, Business ecosystem, IoT ecosystems, Ecosystem business model

Introduction

Many real-world Internet of things (IoT) applications have been postulatedinmanyindustries: thedomainnotonlycoversconventional industrial sectors, but also the consuming industries of everyday life, in which IoT can bring significant improvement, even leading to new business models [1]. IoT, also called the Internet of Everything or the Industrial Internet, is a new technological paradigm envisioned as a global network of machines and devices capable of interacting with each other [2]. It refers to linking the objects of the real world with the virtual world, thus enabling connectivity at any time, in any place, for anything and for anyone. It enables a world in which physical objects and beings and virtual data and the environment interact with each other in the same space and time. Enterprises can utilize IoT to create and capture value by connecting devices integrated with in-house business intelligence applications, traditional enterprise resource planning and supply chain systems, business analytics and decision support systems [3]. The true value of IoT lies in creating an environment in which the crucial information from any of the networked autonomous actors can be shared efficiently with others on a real-time or interval basis [4]. The adoption of IoT technology is rapidly gaining momentum as technological, societal and competitive pressures push firms to innovate. IoT has the potential to disrupt industries through changing products, services and business models, just as the Internet did in the 1990s [5].

IoT is a broad concept and a consensus has yet to be built concerning a common definition. This paper focuses on conventional manufacturing companies (using elevator services as case studies) expanding their new offering in providing IoT services to generate additional revenue as well as to improve productivity, which essentially can bring value to their clients and other stakeholders. In the IoT service domain, information is gathered from various sensors through networks, processed for information analytics and optimization in a central service (cloud computing) and finally suited to decision making and control of the targeted aspects. These services are expected to find users in a wide range of smart applications related to home, factories, energy, healthcare, logistics and maintenance and could revolutionize society. Especially, there are several initiatives aimed at promoting IoT services in the industry, including "Industry 4.0" in Germany, "Made in China 2025" in China, the "Industrial Internet" in the United States (US) and the "Industrial Value Chain Initiative" in Japan [6]. In particular industry 4.0 foster automation and data exchange over cyber-physical systems, internet of things, cloud computing and cognitive computing, which communicate and co-operate each other and with humanin real time both internally and across organization service offered and used by actors of the value chain [7]. Hermann et al. proposed six design principles for Industry 4.0 implementation; they are interoperability, virtualization, decentralization, real-time capability, service orientation and modularity; which rely on full transparency of communication among physical things, physical and virtual network [8]. Some examples for Industry 4.0 are machine which can predict failures and trigger maintenance processes autonomously or self- organized logistics which react to unexpected changes in production, as well as services through machine to machine interface. All these effect needs everything is interlinked with everything else, it is a fair assumption of driving force behind IoT [9]. However, in the moderngl obal, competitive and collaborative business environment, an IoT business model must be designed as a business ecosystem due to the fact that no firm owns content, networks, software and hardware in the same spectrum. Therefore, business model design considering the business ecosystem is required to bridge the gap between expected value and the firm's existing core competence or innovative capability [10].

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Shifting paradigm to service-dominant logic via Internet-of-Things with applications in the elevators industry

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The purpose of this paper is to investigate how latest technology Internet-of-Things (IoT) can enable/facilitate traditional manufacturing firms shifting to more service-centred business perspective. Service-dominant (S-D) logic has emerged to provide the right perspective, vocabulary and assumptions on which to build a service-centred alternative to the traditional goods-dominant (G-D) paradigm for understanding economic exchange and value creation and has been identified as an appropriate philosophical foundation for the development of service science ([Maglio, P. P., & Spohrer, J. (2008). Fundamentals of service science. *Journal of the Academy of Marketing Science, 36*, 18–20; Maglio, P. P., Vargo, S. L., Caswell, N., & Spohrer, J. (2009). The service system is the basic abstraction of service science. *Information Systems and e-business Management, 7*, 395–406]). S-D logic is in its current state of development is conceptual and few empirical studies exist to test such a logic realized in real business applications. On the other hand, IoT is a novel paradigm recently envisioned as a global network of machines and devices capable of interacting with each other to reach desired business goals in the real world. However, there is considerable research on IoT technical specifications but less elaboration on real business applications. This paper aims to describe IoT as a critical vehicle when manufacturing firms desire to transit to a more S-D and value co-creation business model, with an in-depth real business case study in the elevators industry. This paper aims: (1) to explain the distinction between G-D logic and S-D logic and its implication for manufacturing firms, (2) to examine how IoT can facilitate the transition from key S-D logic managerial implication perspective and (3) to conduct a case study in a new service offering of an elevator service business when transition to more S-D mindset by adoption of IoT, the purpose aims to examine whether the underlying technology can bring different ways of thinking when deploying a new industrial service offering.

Keywords: service science; service-dominant logic; goods-dominant logic; Internet of Things; value co-creation

1. Introduction

A new competitive environment for manufacturing and service industries has been forcing a change in the way manufacturing enterprises are developed. The service sector is gradually taking the main stage of the global economy, manufacturing firms, and particularly industrial goods manufacturers, are also adopting a more

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Paper 4 (chapter 6): Lai, C. T. A., Jiang, W. & Jackson, P. R. (2019). Internet of Things Enabling Condition-Based Maintenance in Elevators Service. Journal of Quality in Maintenance Engineering, vol. 25, issue 4, pp. 563-588, https://doi.org/10.1108/JQME-06-2018-0049

Internet of Things enabling condition-based maintenance in elevators service

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Abstract

Purpose – The purpose of this paper is to demonstrate how Internet of Things (IoT) technology can enable highly distributed elevator equipment servicing by using remote-monitoring technology to facilitate a shift from traditional corrective maintenance (CM) and time-based maintenance (TBM) to more predictive, condition-based maintenance (CBM) in order to achieve various benefits.

Design/methodology/approach – Literature review indicates that CBM has advantages over conventional CM and TBM from a theoretical perspective, but it depends on continuous monitoring enhancement via advanced IoT technology. An in-depth case study was carried out to provide practical evidence that IoT enables elevator firms to achieve CBM.

Findings – From a theoretical perspective, the CBM of elevators makes business sense. The challenges lie in data collection, data analysis and decision making in real-world business contexts. The main findings of this study suggest that CBM can be commercialized via IoT in the case of elevators and would improve the safety and reliability of equipment. It would, thus, make sense from technological, process and economic perspectives.

Practical implications – Our longitudinal real-world case study demonstrates a practical way of making the CBM of elevators widespread. Integrating IoT and other advanced technology would improve the safety and reliability of elevator equipment, prolong its useful life, minimize inconvenience and business interruptions due to equipment downtime and reduce or eliminate major repairs, thus greatly reducing maintenance costs.

Originality/value – The main contribution of this paper lies in the empirical demonstration of the benefits and challenges of CBM via IoT relative to conventional CM and TBM in the case of elevators. The authors believe that this study is timely and will be valuable to firms working on similar research or commercialization strategies.

Keywords Condition-based maintenance, Internet of Things, Time-based maintenance, Corrective maintenance

Paper type Research paper

1. Introduction

Elevators are a common form of infrastructure and are widely used by the general public in everyday life. Continued maintenance after installation is critical to high operational reliability. As the reliability of elevators is critical to the safety of people moving from one place to another, maintenance strategy is an important part of the overall strategy for ensuring the reliability, safety, and efficiency of elevator systems during long periods of continuous use (Niu *et al.*, 2008). From the customer's perspective the two most critical objectives of elevator maintenance are ensuring safety and reliability; the other objectives include prolonging the useful life of equipment, minimizing inconvenience or business interruptions due to equipment downtime, reducing or eliminating major repairs and identifying the probability of fault occurrence and troubleshooting (repair or replacement). Conventionally, there are two types of elevator maintenance strategy: corrective

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Appendix B: Interview Protocol

Interviews are a suitable method for carrying out research when the researcher is looking for views, feelings, opinions, knowledge and so on within a population. In this research project, interviews are performed to gain knowledge of phenomena within different business models of IoT theories; hence, the use of a mixture of open-ended and semi-structured interview approaches is appropriate. Certain levels of questions need to be predefined from theories; however, interviewees are also allowed room to be flexible in expanding the knowledge when answering questions, which will enable more insightful information to be obtained from different angles.

In this thesis, paper 1 conducts three interviews mainly to reconfirm and ensure that the researchers understand the data and cases from three exemplary case companies, with the aim of testing the framework of IoT business model design guidelines developed from the content analysis of an intensive literature review. In paper 2, fifteen interviews for three case studies focus on the ecosystem business model to investigate the need for IoT business ecosystem theories rather than conventional business model theories. In paper 3, twelve interviews are conducted to investigate the phenomenon of goods to service transition based on the underlying IoT technology. Finally, in paper 4, ten interviews are related to the IoT–CBM implementation, the purpose being to verify whether the criticality of IoT technology can enable CBM development and hence take advantage of preventative maintenance. The details of the interview companies and interviewees are provided in Table 2.2. Despite the four independent projects (papers), some of the interviews are repeated during the four-year time frame; predefined interview questions are divided into common and specific questions; and common questions may be asked repeatedly either to reinforce the same outcome or to amend it during commercialisation or technological advancement changes. Specific questions are varied due to the different focus subjects in each of the projects; the interview protocol is provided in this appendix categorised by papers as well as by groups of interviewees.

Table 2.2: Summary of interviews by paper

Company and interviewees	Paper 1 (chapter 3)	Paper 2 (chapter 4)	Paper 3 (chapter 5)	Paper 4 (chapter 6)
Main Case Company				
KONE Elevators (Company A)				
Senior Executive, Greater China	X	X		
Service VP, Greater China		X	X	X
New Service Offering Head, Global		X	X	X
Project Manager, China		X	X	X
Code Manager, China				X
R&D Director, China				X
Sourcing Director, China		X	X	X
Service Finance Director, Greater China		X		X
Chinese Elevators Manufacturer (Company B)				
Managing Director		X		
Finance VP		X		
Chinese Elevators Control and System Provider (Company C)				
Sales VP		X		
Project Manager		X		
Ingersoll Rand Trane				
Senior Executive, China	X			
Industrial Scientific				
VP Operation, China	X			
Authoritative Body				
China Elevators Association				
Secretary of Operation		X	X	
Code and Regulation Director				X
IoT Vendors				
Global IoT Partner				
Account Manager		X	X	
Director of Support Operation		X		X
Application User Interface Suppliers				
General Manager		X	X	
Support Manager			X	
Data Transmission Unit Supplier (Hardware)				
General Manager		X	X	
Project Manager				X
Customers/End Users				
Facility Management Company				
General Manager			X	
Property Developer				
Project Manager			X	
3rd P Project Manager				
General Manager			X	
Subtotal (Number of Interviews)	3	15	12	10

Note: A total of 40 interviews are conducted among 8 case studies in 5 companies over a time frame of 4 years and presented in 4 published articles.

Paper 1 (chapter 3): Designing Service Business Models for the Internet of Things: Aspects from Manufacturing Firms (Lai, Jackson & Jiang, 2018a). Three interviews are conducted to gain knowledge on how these companies' business model for their IoT offering and how the design guidelines proposed in this paper are all considered when they design business models for the IoT. These three companies are selected based on similar criteria: a) conventional manufacturing firms with production and an after-sales service business for many years, all with a manufacturing facility based in China, b) all the companies are adopting IoT technology to expand their business revenue and c) one of the companies is located in this thesis's main contextual scope, which is elevator companies, and the other two mainly come from referrals from a business network and in agreement with interviewees. Therefore, the same set of interview questions can be asked in similar ways.

1. Has your company applied or started utilising IoT technology to seize business opportunities?
2. What are the main benefits of applying IoT technology?
3. What are the potential issues if your company does not start utilising IoT technology? Have you thought about other technology alternatives?
4. In your position, why do you believe or not believe that the IoT is the future trend in terms of technology?
5. Other than technology advancement, what are the critical elements when grasping business opportunities through this new business model innovation?
6. What are the key elements when designing your IoT business model?
7. When applying IoT technology to your business model, are you focusing on enhancing equipment sales or service sales?
8. In a more open question, please give some ideas about the critical guidelines when designing a business model under IoT technology?
9. Does your company innovate its IoT business model based on your company's core competence or does it need to work with partners in this business ecosystem? Can you elaborate more on why and how?
10. Can you elaborate on value co-creation vs. value proposition when deploying an IoT offering? Do you work with customers to obtain their input or assume that you know what customers want?
11. Do you expect to maintain a long-term relationship business model with an IoT

offering or simply sell it as an add-on product in the short term? Please explain your company's approach and how you can assure the company's best interests or mutual benefits.

12. In a more specific business model question, what are the key criteria when commercialising an IoT offering?
13. Finally, verify the research objective, examine these guiding principles and gain the interviewees' feedback and input.

Paper 2 (chapter 4): Internet of Things Business Models in the Ecosystem Context – Cases of Elevator Services (Lai, Jackson & Jiang, 2018b). This paper utilises a research design featuring a literature review and case study with a document review and direct observation together with fifteen interviews, aiming to examine the critical design guidelines for IoT business model design, which must have the nature of a business ecosystem instead of a traditional firm-centric or core competence business model innovation. In this paper, the researchers conclude that the value design framework comprising four pillars – value drivers, value nodes, value exchanges and value extracts – proposed by Leminen et al. (2014) is appropriate from an ecosystem perspective on IoT business design. The comparable three case studies in the same industry apply this four-pillar value design framework to analyse business models in the IoT ecosystem. The interviews are conducted with two sets of interview protocols: i) companies A, B and C, which operate in the elevator-related industry and have introduced an IoT offering within similar IoT ecosystems but with different methods of business model design; and ii) IoT vendors, including both hardware and software, from the ecosystem perspective to gain a deeper understanding of the expanded knowledge of the IoT business ecosystem.

The first set of interview questions is designed for three case companies:

1. Please give a brief background of your company's strategy regarding its IoT offering. Does it focus on a product portfolio or aftermarket service or a new business stream in addition to your existing product and service business?
2. Can you elaborate on your newly developed service offering based on IoT technology?
3. What are the main value drivers of the IoT offering in your company from both the company and the customer perspective?
4. Who are the key actors and what are the key elements or processes involved in

designing an IoT offering?

5. When designing this IoT offering, which business model design concept or criteria do you adopt? Do you consider the model from the firm-centric or ecosystem perspective and why?
6. Who are your key partners? Who are your key suppliers? Which resources do you acquire from partners? Which key activities do partners perform?
7. In the development of an IoT offering, how do you work with your suppliers/partners and to what extent?
8. What are the challenges related to the IoT ecosystem and business model?
9. Do you have a future development plan for an IoT offering? In what direction?
10. How do you treat your IoT vendors and software, hardware, application or data analytics suppliers? How do you rely on them to develop or support your business? Are they your partner and do you assume that these suppliers will work with you towards the same goal?
11. Can you perform all the IoT development with your own core competence or do you need to rely on external resources?
12. What is your view on a more specific business ecosystem?
13. Do you see the difference between an ecosystem business model and a traditional business model when developing an IoT business model? What is the difference and how do you tackle it?
14. Can you predict the future trend of IoT offerings? From an ecosystem perspective, who should invest or where can the expertise be found?

The second set of questions targets mainly IoT vendors/partners in the same ecosystem:

1. Please explain what product or service you provide to your clients (company A, B or C)?
2. What key activities do your value propositions require? Your distribution channels? Customer relationship? What is your revenue stream?
3. What is your business model for providing service to a company and do you know your clients' business model? If not, how can you support your clients in growing their business? If yes, how do you align with your clients' business model and work jointly in

the same direction?

4. What value can you provide for your client? What value can you capture (other than monetary value)?
5. Do you agree that you co-exist or co-survive with your clients? Why or why not?
6. How much do you understand the business ecosystem? Do you think that you will stay in/stick to the same ecosystem as your clients?
7. What can you do similarly or differently from your next clients with a similar offering?
8. Within the same business ecosystem, and with experts in IoT software or hardware, what are your suggestions to your clients when testing their new IoT offerings to the market? More specifically, what value does this IoT offering have for your clients' customers?
9. What are the major challenges and risks as an actor in an ecosystem? Are they different from the major challenges and risks arising from simply being a supplier?
10. Lastly, which opportunities can you grasp better today as a member of an entire IoT business ecosystem?

Paper 3 (chapter 5): Shifting the Paradigm to Service-Dominant Logic via the Internet of Things with Applications in the Elevator Industry (Lai, Jackson & Jiang, 2016). This paper utilizes the explanatory research design featuring a literature review and case study with the interview method, which examine the critical design guidelines mainly for service centrism but touch on value co-creation and resource integration under the ecosystem umbrella to achieve a business model for maintaining long-term relationships. An in-depth single-case study in an elevator company is conducted to examine the underlying managerial implications for how the IoT can enable elevator companies to transition to S-D logic as well as to construct an interpretation from real business applications. The data collected for this research are obtained from several sources. Multiple sources of evidence are used to construct the case study: i) participatory observation, which not only enables insights to be gained into their perspectives but also facilitates access to data, including a variety of strategic and operational meetings, documentation, meeting minutes and presentations; ii) twelve semi-structured interviews, which are conducted with individuals from the main case company, the China Elevator Association (CEA), a property/facility management company, a third-party service company, a property developer, end-users and three IoT vendors. The interview length varies, but the interviews typically last for about one hour. The objective is to gain insights into this contemporary phenomenon and to understand the value that can be co-created from these stakeholders towards an IoT offering.

The interviews are conducted as follows: four interviews with the single case company, one interview with the authoritative body, four interviews with IoT vendors and three interviews with customers (a facility management company, a service company and a property developer). This single case company is the same company as in chapter 3 and chapter 4, meaning that seven prior interviews have been conducted and four are repeated interviewees, but this paper is more focused on the service transition perspective of the questions. Meanwhile, two interviews with IoT vendors are repeated from two prior research projects with a focus on the goods to service transition. In this specific project, three customer interviews are critical to construct the interpretation of the service-centric concept from the other end of the equation. As a result, three sets of interview questions are designed as follows:

The first category of interview questions with the main case company:

1. Can you describe your overall company offering from the product and service perspective? Is there any strategy for moving forwards in this market (China)?
2. Are you implementing the IoT as your offering, and is this IoT offering helping you to sell services? Can you describe this in more detail? How and why can the IoT help your business to grow?
3. What is the main purpose of the IoT offering from the perspective of either selling equipment or providing a service or both?
4. Do you have any comment on service-centric vs. equipment-centric business models? What do you think the trend will be in the future?
5. In your IoT offering, do you design the offering on your core competence or do you discuss it with your customers or even other stakeholders? Why and how?
6. Do you buy into the value co-creation concept?
7. To what level you will share information with your customers or stakeholders, and do you agree with the totally transparent shared information concept? Why or why not?
8. The IoT involves a lot of technology that may not be your organization’s core competence. How do you resolve this issue? If you must work with external partners,

what level of involvement is there with them?

9. How do you ensure that customers maintain a long-term relationship with your organization, and how do you build this relationship into your IoT design?
10. How can an IoT project enhance the company's or employees' knowledge and skills? How can you design this in your proof of concept?
11. From the business model perspective, how do you ensure that your customers are willing to pay you or buy into your IoT ideas? Who eventually benefits?

The second set of interview questions addresses the authoritative body:

1. From the authority perspective, what do you expect from elevator companies regarding IoT connected services? What are your biggest concerns for this industry?
2. Are they any benefits of elevator company digitalisation from the regulatory and public society perspective?
3. What kind of shared information does the authority request from every elevator? What is the main purpose of that?
4. How do you deal with the amount of data collected from every elevator? Can these data help to improve public safety or achieve regulatory advancement?
5. Please give some advice to elevator companies on how they can improve their service capability, product enhancement or technology advancement?
6. Are there any direction guidelines that you can recommend to this industry?

The third set of interview questions is posed to customers, here referring to a property developer who purchased equipment with installation, a facility management company that ensures that elevators are properly maintained and a third-party service company authorised by OEM equipment providers to maintain the equipment with technical support from OEMs.

1. Firstly, please help us to understand your company's objective and strategy and the way you run your business. In general, what are your business opportunities and foreseeable challenges?
2. Do you know that the designated company has provided an IoT offering in your

service portfolio? How much do you know about this offering and are you interested in it?

3. What value do you perceive from this offering? What value can it bring to your customers?
4. Do your customers expect similar value to your company? What can the IoT offering do to facilitate your customers' needs?
5. What are the key elements that you urgently require? Can the IoT offering help you to achieve those? Why or why not? How can the company improve the offering to provide what you want?
6. Are you willing to pay to obtain it and at what expected value? In what way: by subscription or by usage?
7. Did the company discuss value co-creation with you and help you to serve your customers better before they designed the IoT offering portfolio?
8. In brief, what does the IoT offering provide you as a 'product', a 'service' or a 'solution'? How can you elaborate that?
9. Do you agree that now the service economy is the key in your business or do you believe that products play a dominant role in terms of value and pricing from the perspective of you or your customers?
10. In the elevator ecosystem, what role do you play and what objective do you align with the OEM provider? What does the OEM need to do to be aligned and make sure that the ecosystem is moving towards the same goals?

Paper 4 (chapter 6): The Internet of Things Enabling Condition-Based Maintenance in Elevator Services (Lai, Jiang & Jackson, 2019). This project involves a single, in-depth case study of a company operating in the elevator industry in China. The same case company is investigated over four years, and related research is published in the three prior papers (chapters 3 to 5). The motivation for continuing to study the same company is that it enables us to carry out in-depth research on certain phenomena in a real-life context. The continuation of this research aims to investigate further how the IoT facilitates the implementation of CBM in elevator servicing and elaborate the main benefits of CBM relative to conventional CM and TBM using two years of real-world data collected from more than six hundred installations at different sites operating under different conditions using the company's IoT connected service. The data for this research are obtained from direct participatory observation, a review of publicly available information and an examination of the outcomes of analytical modelling, which encompasses installed IoT units running in a time frame from one to two years. At the same time, seven semi-structured interviews are conducted with company leaders and subsequently three additional interviews with various IoT vendors. The interviews vary in length but typically last for one hour. The interviews are conducted at various stages of the project: proof of concept, practical implementation, when customer feedback becomes available and when the outcomes of implementations are evaluated. The objective is to gain an understanding of the in-depth contemporary phenomenon, the conceptual design framework and the outcomes of execution.

To conduct the interview, two categories of interview protocols are designed. The first category is the company case study as follows:

1. What is your role in the overall project design and what are your contributions to the project? More specifically, what is your role on the technical or commercial side of the equation?

2. What are the key elements of value drivers from the business model perspective and the underlying challenges?

3. What are the main drivers of the value of the IoT offering in elevator maintenance from the clients' perspective? Similarly, what are the key elements from the technical perspective and the underlying challenges?

4. What is the main purpose of CBM, and what are the pros and cons from implementing CBM to replace traditional CM and TBM?

5. If there is an amount of benefits of CBM, why cannot companies implement CBM earlier, and what are the main bottlenecks from both the technical and the business side?

6. What can the IoT bring to the implementation of CBM? Why is the IoT necessary: can some other technology be used? How confident are you that you can implement IoT–CBM successfully? Why or why not?

7. How do the outcomes of CBM compare with those of traditional CM and TMB models and what are the challenges of CBM implementation?

8. Can you be more specific about the benefits of IoT–CBM over TBM and IoT–CBM over CM?

9. What is the value that you or your clients perceive vs. the monetary value paid for IoT–CBM?

10. Are your clients happy with the offering in general? Why or why not? Can anything be improved over time from either the technology or the commercialisation perspective?

11. What key challenges do you expect need to be overcome in the future from the business model, technology or others?

The second set of interview questions addresses IoT vendors; here, in particular, the IoT consultant company is engaged to review the outcome of IoT–CBM implementation.

1. What is your role in the overall project design and what are your contributions to the project? More specifically, what services or products do you provide to the case company?

2. From a vendor or partner perspective, what do you believe the key drivers of the IoT can bring to the company on both the technical and the commercial side? Do these mean value or benefits to the project?

3. What is the key role and what are the key elements of value drivers that your company can bring to this ecosystem from the IoT business model perspective?

4. What are the main drivers of the value of the IoT offering in elevator maintenance from the client's perspective? Similarly, what are the key elements from the technical perspective and the underlying challenges?

5. From a partner perspective, what are the main benefits of CBM over TBM and CM?

6. What are the main challenges of the implementation of CBM, and how can you help to overcome these challenges?

7. If there are benefits from CBM, why cannot companies implement CBM earlier and what are the main bottlenecks on both the technical and the business side?

8. What can the IoT bring to the implementation of CBM? Why must it be the IoT? Can it be some other technology? How confident are you that you can implement IoT–CBM successfully? Why or why not?

9. What is the value that you or your clients perceive vs. the monetary value paid for IoT–CBM?

10. What are the main challenges from a vendor/partner position for this IoT–CBM offering? What are the solutions to these challenges?

11. Can any innovation in either software or hardware improve business opportunities? What is the new trend from technology or digitalisation that can further improve new business model innovation?