Investigating the goal-oriented use of IoT in servitization: an affordance theory perspective

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Thesis Summary

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Manufacturers are seeking differentiation strategies as products are commoditised, markets are saturated with competitors, and the overall growth of the manufacturing industry declines. Servitization is an effective strategy based on transforming the manufacturer from being product-centric to becoming customer-centric through the integration of products and services. This transformation is challenging in terms of service development processes, customer relationship management, and risk management for which manufacturers require practical enablers.

Internet of Things (IoT) is considered as a critical enabler of servitization. The integration of IoT in the manufacturers' products with a focus on servitization is, however, challenging and complex. Literature has focused on exploring the potential value of IoT and its technical specifications. Such a focus has ignored the manufacturers' role in making goal-oriented use of IoT and the process of integrating it in the manufacturers' businesses. By adopting the affordance theory as an actor and process-focused lens, this thesis aims to contribute to the servitization literature by investigating how manufacturers use IoT in servitization.

The thesis identifies four types of opportunities to use IoT as perceived by the manufacturer, three types of actions for realising these opportunities, and a cascading relationship between these opportunities that results in IoT enabled servitization. It argues that the use of IoT to enable servitization is a step-by-step process starting with gathering essential information about the manufacturer's product and its use, followed by improving product performance using the gathered information, and finally supporting the customers' businesses through additional services. The IoT plays the role of a platform that creates servitization enabling outcomes. The manufacturers play an active role in deciding the use of IoT based on their organisational goal and taking actions based on the IoT's features.

The thesis contributes to servitization literature by introducing a new perspective to study the process of using IoT in servitization and by arguing that the services created from the use of IoT do not exist independent of each other. The literature on affordance theory is extended in this thesis through its application in a new context on an organisational level. The thesis also substantiates the theory's key principle of affordance dependency using new empirical data. Practically, the thesis provides a framework for practitioners that allows managing the steps involved in IoT enabled servitization, the role of individual IoT features driving these steps and their role as an actor in this process.

Keywords: *Manufacturing*, *Transformation*, *Servitization, IoT, Affordance theory*

Publications

- **Naik, P.,** Schroeder A., Bigdeli A. Z., and Baines, T. (2017) *Enabling servitization by affordance actualization: The role of digitalization capabilities.* Paper presented at the 24th EurOMA conference, 2017, Edinburgh, UK.

- Schroeder A., **Naik, P.,** Bigdeli A. Z., and Baines, T. (2018) *IoT enabled advanced services: exploring the IoT artefact as a socio-technical construct.* Paper presented at the 25th EurOMA conference, 2018, Budapest, Hungary.

- **Naik, P.** and Schroeder, A. (2019) *The key features and opportunities underpinning IoT contributions for servitization.* Paper to be presented at the Spring Servitization Conference, 2019, Linkoping, Sweden.

- Schroeder A., **Naik, P.,** Bigdeli A. Z., and Baines, T. (2020) (Accepted for publication) IoT enabled advanced services: exploring the IoT artefact as a socio-technical construct. *International Journal of Operations Management.*

- **Naik P.,** Schroeder A., Kapoor K.K., Bigdeli A. Z., Baines T., (2019) *Behind the scenes of digital servitization: actualizing IoT-enabled affordances.* Paper presented at the 79th Academy of Management annual conference, 2019, Boston, USA.

- **Naik P.,** Schroeder A., Kapoor K.K., Bigdeli A. Z., Baines T. (2020) (In press) Behind the scenes of digital servitization: actualizing IoT-enabled affordances. *Industrial Marketing Management*.

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Chapter 1 Introduction

This chapter provides a research overview by first presenting the research motivation. The study is motivated by the current state of British manufacturing (section 1.1), the increasing adoption of servitization as a strategy to address some of the manufacturing challenges (section 1.2), and the intersection between servitization and the industrial trend of embedding IoT in manufacturing businesses (section 1.3).

Secondly, the chapter introduces the role of affordance theory as a new lens of investigation in this study (section 1.4), followed by an introduction to the research programme developed to achieve the research aim (section 1.5). Third, the chapter introduces the output of this study (section 1.6), which includes key findings to help manufacturers address the challenge of embedding IoT in their products and business processes to enable servitization. Driven by the key principles of affordance theory, the study provides insights on how manufacturers perceive and realise different opportunities to use IoT that lead to servitization enabling outcomes. Finally, the chapter concludes with a description of the structure of the thesis (section 1.7).

1.1 Challenges in British manufacturing

Britain is known as the birthplace of the industrial revolution and a world leader in hi-tech sectors such as aerospace and defence. The Office of National Statistics (2016) states that manufacturing directly employs 2.6 million people, and it recorded a sale of £364.7 billion. It also accounts for 44% of the total exports from the UK. Although these figures indicate a crucial role of manufacturing in the British economy, the growth of manufacturing has been stagnating since the credit crunch of 2008. Therefore, the manufacturing sector faces a challenge to sustain itself, especially with the growing importance of services for the British economy (Forbes, 2018).

With stagnating growth of British manufacturing since 2008, the UK has dropped to the 9th place from being the 6th largest economy by manufacturing output. Over the past five years, British manufacturing has recorded a growth of 0.4% (average) with the highest growth of 2.8% experienced in April 2016 and lowest growth of -3.2% experienced in August 2019 (ONS, 2019). It was predicted that growth would decline below the recorded 0.4% towards the end of 2019. Although the current political atmosphere in the UK is considered to play a crucial role in this decline (Forbes, 2018;

TheTelegragh, 2018; TheManufacturer, 2018), manufacturers face other challenges that impede their growth and endanger their financial sustainability.

British manufacturing is challenged by reduced levels of productivity, lack of digital technology adoption, and increasing commoditisation of the market (FinancialTimes, 2017). A commonly used productivity measure shows that the UK is one of the G7 countries with the lowest GDP per hour, which was marginally higher than 100 in 2018. Additionally, the adoption of digital technology has been stunted, although it is recognised by the government as a critical promoter of productivity. This challenge is acknowledged by the government, and it plans to invest in training to increase the adoption of digital technologies in manufacturing. Finally, with reduced growth, the manufacturing industry has become increasingly saturated with competitors squeezing profit margins to gain market share (TheManufacturer, 2018). Product commoditisation is making it increasingly difficult for manufacturers to differentiate themselves from their competitors.

Numerous reports show that the future of manufacturing will be dictated by complex customer demands and the disruptive impact of digital technology and data (PwC, 2019; TheTelegragh, 2018; Autodesk, 2018). Customisation and flexible manufacturing will be vital capabilities expected from manufacturers, along with a collaborative approach towards product designs and innovation. Additionally, the nature of customer expectation is changing with customer’s expecting more value over the product’s lifetime with lower risks undertaken in owning and operating the products (Autodesk, 2018). Effective adoption of digital technologies is expected to help the manufacturers in satisfying the customer demands and make the factories smarter by streamlining production and simplifying supply chains (TheTelegragh, 2018).

The customer demands of increased value and lower ownership risks are recently being addressed by manufacturers through services (Baines et al., 2009a; Baines and Lightfoot; 2014). Incumbent manufacturers such as Rolls Royce and Alstom Trains UK are leading examples of manufacturers that base their competitive strategy around services. These manufacturers offer the capability of their products as services (*thrust* from Rolls Royce engines, *mobility* from Alstom Trains) instead of offering the product and its ownership. Such services require a more profound integration of digital technology, services, and product sale, which is recognised as a future trend of the manufacturing industry (Forbes, 2018). In some cases, the services can even replace the sale of products where manufacturers adopt a business model which uses the products as a vehicle for the delivery of the product's capability (Vargo and Lusch, 2008).

1.2 Increasing adoption of servitization

The process of bundling products and services to deliver increased value for the customer based on the provision of capability rather than product ownership is called servitization of manufacturing (Baines and Lightfoot, 2014). Servitization can help manufacturers differentiate themselves from their competitors and develop a sustainable competitive advantage by becoming a crucial part of the customer's business (Neely, 2008). Customers are offered the ability to use the product without the risks of maintaining and repairing the product, which creates a dependency between the customer's business process and the manufacturer's offerings (Kowalkowski et al., 2017). Such a process of customer lock-in has been recognised by manufacturers as a vital avenue to regain growth and is thus becoming a trend in manufacturing (section 2.1 for further explanation).

Servitization has become an essential trend in manufacturing because it promises a sustainable future for the industry. With more accessible digital technology and lower entry costs for new competitors, incumbent manufacturers have to compete on product features and functionality. However, servitization helps manufacturers shift to a more customer-centric approach based on added value and long-term relationships, which are difficult for new entrants to achieve. Customers are driving the manufacturers' strategies to provide multiple offerings as a service (Microsoft, 2018). These offerings can include design, experimentation, equipment maintenance, repair, operations, and uptime as a service. The offerings are combined with the transfer of ownership risks to the manufacturer and customer payments based on the measurable value delivered through product usage.

Such service offerings require several fundamental changes to the current nature of the manufacturing industry. Manufacturers are required to change how they measure delivered value and frame contracts based on these measures (Batista et al., 2017). They must change their product-centric culture and mentality to a service and customer-centric culture (Jovanovic et al., 2019). This cultural change means aligning and customising their offerings to support the customer's business through product usage. Since the manufacturer is required to take additional risks and responsibility, they also need to change how they can ensure correct product usage by the customer in their business (Spring and Araujo, 2017). These offerings also require the manufacturer to manage long-term relationships as compared to the current transactional relationships that exist purely through the sale of products (Kamalaldin et al., 2020).

Such changes to the manufacturers' business are challenging because manufacturers must acquire or develop new resources and capabilities to transform themselves into service-centric organisations (Raddats et al., 2017; Zhang and Banerji, 2017). Delivering long-term service contracts based on product usage and guaranteeing product performance is a crucial challenge for which manufacturers seek new capabilities (Batista et al., 2017). Relocating financial resources for managing the risks in these service contracts is another crucial challenge (Reim et al., 2018). Furthermore, management of the product's performance to support the customer's business presents another challenge. Manufacturers seek different ways to address these challenges, which leads them to the adoption of digital technology.

1.3 Value of IoT

A critical industrial trend that holds the potential to address some of the manufacturers' challenges is the adoption of digital technology, specifically the Internet of Things (IoT) (Baines et al., 2014). The adoption of IoT in industrial contexts is recognised through the concept of Industry 4.0, which refers to using digital technologies such as IoT to improve the efficiency of their business processes (See section 2.3.2). Embedding products with IoT connects them to conventional networks and allows the manufacturer to identify the product and its characteristics remotely, possibly also changing these characteristics by making interventions (Schroeder et al., 2018). This ability to identify and intervene creates substantial value for the manufacturer as the product use can be monitored, and the manufacturer can develop new offerings informed by the data. Similarly, there are three key reasons why manufacturers are adopting IoT which include the easy availability of IoT hardware, better availability of data processing capabilities, and the synergy between the hardware and software involved in embedding IoT. Figure 1 summarises and illustrates the different ways in which IoT is valuable to the manufacturing industry.

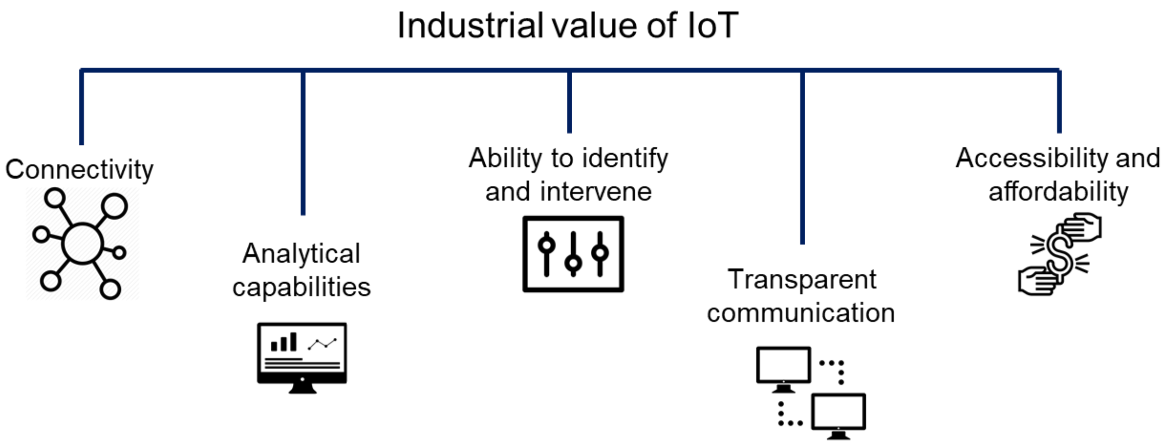

Figure 1 Value of IoT

The first reason for the increased adoption of IoT is more accessible data collection, enabled by improvements in sensor technology (Grubic et al., 2018). Sensors have become smaller, more powerful, and less expensive—projected to reach an average cost of £0.20 by 2020, down from £1.00 in 2004 (Microsoft, 2018). The adoption of sensors has made data collection economically viable. When embedded into products, these sensors provide manufacturers with near real-time feedback about product usage. They can also be used to collect a wide range of data from across the supply chain and manufacturing operations (see section 2.2 for further explanation).

The second reason is better connectivity and computer processing capabilities that are more readily available (Jernigan et al., 2016). While manufacturers were undoubtedly able to collect product and operations data before, effective data analytics has enabled them to interpret this data and create actionable insights. Coupled with AI and machine learning, these interpretations can be made faster, perhaps based on live data, and allow automatic interventions as well (Shanthamallu et al., 2017). Furthermore, advancements in computer processing now enable these functions to run on a large scale, which was not economically feasible previously.

The third reason is the synergy between the hardware and software as it provides manufacturers with opportunities to build their relationships with customers over the lifecycle of a product. As products become more intelligent and connected, it becomes harder to distinguish the product from the technology on which the product runs—particularly the software (Isaksson et al., 2018). The product can be represented digitally through the software, which allows transparent information sharing and communication between the manufacturer and the customers (Martinez et al., 2019). This helps the manufacturer to augment products with digital services, providing training and proactive offers, and adding new functionalities to legacy products through over-the-air software updates (see section 2.2.3 for further explanation)

Through the integration of IoT, manufacturers can address multiple challenges that servitization presents them with. Monitoring product usage and ensuring proper training to the operators helps tackle the risks of guaranteeing product performance (Baines et al., 2014). It also helps the manufacturer ensure the product uptime and availability by providing predictive maintenance and identify faults accurately (Coreynen et al., 2017). The manufacturers can also educate the customer about how they can extract more value from the product through performance advisory services (Advanced Services Group, 2018), and thus support the customer's business directly. However, the lack of examples of manufacturers integrating IoT in their business indicates that they have been struggling with operationalising the idea of IoT enabled servitization. This lack of IoT adoption can be attributed to the inadequate knowledge of making servitization-oriented use of IoT, which leads to the research problem being addressed in this thesis.

1.4 The need for a new lens of investigation

The adoption of IoT in servitization has been inadequately addressed in literature as it has focused on investigating the contributions and value of IoT for servitization while ignoring the process of using IoT to create these contributions and value (section 2.4.3). Additionally, the focus on IoT as technology assumes that embedding IoT into physical products creates servitization enabling outcomes and thus ignores the active role of the manufacturers in deciding how IoT is used. Addressing these gaps is essential to develop a holistic picture of IoT enabled servitization that helps manufacturers manage their servitization strategy better. However, scholars have not found a suitable theoretical lens which allows focusing on the manufacturer and the process of using IoT in servitization. In practice, manufacturers find that the implementation of IoT enabled servitization to be challenging (section 2.4). Only a few cases can be found that exemplify successful IoT enabled servitization.

Digitally-enabled organisational transformation has been investigated in the domain of Information Systems using the affordance theory (Strong et al., 2014). Since IoT enabled servitization is also a type of digitally-enabled organisational transformation, the affordance theory holds potential value for this research making it a promising theoretical lens to address the research problem (see section 2.3 for further explanation). Therefore, the study aims to verify the suitability of the affordance theory as a new lens to investigate how the use of IoT enables servitization (see section 2.4 for further explanation).

The aim of the study is presented as:

"To use the affordance theory as an actor and process-focused lens to investigate the role of the manufacturer in the process of using IoT to enable servitization."

The theory is designed to focus on an actor's role in using a specific artefact in an organisational transformation (section 2.3), and it has been used to study organisational transformations that use various technological artefacts such as IT systems, electronic health records, and ERP systems (section 2.5.2). The theory is based on three core principles driven by the concept of affordances, namely *affordance perception, affordance actualisation, and affordance dependency* (section 2.3.1). Affordance perception states that the interaction between a goal-oriented actor and the artefact's features leads to opportunities (called affordances) for creating outcomes desirable for the actor's goal. Affordance actualisation states that these opportunities can only be realised if the actor decides to take specific actions to create outcomes. Affordance dependency suggests that the perception and actualisation of specific opportunities can lead to the perception and actualisation of new opportunities. These principles together form the theoretical framework used to design this study in which the manufacturer is the *actor,* using the IoT as an *artefact,* enabling servitization as the *organisational transformation* (section 2.3.5).

1.5 Research programme

The thesis is structured by using a three-phase research programme. The phases are Phase 1: Plan and implementation, Phase 2: Analysis and findings, and Phase 3: Evaluation and conclusions.

Phase 1 starts with the establishment of the research programme along with the decisions regarding the research design (chapter 3). This study takes a qualitative approach to research. Case study approach was found as a suitable method to address the research aim. The case studies were designed to focus on collecting the accounts of IoT usage instances from the manufacturer's perspective and exploring how this use led to enabling the manufacturer's servitization (chapter 4). Data was collected through an expert interview technique which involved interviewing employees within the manufacturing organisations that hold expertise in the topic of this study, which is IoT enabled servitization. A pilot study was conducted to validate the interview design before the final data collection is conducted (chapter 5).

Phase 2 started with a compilation of the cases which occurred once the data was collected. Followed by this, the data was analysed through a two-step process of individual and cross-case analysis (chapters 6 and 7). The use of codebook to individually analyse the cases is described, laying the foundation for cross-case analysis where cases are compared based on the key constructs of the affordance actualisation framework.

Phase 3 starts with the discussion of how the study has addressed the research gaps and the research aim set for this study as compared to the existing literature on this topic (chapter 8). Finally, the contributions of this study are presented, along with research limitations and topics for future research (chapter 9).

1.6 Research output

The research makes three key findings as a result of the cross-case analysis. First, it was found that the manufacturers perceived opportunities to use IoT that were categorised into four types as *informative, enhancive, supportive,* and *demonstrative.* Second, the manufacturers realised these opportunities by taking three types of actions, namely *monitoring, analysing,* and *sharing.* Third and most importantly, the research found that the opportunities are perceived and realised in a specific sequence that can be visualised as a step-by-step process. This process represents how IoT can be used to enable servitization, the manufacturers' progression in their IoT enabled servitization journey and the different services created by realising the opportunities to use IoT (see Figure 6, section 7.4 for further details).

Based on these findings, the thesis argues that manufacturers' goals and actions play a crucial role in the perception and realisation of opportunities to use IoT and create desirable outcomes. IoT should be viewed as a platform made of specific features that are used for perceiving opportunities to create desirable outcomes. It is not a technological phenomenon creating outcomes on its own, based on an intrinsic agenda. The thesis contributes to advancing the field of servitization by introducing an actor and process-focused theoretical lens and explaining the manufacturer's role in making servitization-oriented use of IoT. It also extends the application of the affordance theory to a new context and on an organisational level. For practitioners, the thesis helps plan IoT use for servitization with a focus on the different services it can create. Manufacturers can also use the affordance dependency mechanism (Figure 6) as a tool to assess and manage their progression of IoT enabled servitization.

1.7 Thesis structure

The thesis is divided into nine individual chapters, as visualised through Figure 2. This chapter (1) has introduced the research motivation and positioning at the intersection of servitization and IoT with a brief introduction to the thesis. Chapter 2, *Literature review*, describes the literature review conducted on the domains of servitization and IoT along with the affordance theory as a suitable theoretical lens to address research gaps in the IoT enabled servitization literature. The second chapter ends with articulating the research questions to be answered in this study. Chapter 3, *Research design*, presents the decisions made about the key aspects of research design followed by the development of the research programme. Chapter 4, *Case study design,* describes the key aspects of case design in this study. This is followed by the case design execution and data collection, which is described in Chapter 5, *Research execution*.

Chapter 6, *Within-case analysis,* explains the individual case analysis of the results as part of a two-step analysis technique. This chapter also presents the findings of analysing the individual cases using the theoretical framework of the affordance theory. Chapter 7, *Cross-case analysis*, is based on the findings of the within-case analysis as a foundation to conduct a cross-case analysis. This analysis explicitly answers the research questions of this study. Chapter 8, *Discussion*, reflects upon these findings in comparison to the extant literature while also evaluating the accomplishment of the research aim of this study. In the end, Chapter 9, *Conclusions*, concludes the thesis by describing the theoretical and practical contributions of the research along with the research limitations and avenues for future research.

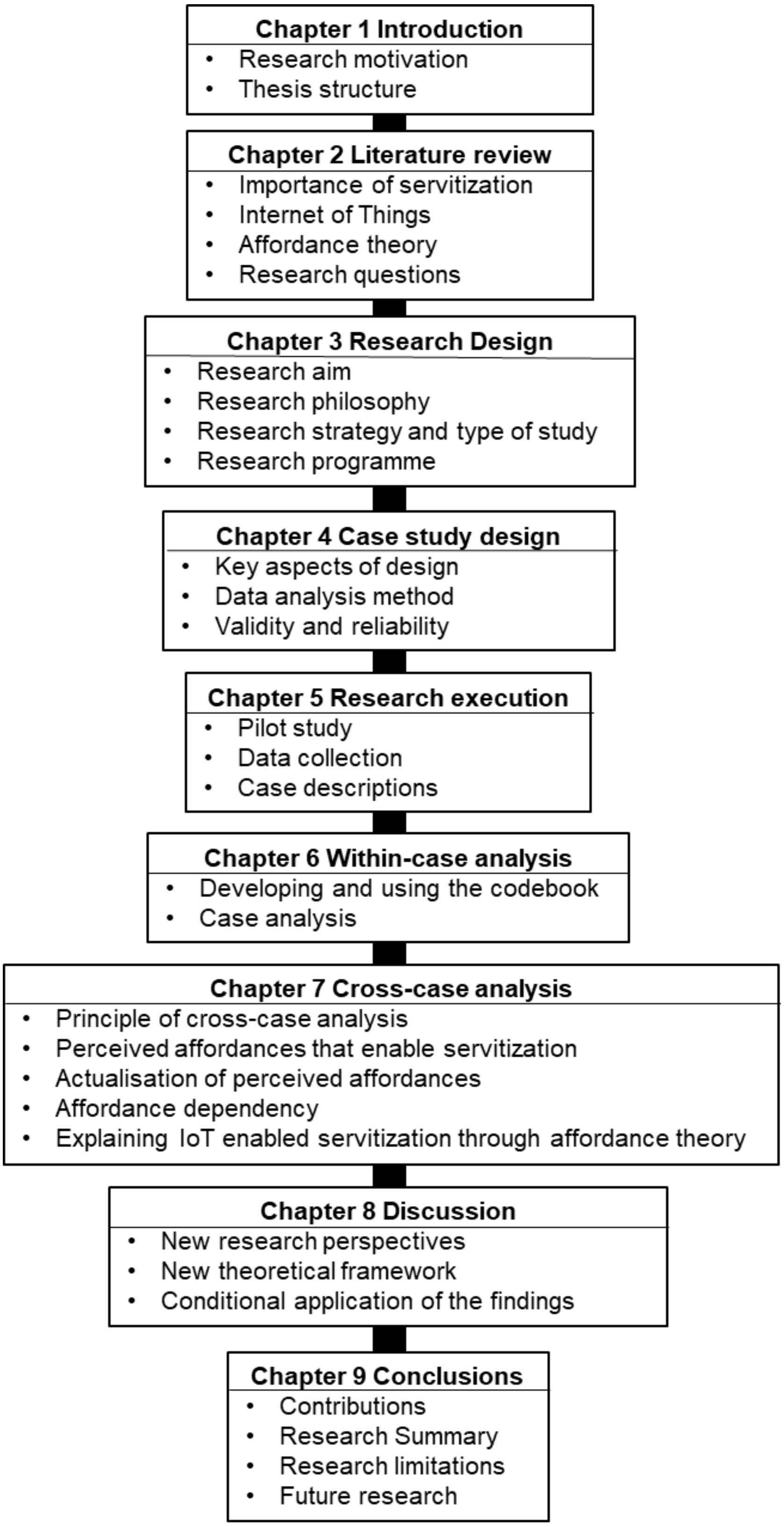

Figure 2 Thesis Structure

Chapter 2 Literature review

The present study addresses a topic that is positioned at the intersection of two concepts, ‘Servitization’ and ‘Internet of Things (IoT)’. This chapter explains these two concepts individually followed by an explanation of their intersection. Furthermore, the chapter introduces the affordance theory as a suitable theory to address this research. The chapter concludes by presenting the research questions that address the principal research gaps and guide the present study.

The chapter will first explain the importance of servitization (section 2.1) followed by the importance of IoT in the manufacturing industry (section 2.2). At this point, the chapter establishes the intersection of IoT and servitization positioning IoT as a way to address the challenges of servitization. Section 2.2.5 explains this intersection further and also establishes the need to adopt a new actor-focused perspective. This leads to the description of the affordance theory; a theory that has been widely used in the field of Information Systems to investigate digitally-enabled organisational transformations (section 2.3). The chapter ends with the formulation of a primary research question, which is further divided into three sub-questions (section 2.4).

2.1 Importance of Servitization

This section focuses on explaining the importance of servitization by first clearly defining it, followed by exploring the different types of services in its context. Next, this section presents the motivations for the adoption of servitization within manufacturing firms. In practice, however, manufacturers face particular challenges in adopting servitization which is further elaborated upon in this section before indicating how IoT can enable the manufacturer in addressing these challenges.

2.1.1 Concept of servitization

Servitization is most commonly defined as a transformative process through which manufacturers shift from selling products to offering bundles of products and services (Lightfoot and Baines, 2014; Baines et al. 2017). The transformation requires the manufacturer to shift from a product-centric focus with transactional sales to a customer-centric focus with long-term contracts. Servitization also involves the relocation of the firm's capabilities and resources, allowing them to change their organisational focus and culture for servitization (Chen and Moller, 2019).

As a topic of research, servitization has been studied since the 1980s, with researchers seeking to understand the meaning of servitization and its benefits for manufacturing firms (Vandermerwe and Rada, 1988; Wise and Baumgartner, 2000; Oliva and Kallenberg, 2003). From 2000, concrete servitization definitions have emerged (Baines et al., 2009b), and research moved on to explore impacts (Mathieu, 2001; Baines et al., 2009a; Neely, 2008), implementation challenges (Matthyssens and Vandenbempt 2008; Baines et al., 2009c; Isaksson et al., 2009) as well as underlying relevant theories (Brax, 2005; Lindberg and Nordin, 2008; Vargo et al., 2008).

More recently, researchers have explored specific servitization processes (Baines and Lightfoot, 2013a; Kastalli and Van Looy, 2013; Bigdeli et al., 2018a), organisational capabilities (Baines et al., 2013b; Raddats et al., 2016), more theoretical approaches (Smith et al., 2014; Neely et al., 2015; Burton et al., 2015), as well as digital enablers of servitization (Opresnik and Taisch, 2015; Barnawi et al., 2015; Grubic and Peppard, 2016; Parida et al., 2017).

The majority of servitization research is found in the domains of industrial marketing (Ulaga and Reinartz, 2011; Kohtamäki et al., 2013; Kindström and Kowalkowski, 2014; Ulaga and Loveland, 2014), service management (Kindstrom, 2010; Raddats et al., 2015) and operations management (Baines and Lightfoot, 2013a; Smith et al., 2014; Baines et al., 2016). Overall, servitization research has progressed substantially since its inception in 1988 to reach a stage where scholars are making practical contributions focused on assisting manufacturers in their transformation (Baines and Lightfoot, 2015; Kohtamaki et al., 2018; Andrews et al., 2017; Andrews et al., 2018).

Currently, scholars are focusing on investigating how manufacturers shift their focus from product development, improvement, and delivery to a combination of product and service solutions that deliver increased value to the customer and support their business (Bustinza et al., 2017). During this transformation, the manufacturers redesign their processes, reallocate resources and capabilities, and modify value propositions and financial performance measurement (Opresnik and Taisch, 2015;

Rabetino et al., 2017). Latest research has identified four stages (*exploration, engagement, expansion,* and *exploitation)* across which the manufacturers' transformations can be mapped (Baines et al., 2019).

2.1.2 Types of services within servitization

Different types of services exist in the context of servitization (Vandermerwe and Rada, 1988; Vendrell-Herrero et al., 2014), such as warranty, spare parts, repair, maintenance, operator training, condition monitoring, in-field service, performance advisory, availability, and uptime guarantees (Baines and Lightfoot, 2014, Ng et al., 2009; Ng et al., 2013). By focusing on different aspects of these services, scholars have categorised these services differently. A commonly adopted categorisation of services is presented by Oliva and Kallenberg (2003) with a focus on the interaction between manufacturers and customer, thus categorising services as transaction-based and relationship-based. Tukker (2004) focuses on the value offered by the manufacturer through their service and thus categorise these services as a product-, use-, and result-oriented. Baines and Lightfoot (2014) present the most commonly used categorisation that identifies the services as base, intermediate and advanced services based on customer demands (Coreynen et al., 2017; Story et al., 2017; Alghisi and Saccani, 2015; Rabetino et al., 2017; Ardolino et al., 2018

Oliva and Kallenberg (2003) present four categories of services which are basic installed-base services, professional services, maintenance services, and operational services. They propose a matrix to categorize the offerings based on whether services are transaction-based (a transaction for labour and parts every time a service is provided) or relationship-based (charging a fixed price covering all services agreed over a period) and whether services are product-oriented (whether the product works) or process-oriented (product's efficiency and effectiveness within the end-user's process) (Table 1).

Table 1 The service space

	Product-oriented	**Process-oriented**
Transaction-based	*Basic installed base services* Documentation Transport to client Installation/commissioning Product-oriented training Hot line/help desk Inspection/diagnosis Repairs/spare parts Product updates/upgrades Refurbishing Recycling/machine brokering	*Professional services* Process-oriented engineering (tests, optimization, simulation) Process-oriented R&D Spare parts management Process-oriented training Business-oriented training Process-oriented consulting Business-oriented consulting
Relationship-based	*Maintenance services* Preventive maintenance Condition monitoring Spare parts management Full maintenance contracts	*Operational services* Managing maintenance function Managing operations

Tukker (2004) propose three categories such as; product-, use-, and result-oriented services which are identified through a sustainability lens that suggests that the combination of tangible products and intangible services can foster environmental sustainability along with competitiveness (see table 2). They propose a categorisation of the offerings based on a spectrum of the value offered by the manufacturer, moving from pure product to pure service.

Table 2 Product service systems

	Product-oriented	**Use oriented**	**Result oriented**
Description	Sale of products along with few extra services.	Product owned by the manufacturer but used by the customer.	Manufacturer and customer agree on a result to be delivered.
Examples	Supply of consumables Advice on best and efficient use	Product leasing, Product sharing, Product pooling.	Activity management/outsourcing Pay per result

The examples provided by Tukker (2004) such as product leasing, product pooling, pay per result, indicate a clear overlap with the manufacturers' revenue models is similar the categorisation by Oliva and Kallenberg (2003) (short-term vs long-term transactions). The process of servitization is not limited to how products and services are monetised but instead focused on how manufacturers view their products as a way to address the customer's demands (Frank et al., 2019).

Baines and Lightfoot (2014) categorise the services as base, intermediate, and advanced based on the customer's demands (see table 3). The base services give ownership to the customer and the customer repair products (or assets) themselves, only relying on the manufacturer to supply the product and spare parts. The intermediate services include maintenance, repair and overhaul in addition to the base services. The advanced services hold a contract for the "capability" offered through the "use" of a product, and hold the manufacturer responsible for ensuring the delivery of the capability.

Unlike the two categorizations by Tukker (2004) and Oliva and Kallenberg (2003), Baines and Lightfoot (2004) explicitly state that the base, intermediate, and advanced services exist together as a bundle. They can also be understood as three steps of developing service offerings rather than three independent types. Additionally, this indicates that servitization has cascading elements that deliver a solution when bundled together rather than a single overall solution. Although this categorization does not define the focus of this study, the idea that the service offerings from servitization have a bundling effect has theoretical implications on the later parts of the study, explicitly relating the principle of dependency in the affordance theory.

Table 3 Product-service categorisation

	Definition	**Examples**
Base services	Focused on product provision	Product/equipment provision, spare part provision, warranty
Intermediate services	Focused on the maintenance of product condition	Scheduled maintenance, technical help-desk, repair, overhaul, delivery to site, operator training, condition monitoring, in-field service
Advanced services	Focused on capability delivered through the performance of the product	Customer support agreement, risk and reward sharing contract, revenue through-use contract

Multiple examples for servitizing manufacturers exist such as Alstom, ABB, Thales training and simulation, Rolls Royce Aerospace, Goodyear Tyres (Davies, 2004; Miller, 2002; Mulholland, 2000; Howells, 2000), which specifically focus on intermediate and advanced services. Base services do not need an explicit explanation, as they are commonly provided by every manufacturer (Baines et al., 2014).

As an example of intermediate services, Goodyear launched the offering ‘Proactive Solutions’ intending to serve their commercial trucking customers. This offering was designed to tackle the rapidly changing market and the entry of new competitors. Through Proactive Solutions, Goodyear managed the tyre pressures, tyre-treading condition, estimates of tyre life, and fleet management services. As a result, Goodyear reduced breakdown time, tyre-related incidents, improved delivery routes, and extended tyre life (Advanced Services Group, 2018).

An example of advanced services is the ‘Train Life Services’ offering of Alstom trains (UK) to Virgin Rail Group on the West Coast Mainline. The contract was designed to deliver the best outcomes for Virgin’s business process; moving people on trains. As part of this contract, Alstom managed multiple service activities such as spare parts, accident repair, technical support, training, asset management, e-documentation, recycling, fleet support, modernisation upgrades, and passenger experiences upgrades. As a result of such a wide range of service activities, Alstom was able to achieve their promise of train availability, business sustainability, and day-to-day support (Advanced Services Group, 2018).

2.1.3 Motivations to servitize

Closely related to the different types of services are the manufacturers’ motivations for servitization. Early studies suggested that manufacturers are motivated by the possibility to increase revenue streams or customer proximity (Wise and Baumgartner, 1999). Several more motivations are identified in recent literature such as improving profit margins, locking out competitors, and creating sustainable competitive advantage by differentiation (Porter and Ketels, 2003; Bigdeli et al., 2018b). As the literature substantially emphasises identification of the manufacturers’ motivations, it also indicates that it is essential for the manufacturer to articulate their motivation to servitize. The manufacturers' motivations play a crucial role in defining the benefits that the manufacturers can receive from servitization (Raddats et al., 2016).

The different motivations for servitization can be categorised based on, competitiveness (to ensure the correct functioning of the product), customer demands (to improve customer satisfaction), or economics (to support operational needs of the customers and enable new revenue streams) (Wise and Baumgartner, 1999; Oliva and Kallenberg, 2003; Baines et al., 2009a). Table 4 (adapted from Raddats et al., 2016) provides examples of these motivations observed across the literature.

Table 4 Motivations to servitize

	Competitive	**Demand-based**	**Economic**
Example	Using services as a way of differentiating the firm from the competition.	Satisfying customer demands through services such as deliveries and spare part-provision.	Achieving new and stable revenue streams through long term service contracts.
Reference	(Mathieu 2001)	(Araujo and Spring 2006) (Fischer, Gebauer et al. 2012) (Lightfoot and Baines 2014)	(Mathieu 2001) (Fischer, Gebauer et al. 2012) (Oliva and Kallenberg 2003) (Kindström and Kowalkowski 2014)

As presented, competitive motivations suggest manufacturers view their products as their primary resource ('physical'), with services being an essential element of a differentiation strategy (Dachs et al., 2014). It has become increasingly difficult for manufacturers to differentiate themselves from competitors based on their tangible products alone because of the increasing commoditisation from low-cost competitors. Aggressive price-based competition and new tech-disruptors which use disruptive digital technology to reduce the need of manufacturer's support in the aftermarket sector add to the manufacturers' needs to differentiate using services (Fischer et al., 2012).

In the case of demand-based motivations, customers are likely to demand several services from the manufacturer, such as product deliveries, spare part provision and warranties (Baines and Lightfoot, 2014). Customers may also want manufacturers to provide after-sales services, such as a technical help-desk, training, maintenance, but still perform other service activities in-house. To meet rising customer demands, manufacturers find it necessary to develop service offerings that can enable deeper customer relationships and address more complex requirements (Dachs et al., 2014); for example, risk/reward sharing (Baines and Lightfoot, 2014).

Economic motivations are common and crucial for manufacturers, as changing the corporate focus from products to services is widely considered to be a route to economic success (Reinartz and Ulaga, 2008). This re-focusing process is similar to the latter stages of Oliva and Kallenberg’s (2003) product-service continuum, involving new service business models (Kindström and Kowalkowski, 2014; Spring and Araujo, 2009). Services can deliver a new sustainable source of revenue to a manufacturer, helping it to overcome stagnating product markets (Eggert et al., 2011; Slack, 2005). The services market is often worth many times that of the product market, particularly as the installed product base increases (Auramo and Ala-Risku, 2005). Furthermore, sales of services are to some extent counter-cyclical to those of products, helping manufacturers achieve stability in revenue as compared to peaks and troughs often associated with one-off product sales (Gebauer and Fleisch, 2007; Slack, 2005).

The manufacturers’ motivations influence the benefits they achieve from the servitization process. However, the achievement of any benefits from servitization is riddled with specific challenges. Research has started to recognise and identify these challenges faced by manufacturers as they move towards servitization (Raddats et al., 2019; Zhang and Banerji, 2017; Story et al., 2017; Reim et al., 2019). A wide range of challenges has been discussed in the literature, which is a crucial source for researchers to investigate how manufacturers tackle these challenges.

2.1.4 Challenges of servitization

The long-term benefits of servitization (Bigdeli et al., 2015) is fraught with a set of critical challenges (Kastalli and Van Looy, 2013; Kohtamäki et al., 2013). With the globally dynamic state of the manufacturing industry, realising the full potential and opportunities offered by servitization has become increasingly complex (Coreynen et al., 2017), and thus addressing them is increasingly important. As a testament to the real-world challenges of servitization, Visnjic et al. (2016) highlight that some manufacturers even abandon their servitization efforts. The different challenges observed across servitization literature have been compiled and categorised as *organisational structure, business model, development process, customer management* and *risk management* (Zhang and Banerji, 2017).

The first challenge of changing organisational structures has gained a growing focus in literature (Alghisi and Saccani, 2015; Martinez et al., 2010; Kowalkowski et al., 2015). One critical change here is the cultural shift from being product-centric to becoming service-centric (Fang et al., 2008; Kowalkowski et al., 2015; Oliva and Kallenberg, 2003). The manufacturers need to embrace and develop a new product-service culture in order to meet customer expectations. A firmly embedded traditional manufacturing culture in the organisation is observed to hinder transition towards the provision of an integrated offering (Martinez et al., 2010). Employees in manufacturing firms fully understand the concept of products but may lack the understanding of services, particularly bundles of products and services rather than basic services such as insurances, repairs, and overhauls (Baines et al., 2009c). All these activities create a complicated challenge for the manufacturer in terms of shifting the organisational structure and culture.

The second challenge is changing the business model, which is an essential component of the organisation as it embodies the core business logic of how a company creates, develops, and delivers value to customers (Shafer et al., 2005). Business models for servitized organisations have attracted much attention as numerous changes are required to integrate a service strategy with a production system (Kastalli and Van Looy, 2013; Kindstrom and Kowalkowski, 2014; Parida et al., 2014). The manufacturers' value propositions change from being a unidirectional value delivery from the manufacturer to the customer, to value co-creation between the manufacturer and the customer. This is not an easy task as internal employees with a product perspective, may design weak value propositions that are not aligned with customer interests (Barnett et al., 2013; Pawar et al., 2009; Vandermerwe and Rada, 1988). Changing business models requires new configurations of resources and capabilities that can ensure the creation and delivery of the proposed value (Visnjic et al., 2013; Raja et al., 2017). In addition to this challenge, integrated revenue models need to be developed as products and services are bundled together (Mallaret, 2006).

This is difficult as the prices of servitized offerings and how payments are scheduled often create barriers to adoption and disagreements on the customer side (Barquet et al., 2013).

The third challenge of changing the development process refers to the overall activity of turning an idea into a deliverable, is also a crucial for servitizing manufacturer (Cooper and Edgett, 2003). Given that a servitized offering is a bundle of services and products, a combined development process for products and services also required. Conventional product development is not suitable to develop services as services cannot be stored or stocked and tested before consumption (Parida et al., 2014; Baines et al., 2009a; Kowalkowski et al., 2015). This challenge requires a set of new tools and techniques to support the development process. However, these tools and techniques are still underdeveloped at the initial stages of servitization (Tukker, 2015).

The fourth challenge refers to building and maintaining customer relationships (Kowalkowski et al., 2017). Business-to-business relationships are key to servitization, making it important to tackle this challenge. Customer engagement and education about servitization is also crucial in the development process since the concept of a servitized offering is new to the customers. The operations and development teams in manufacturing firms must work together with the customers to successfully tackle challenges in the development of servitized offerings (Brax, 2005). Although manufacturers can align their offerings with the customer needs to make communication and customer education easier (Johnstone et al., 2009), it is found that value perception by customers is not always the same as that of the manufacturer, due miscommunication and misunderstanding of the customer’s needs (Matthyssens and Vandenbempt, 2008). Servitization also requires the manufacturer to co-create value with the customer (Lenka et al., 2017). In such cases, if the communication is inefficient, it can damage the credibility of the manufacturer and create new challenges in maintaining close customer relationships (Martinez et al., 2010).

The fifth challenge of risk management is one of the biggest challenges faced by manufacturers adopting servitization (Bigdeli et al., 2017). Risk is defined as the probability of uncertainties, such as loss, failure, and unexpected circumstances (Harland et al., 2003). A risk-management perspective has gained substantial traction in servitization research as scholars have identified that manufacturers find it increasingly difficult to manage the risk that they bear by offering new services based on the product's outcome or use (Benedettini et al., 2015; Gebauer et al., 2005). Servitizing manufacturers face increasing investment in mitigating the risks described in this section, which eventually offsets any financial returns from the services in the early stages of servitization (Neely, 2008). Although servitization may provide increased profitability, there is no guarantee of achieving the expected outcome (Gebauer et al., 2005).

2.1.5 Role of IoT in addressing challenges

A key enabler of servitization is digital technology (Saul and Gebauer, 2018; Vendrell-Herrero et al., 2017; Coreynen et al., 2017; Ardolino et al., 2015; Lenka et al., 2017). Scholars have found digital technology to enable service development process specifically and customer management in the transformation journey (Stantchev et al., 2015; Lenka et al., 2017; Grubic, 2014; Coreynen et al., 2017). Digital technology provides the manufacturers with remote visibility of their products, and that of their product's usage in the customer's business. This informs the design of new services and helps the manufacturer communicate and understand customer needs more effectively (Lenka et al., 2017).

Servitization exposes the manufacturer to operational risks, explicitly dealing with new resources and capabilities required to deliver services. Additionally, servitized offerings may involve guarantees of performance, availability, or uptime which makes the manufacturer responsible for ensuring the product performs as guaranteed and failure to do so may result in penalties. (Li et al., 2015; Nordin et al., 2011). Digital technology plays a vital role in allowing the manufacturer to address these issues that relate to risk management. By knowing more about the product's use in the customer's business (Rymaszewsa et al., 2017), the manufacturer can understand the product's condition and usage, therefore being able to take the necessary steps that guarantee the product's performance (Baines et al., 2014). Fast data processing enables quick and efficient decision making to support the product's performance and also influence the improvements in product design (Martin-Pena et al., 2018). These applications of digital technology allow the manufacturer to manage the risks in guaranteeing the product's performance.

Before further exploring the link between IoT and servitization, it is crucial to establish the fundamental concept of IoT and describe its general applications. The next section addresses these elements through the extant literature addressing the role of IoT in servitization.

2.2 Internet of Things

A range of digital technologies are at the manufacturer's disposal to enhance their productivity, but IoT is a technology specifically converging with the trend of servitization (Spring and Araujo, 2017; Ardolino et al., 2016; Frank et al., 2019). This is also the case because IoT can be applied in conjunction with other technologies such as cloud computing, machine learning, and AI (Theoleyre and Pang, 2013). This section focuses specifically on IoT by reviewing the extant literature that describes IoT, its applications, and the essential technical features that justify its applications.

2.2.1 Definition of IoT

Internet of things is defined as "interconnection of sensing and actuating devices providing the ability to share information across platforms through a unified framework, developing a common operating picture for enabling innovative applications" (Gubbi et al., 2013, pg. 1647). The phrase "Internet of Things" was coined from the two words, i.e. "Internet" and "Things". The Internet is a global system of interconnected computer networks that serve billions of users worldwide. It is a network of networks that consists of millions of private, public, academic, business, and government networks, of local to global scope, that are linked by a broad array of electronic, wireless and optical networking technologies (Madakam et al., 2015). Things can be a range of physical artefacts that can be digitalised by connecting them to the internet.

IoT is made up of three core components, namely; hardware, middleware, and presentation (Atzori et al., 2010; Gubbi et al., 2013). The hardware includes identification, sensing and communication technologies such as wireless sensors and transmitters that allow remote monitoring (Grubic, 2018; Grubic et al., 2014; Johnsson et al., 2008; Peppard and Ward, 2016). Middleware includes storage and computing tools for data analytics (Opresnik and Taisch, 2015; Lee et al., 2014; Rizk et al., 2017; Sakao et al., 2019; Shukla et al., 2018). The presentation includes visualisation and interpretation tools that can be widely accessed and shared (Cenamor et al., 2017;

Barrett et al., 2015; Gubbi et al., 2013). These components form the key IoT features and consequentially define the extent of its contributions to servitization. Essentially, IoT is not one standard technology that can be identified but rather a combination of technologies making it very valuable (Lee and Lee, 2015).

2.2.2 Applications of IoT

Gartner (2014) forecasts that the IoT will reach 26 billion units by 2020, up from 0.9 billion in 2009, and add a value of $14.4 trillion to the world economy by 2022 (Bradley et al., 2013), which is expected to affect all types of businesses. The applications of IoT can be broadly subdivided as domestic, healthcare, transport, personal, and manufacturing (Madakkam et al., 2015). The domestic, healthcare, transport, and personal applications of IoT have received substantial attention in the literature as the impact, and the technology is often directly visible to all the stakeholders (Shah and Yaqoob, 2016). Domestic applications include smart home appliances to control and monitor utility and security systems. Healthcare applications include remote controlled and monitored pacemakers, life support systems, and assisted the living. Transport applications involve remotely controlled and monitored vehicle access and security and remote performance monitoring. Personal applications include wearable watches, gesture-controlled devices, voice-activated personal assistants (Khan et al., 2012).

2.2.3 IoT in manufacturing

Out of the $14.4 trillion expected added-value (Bradley et al., 2013), the manufacturing industry is expected to make 27% or $3.88 trillion. From the production line and warehousing to retail delivery and store shelving, IoT is transforming business processes by supplying more accurate and real-time visibility and interactivity into the flow of materials and products. Firms will invest in the IoT to redesign factory workflows, improve tracking of materials, and optimize distribution costs. Majority of value for manufacturers come from greater agility and flexibility in factories, and from the ability to make most of the workers ‘skills.

Holistically, the use of IoT in manufacturing is focused on developing a digital and intelligent factory and promoting information-driven, customised, and green manufacturing (Zhou et al., 2015). This enables building a highly flexible manufacturing industry of personalized and digitally-enhanced products and services, with real-time interactions between people, products and devices during the production process (Lee et al., 2015).

For example, both John Deere and UPS are using IoT-enabled fleet tracking technologies to cut costs and improve supply efficiency (Schimek, 2016). Kroger's new IoT-based system, Retail Site Intelligence, is a retail platform of video analytics, wireless devices, handheld sensors, cameras, and video management software that was designed to improve the customer's shopping experience (Lee and Lee, 2015). The manufacturing applications are specifically gaining more attention since the inception of Industry 4.0 in the German economy (Roblek et al., 2016).

IoT relates to Industry 4.0 as it refers to the integration of IoT in manufacturing to fulfil the agile and dynamic requirements of production and improve the effectiveness and efficiency of the entire industry (Lu, 2017). In 2011, the German government presented Industry 4.0 to promote improvements and efficiency in the German manufacturing industry using digital technology, which has become an umbrella term for discussions on industrial applications of the IoT (Russmann et al., 2015). In research, the applications of Industry 4.0 present substantial overlaps with existing literature on IoT and is a term often used when discussing manufacturing applications of IoT (Wan et al., 2015).

On a production level, manufacturers often conduct a large-scale deployment of radio frequency identification (RFID) tags attached to production parts. This allows remote monitoring of product parts in the supply chain, which provides vital information about the product. Sensors on a machine monitors parameter such as vibrations, temperature, and pressure which notify the system when observations beyond threshold limits are made, thus showing signs of failure, breakdown, maintenance, or accidents (Spiess et al., 2009). In addition to the value IoT creates for the production level, IoT also offers substantial value for manufacturers aiming to use it in the after-sales stage, such as; for fulfilling their service-oriented motivations (Bustinza et al., 2017).

The use of IoT for service-oriented motivations has substantial overlaps with existing research on digitally-enabled servitization (Bustinza et al., 2018) which is commonly understood as digital servitization (Vendrell-Herrero et al., 2017). Within this domain, scholars have led many studies to understand the specific value of IoT to drive servitization (Rymaszewska et al., 2017; Zancul et al., 2016; Heinis et al., 2018; Ardolino et al., 2016; Turunen et al., 2018). Although these studies might take different angles to study the concurrence of IoT and servitization, they all suggest that IoT is a crucial enabler of servitization (see section 2.2.5). Before that, it is essential to acknowledge the key features of IoT that create the value discussed in this chapter so far.

2.2.4 Key features of IoT

As defined in section 2.2.1, the core components of IoT are the hardware, middleware, and the presentation. WSN and GPS form the hardware component of IoT, analytical software forms the middleware component, and the visualisation and sharing platforms form the presentation component. Based on these core components, IoT possesses a set of three key features, namely *Remote Monitoring, Data Analytics,* and *Data Sharing* (Lee and Lee, 2015; Ng and Wakenshaw, 2017). Using these features, manufacturers can drive their servitization based on connected intelligence that collects data, transforms data, automates processes, and enhances the actions of the organisations aiming to innovate their businesses based on the use of IoT (Lee at al., 2015).

Remote monitoring consists of spatially distributed autonomous sensors to monitor physical or environmental conditions and can cooperate with RFID systems to better track the status of things such as their location, temperature, and movements (Atzori et al.,2010). Recent technological advances in low-power integrated circuits and wireless communications have made WSNs efficient, low-cost, and low-power consuming (Gubbi et al.,2013). GPS allows very similar abilities but focused only on location and movement. Remote monitoring allows managers to continuously track and measure the performance and condition of the products while they are in operation. Ulaga and Reinartz (2011) found that data on product usage provided by remote monitoring was identified as the leading strategic resource and the capacity required to deliver product-related support.

Data analytics demonstrates the interpretation of the data collected from remote monitoring and develop knowledge about the product's performance and condition (Lee and Lee, 2015). Products with embedded sensors generate enormous amounts of data that can be analysed for decision-making (Lee at al., 2014). These data are used to discover and resolve business issues such as changes in customer demands and new business opportunities. Analytic tools may be embedded into the product so that real-time decision making can take place at the source of data. Advances in analytics now make it possible to capture and interpret vast amounts of usage and performance data (Opresnik and Taisch, 2015). This enables identification of common usage patterns and health predictions (Baines et al., 2014), creating opportunities for the provision of offerings based on improved maintenance and performance advisory.

Data sharing provides insights and information as the third feature of IoT. Sensing a predefined event is usually the first step for information sharing and collaboration, but also revolves around regular communication (Lee and Lee, 2015). Many manufacturers use digital platforms that serve as a destination for all stakeholders to access the data and knowledge from remote monitoring and data analytics. This communication plays a critical role in contracts as it allows firms to demonstrate the delivery of offerings, all circulate other services related information (Lightfoot et al., 2011; Kryvinska et al., 2014).

The outcomes created by using these key features are multiple (Lee and Lee, 2015). Use of remote monitoring creates outcomes such as information of different product parameters, for example performance, location, health, live operations, environment, and users. (Grubic et al., 2019). Use of data analytics creates outcomes such as predictive algorithms, analytical tools, efficiency improving insights, performance patterns and trajectories (Opresnik and Taisch, 2015; Nino et al., 2015). Use of the data sharing feature creates outcomes such as customer education, performance reporting, fault reporting, alarms and notifications, and process transparency (Kamp et al., 2017; Sjodin et al., 2018; Cenamor et al., 2017). However, research does not explain how the use of a limited number of features can create a wide range of outcomes. IoT is increasingly conceptualised as a technology that creates different outcomes in different contexts, highlighting the importance of context

(Dmitrijeva et al., 2019; Perera et al., 2013). This study is an important context to understand how IoT's features create a range of outcomes.

2.2.5 IoT enabled servitization

Overall, the IoT contributes to servitization by facilitating and accelerating the servitization process, enables the development of novel product-service offerings (Lerch and Gotsch, 2015) and generally helps manufacturers to differentiate themselves from the competition (Porter and Heppelmann, 2014).

In the shift to a service business, manufacturers have introduced IoT to potentially increase the efficiency of service delivery and drive the provision of data-driven services (Rymaszewska et al., 2017; Adrodegari et al., 2017; Lightfoot et al., 2013). For example, by connecting products to a (remote) control room, manufacturers can provide intermediate services such as predictive maintenance and advanced services (Allmendinger and Lombreglia, 2005). As large amounts of usage data are collected, manufacturers can develop knowledge about how, when and where their products are used by whom, which problems occur in time and why. (Opresnik and Taisch, 2015; Neff et al., 2014). In turn, firms can use this pool of data to develop new services that support the customer's business as well (Porter and Heppelmann, 2014, Evans and Annunziata, 2012; Rijsdijk et al., 2007).

Predictive maintenance involves live-monitoring of equipment condition, while it is in operation, to measure and collect information on the deterioration and usage patterns of the product (Kohtamaki et al., 2019). This information is used to optimize maintenance schedules, plan the replacement of parts based on product usage, optimizing resource allocation across multiple sites, and predicting product breakdown shortly (Ardakani et al., 2015). These services allow the manufacturer to ensure uptime and availability of the product, thus having a meaningful impact on the product utilization and the customer's business (Wan et al., 2018).

As an example of predictive maintenance services, MAN Truck and Bus UK connect their product's engines to a central control centre, where they monitor driver performance and truck condition allowing a better estimation of the maintenance requirements and schedules. Improved maintenance services help the manufacturer reduce the risk involved in guaranteeing performance or availability. They also use the information from the monitoring to deliver an engine management system that makes recommendations about best driving habits for the driver. This allows the manufacturer to help improve the customer's business performance by reducing their fuel costs and improve truck performance.

Another example of predictive maintenance is Alstom UK, who provide maintenance, repair, and overhaul capability to Virgin Trains UK against an availability contract. As part of this contract, Alstom takes complete responsibility for the maintenance and upkeep of the trains. To enable this service, Alstom employs an IoT system that monitors and analyses various parameters such as propulsion, air, location, braking, and high tension that allow them an accurate estimation of the train condition and plan maintenance and repairs to minimise downtime. This allows Alstom to manage the risks involved in guaranteeing the availability of the trains to Virgin Trains UK (Lightfoot, Baines et al. 2011).

IoT also enables advanced services such as performance advisory services. Performance advisory services are an offering of recommendations made to the customer by the manufacturer to improve their business performance. Manufacturers analyse the product condition and usage information to develop insights for the customers on improving product use (Advanced Services Group, 2019). Such services allow manufacturers to support their customer's business operation, increase customer satisfaction, and reduce proximity. The manufacturer can recommend the best practices adopted across multiple customers which helps them to ensure the product's upkeep, reduce damage and breakdown due to faulty operating procedures. Overall, performance advisory services allow the manufacturer to take a crucial position in the customer's business and gain more visibility and control over the condition and use of the product (Baines and Lightfoot, 2013a).

As an example of performance advisory services, Rolls-Royce aerospace employs IoT to sense and acquire data (e.g. pressures, temperatures, vibrations) about the health performance and usage of the engines being used by their customer. These data are analysed at their control centres using various analytical tools and turned into information about current and predicted the health of the engine. Furthermore, this information is shared within the organisation and with the customer to decide on actions that will maximise the performance, optimise maintenance resulting in minimised risks for the manufacturer (Grubic and Jennions, 2017).

2.2.6 New lens to study IoT enabled servitization

The literature on IoT enabled servitization makes numerous claims of IoT's value for servitization as a critical enabler (Rymaszewska et al., 2017; Coreynen et al., 2017; Vendrell-Herrero et al., 2017; Kohtamaki et al., 2019). However, by focusing on value of IoT for servitization, research has increasingly implied that IoT creates this value on its own through product digitalisation. Thus, the research considers that IoT enabled servitization as a technological phenomenon, purely dictated by the technical capabilities of IoT. This ignores the importance of the context (servitization) in which the technology is used (Dmitijeva et al., 2019), thus undermining the complexity of the servitization as a transformative process.

Additionally, the research does not explore how IoT enables a manufacturer's transformation, but only focuses on the overall value IoT creates. Research does not indicate whether IoT plays a role throughout the transformative process. As a result, extant literature only provides a partial picture of how IoT enables servitization by describing the applications and value of IoT in servitization. Capturing the manufacturers' role in making the contextual use of IoT will substantially contribute to advancing the knowledge of IoT enabled servitization. Taking a process-perspective will allow exploring the use of IoT along with the manufacturer's transformation.

Failure to address an actor's efforts in using a digital technology that enables organisational transformation has been highlighted as a research gap in information systems literature (Pozzi et al., 2014). To address this issue, scholars in the domain of Information Systems adopted an actor-focused perspective to acknowledge the efforts of the actor in making goal-oriented use of digital technology. This actor-focused perspective was provided by the affordance theory, which has been increasingly used to investigate digitally-enabled organisational transformation (Wang et al., 2018). The affordance theory is commonly found suitable for a wide range of studies addressing digitally-enabled organisational transformation similar to IoT enabled servitization. By applying the theory in the context of servitization, the study explores the manufacturer's role in using IoT (actor-focused perspective) and the process of using IoT in servitization (process-focused perspective). The next section (section 2.3) further explains the affordance theory and its suitability to explain the actions in IoT enabled servitization.

2.3 Affordance theory

The affordance theory was conceptualised in the field of ecological psychology by Gibson (1986). Gibson developed the theory to explain how animals react to their surroundings, specifically when they interact with particular objects in their surroundings and how that interaction generates new actions. Since then, the theory has gained substantial attention, specifically in the field of information systems (Pozzi et al., 2014; Wang et al. 2018). This can be attributed to the theory's potential to satisfactorily explain the rise of opportunities for actors to use technological artefacts and create desired outcomes. Affordance theory provides a focus on the alignment between an actor's goal and an artefact's features that allow the actor to achieve their goal. It emphasises the existence of opportunities perceived by the actor to achieve their goals as well as the actions they take to realise these opportunities.

Recently, the theory is increasingly used to explain the role of digital technology in organisational transformation (Zammuto et al., 2007; Markus and Silver, 2008; Leonardi, 2012; Majchrzak and Markus, 2012; Volkoff and Strong, 2013). Furthermore, affordance theory has been correctly used to study the application of various digital technologies in organisational contexts uncovering how organisations took specific goal-oriented steps to use these technologies (Pozzi et al., 2014).

The concept of *affordances* in the theory is defined as potentials or opportunities for action arising from the relationship of a goal-oriented actor and features of an artefact to achieving the desired outcome (Volkoff and Strong, 2013; Strong et al., 2014; Wang et al., 2018). The definition is commonly used in contexts relating to organisational transformation using digital technology (Pozzi et al., 2014).

The definition has evolved with its increasing application and theoretical development from the field of ecological psychology to the field of information systems. At its inception, the concept of affordances was used to indicate a possibility for an action available to an actor (for example, animals) in their natural environment (Greeno, 1994). Since its application in investigating digital technologies as artefacts, affordances are considered to exist as a relationship between an actor and an artefact, instead of the actor and the environment (Hutchby 2001).

2.3.1 Key principles

Influenced by the seminal work of Strong et al., (2014), the affordance theory is recognised to have three key principles. These principles are namely (i) *affordance perception*, (ii) *affordance actualization,* and (iii) *affordance dependency,* which define the utility of the theory.

(i) Affordance Perception

As the name suggests, affordance perception is about perceiving or acknowledging the affordance (an opportunity for action). Perception occurs when the goal-oriented actor interacts with specific features of an artefact and perceives an opportunity to use the artefact to achieve outcomes aligned with their goal.

Affordance perception is a relational occurrence. The theory states that an actor perceives affordances based on what they want to achieve (goal or motivation) and the artefact (features of the artefact if more than one) that enables the achievement (Markus and Silver 2008). The artefact does not present affordances by itself, but only with a goal-oriented actor (Volkoff and Strong 2017). Similarly, the technology does not define the outcomes created by the actualization of the affordances, as outcomes vary with the actor's context. Since the affordance cannot be perceived solely from the actor or the artefact, they are inseparable when studying affordances which is why affordances are considered relational. (Davis and Choinard, 2016).

For example, an organisation to manage its customer portfolio interacts with the data-sorting feature of Customer Resource Management (CRM) system. This interaction leads to the perception of an opportunity to obtain a new resource to manage customer data (affordance). Therefore, the affordance is only perceived by the actor with the technological artefact being used.

(ii) Affordance Actualization

The second key principle of the theory is affordance actualization. Affordance actualization is the process of the actor taking *actions to realise the perceived* *affordances by using the artefact to achieve outcomes that support the organisation's goals for its transformation* (Strong et al., 2014). This process is a combination of actions taken by the actor, within the scope of their capabilities, to use the artefact's specific features and the resulting outcomes aligned with their organisational goal.

The principle of affordance actualisation also emphasises that affordances are a prerequisite for an action to occur, but do not imply that the specific action will or has occurred (Hutchby, 2001). The actualisation focuses on this process of realising the opportunity presented by the affordance, the importance of which was not recognized by ecological psychologists (Gibson 2000; Greeno 1994) and scholars involved in early applications of affordances to Information Systems (Hutchby 2001; Zammuto et al., 2007). Earlier studies assumed that every perceived affordance is actualised. When applying the concept to organisations interacting with technologies, the scholars observed that not all affordances that are perceived are actualised. The actor that has perceived the affordance is required to take suitable actions that result in the achievement of the desired outcome. Only then can the affordance be considered as actualised. (Strong et al., 2014; Volkoff & Strong, 2013).

Based on the previous example, the organisation (actor) would take action or purchasing/procuring/developing a CRM system. This would result in having a resource available for managing the customer portfolio. Although this outcome is desirable to achieve the set goal, it is not always the case. Often, the outcome of affordance actualization leads to the perception of a new affordance, therefore creating a need to actualise multiple affordances to achieve the set goal. The occurrence of a chain of perception and actualisation processes makes the affordance perception and actualization an iterative process.

(iii) Affordance Dependency

The third key principle of affordance theory is affordance dependency. Since the affordance perception and actualisation is an iterative process, it is also observed that specific affordances cannot be perceived without another affordance being actualised. This indicates a dependency between the affordances (Strong et al., 2014). The affordance dependency has not been empirically substantiated to explain why this dependency occurs and how it affects the realisation of the actor's goals.

Strong et al., (2014) describe this dependency as a cascading relationship between multiple affordances perceived by an actor which indicates that the affordances have to be perceived and actualised in a specific sequence before the actor's goal can be realised. Strong et al., (2014) identified this occurrence in their study of affordance actualization in implementation of an EHR system, where they found that some affordances were dependent on the actualization and resulting outcome of other affordances (e.g. 'coordinating patient care' is dependent on actualizing the affordance, 'accessing and using patient information at anytime from anywhere'). This also led them to understand that not all affordances are perceived or actualised at once, but in fact, affordances are cascading (Michael 2000; Bloomfield et al., 2010, Strong et al., 2014).

Based on the key principles of affordance perception and actualisation, the relationship between the different constructs, in theory, can be visualised through Figure 3 as conceptualised by Strong et al., (2014). This figure presents the affordance actualisation framework as a reference for the rest of the study.

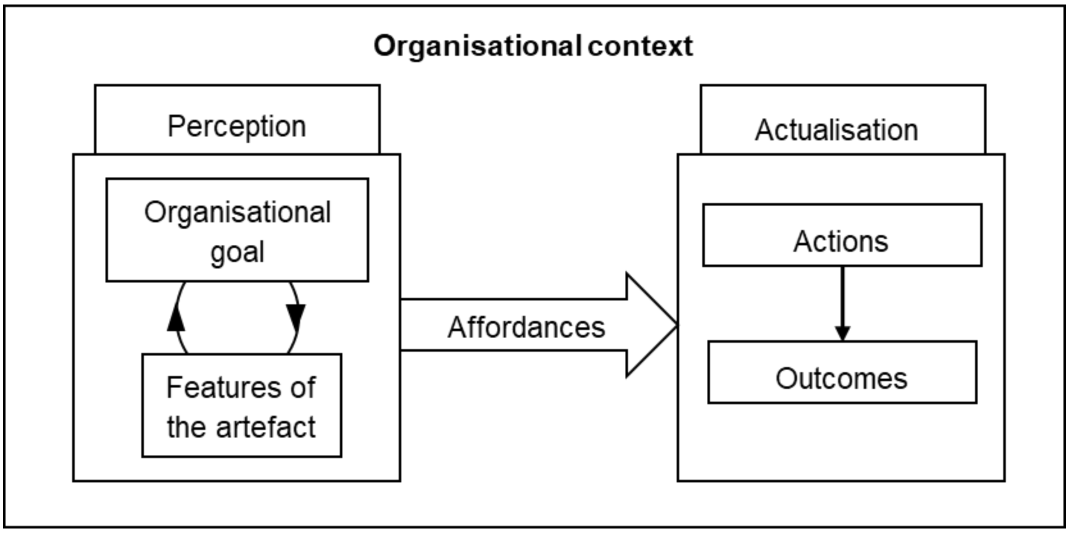

Figure 3 Affordance actualisation framework (adapted from Strong et al., 2014)

According to Figure 3, (adapted from Strong et al., 2014), affordance perception comprises of the actor's goal which drives their efforts in undergoing the organisational transformation, the features of the technological artefact that the actor interacts with, and the resulting affordance perceived by the actor. This completes the process of affordance perception, which is then followed by affordance actualisation.

The actualisation comprises of specific actions that the actor takes to realise the affordance and the resulting outcome of the actions. The achievement of the outcome marks the end of the affordance actualisation. These two processes occur within the boundaries of the organisational context, which is defined by the type of organisational transformation. Having established the connection between the different concepts, Table 5 clearly defines these concepts.

Table 5 Definitions of theoretical constructs

<table>
<tr><th colspan="2">Affordance perception</th><th colspan="2">Affordance actualisation</th></tr>
<tr><td colspan="4">Organisational goal: The overarching goal of the organisation to achieve a change enabled by the use of the artefact.</td></tr>
<tr><th>Features of the artefact</th><th>Affordance</th><th>Actions</th><th>Outcomes</th></tr>
<tr><td>Specific features of the digital technology interacting with the actor</td><td>The potential or opportunity to act associated with achieving the desired outcome that arises from the relation between an artefact and a goal-oriented actor.</td><td>The actions were taken by the actor to actualize the affordance with the overarching goal in focus</td><td>A specific outcome from actualization that is viewed as useful for realizing overarching organisational goals.</td></tr>
</table>

2.3.2 Using the affordance theory

The theory is used in several studies to investigate organisational transformation, but often the use is limited to the adoption of affordances as a terminology rather than a theory, thus disregarding the key principles of the theory (Leonardi and Vaast, 2017). Such a use of the theory undermines its utility in providing a detailed account of how organisations make goal-oriented use of the technology to drive their transformation. Strong et al., (2014), and Volkoff and Strong (2018) propose six rules that should be followed when using affordance theory in order to maintain consistency with the utility of the theory.

The first rule is to acknowledge that affordances arise from the relation between technology and the actor. Commonly, authors have used the language and arguments that treat affordances similar to the features of a technology, considering affordances as inherent characteristics of the technology. A technical artefact does not possess any affordances. Affordances are only perceived with a goal-directed actor, and the actor should not be separated from the artefact.

The second rule expects scholars to maintain a clear distinction between the two parts, perception and actualization. The perception should always relate to a function (what the affordance it allows the actor to do) and the actualization should relate to the structure of actions (actions that realise the affordance and create the outcomes). In other words, perception relates to potential actions and purposes they are intended to achieve, while actualization relates to the particular actions taken by the actor to fulfil the purpose of the affordance.

To maintain a focus on the identification of mechanisms and the actor's actions, Volkoff and Strong (2018) recommend the third rule, distinguishing the actions and outcomes by using a verb participle such as “communicating” and “monitoring” when describing actions and reserving the use of nouns for the resulting outcomes. A crucial contribution of using the affordance theory is the power to explain mechanisms, actor's actions, and the role of technology in organisational transformation. However, scholars tend to focus on the state reached after an affordance has been actualised, the outcome. By doing so, the research differs little from a study investigating the impact of the technology, therefore losing sight of the real purpose of the theory.

Choosing the appropriate level of granularity is the fourth rule of using the affordance theory. The definition of affordances provides little explanation on the level of granularity expected when identifying and describing affordances. Gibson (1979) makes it clear that affordances can be described at different levels. For example, an email system affords the user a possibility of communicating, as a general-purpose of the system, but also affords the possibility of drafting, editing, formatting, and receiving emails on a more macro level. Both the levels present legitimate examples of affordances. Strong et al. (2014) suggest that the appropriate level of granularity is dictated by the research question in focus. By focusing on largely macro-level affordances, the scholars risk identifying a large volume of affordances that represent a functional level of the phenomenon while focusing a broader level of affordances bears a risk of losing the focus on identifying multiple affordances that enable organisational transformation. Therefore, a balance between the two scenarios needs to be found that sufficiently addresses the research question.

Identification of all the affordance is equally crucial and forms the fifth rule of using the theory. Since the work of Gibson (1979), the focus of the theory has moved towards an interest in identifying multiple affordances as compared to one broad affordance that describes a phenomenon. The use of technology can lead to multiple affordances due to its multiple features, often more sophisticated affordances that depend on the successful actualization of more basic affordances (Volkoff and Strong, 2013). Such instances indicate dependency between the affordances (Strong et al., 2014). Such dependencies can only be identified when a maximum number of affordances are identified at the appropriate level of granularity. Volkoff and Strong (2018) recommend using the theory to address organisational change with these rules at the core in order to use the theory correctly for what it was intended to do.

Giving due importance to the actor and the artefact is the sixth rule when using the theory. The theory is adopted in the field beyond ecological psychology to focus on characterising the roles of IT and the organisation in the transformation process as scholars had focused on only either of the sides (Bloomfield et al. 2010). A few studies are claimed to privilege the social and lose sight of the technology (Leonardi and Barley, 2010) by taking approaches that generalize the technology, therefore, ignoring the features of the technology. On the other hand, others have focused on the technology by limiting the social investigation to the mere interaction of the actor with the artefact when using the artefact (DeSanctis and Poole, 1994). The theory focuses clearly on the features of the technology and the general intent to use the technology in the form of actor’s goals and actions, therefore making it very important to balance the focus between the social and technical side of the phenomenon.

2.3.3 Extant literature on affordance theory

Extant literature on affordance theory comprises of conceptual studies that contributed to the establishment of the key principles, and empirical studies that have tested or applied the theory in contexts of organisational transformation. Within these empirical studies, scholars have used the affordance theory as a theoretical framework and a tool of analysis that guides the analysis of their data.

In conceptual studies, the use of the affordance theory to explain digitally-enabled organisational transformation has helped substantiate the concept of affordances and the key principles of the theory (Robey et al., 2013). Zammuto et al. (2007), stipulate that IT affordances can affect the form and functions of an organisation and the evolving relationship between IT and organisations. Markus and Silver (2008) also found that features of artefacts can provide affordance-related information, but affordances themselves are not features of the artefact. They also concluded that artefact features are insufficient to explain the use and effects of the artefacts, in the context of using digital technology. Volkoff and Strong (2013) further extended the knowledge with ontological considerations behind the use of the affordance theory by taking a critical realist perspective. Strong et al. (2014) contributed to the advancement of the theory substantially by their grounded-theory approach towards developing the principle of affordance actualisation and conceptualising affordance dependency.

In empirical studies, the theory has been applied to cases such as the implementation of IT to study the challenges and interactions between the IT and clinic routines in the healthcare industry (Goh et al. 2011). The study unravelled the mechanisms behind the implementation of medical-IT and highlighted the emergence of different opportunities to change clinic routines by using IT. The study also concluded that affordance actualisation might lead to the emergence of more affordances which requires further reinforcing with empirical evidence. This indicates affordance dependency, but the study does not substantiate this with relevant empirical data. Along a similar vein, Volkoff and Strong (2013) applied the theory to investigate the implementation of an ERP system and customised engineering software, and its interactions with organisational actors. They concluded that affordances are generative mechanisms in an organisational change process, improving the understanding of IT-related changes (Volkoff and Strong, 2013).

Other studies have used affordance theory to explain IT-associated organisational change (Zammuto et al., 2007; Markus and Silver, 2008; Volkoff and Strong, 2013; Strong et al., 2014) or IT use (Orlikowski, 2007; Orlikowski and Scott, 2008) in different contexts. The theory has helped researchers to explore IT artefacts as diverse as visualisation software (Van Osch and Mendelson, 2011), simulation software (Leonardi, 2013), electronic health records system (Volkoff and Strong, 2013) or general business systems (Sebastian et al., 2012; Savoli and Barki, 2013; Seidel et al., 2013). In these studies, affordance theory is not only used as a guiding framework to understand technology-based opportunity identification and realisation but also as an analytical tool to structure the actual analysis. Affordance theory, with its specific constructs, has been used as a template to systematically analyse technology-associated organisational change (Volkoff and Strong, 2018).

When used as an analytical tool, the affordance theory provides predefined categories for structuring the analysis. Inspired by Strong et al., (2014) the theory has been used to guide researchers' coding efforts in different organisational contexts (Lehrig et al., 2017, Mallampalli et al., 2018; Dremel et al., 2019; Du et al., 2019). Lehrig et al. (2017) used it as a tool for coding the collected data about the actualization of opportunities on collaborative platforms. Dremel et al. (2018) and Du et al. (2019) also used it as a coding tool to analyse the affordance actualization in the use of big data analytics and blockchain technology in organisational transformation. In general, Volkoff and Strong (2017) recommend using the affordance theory as a lens to investigate the phenomenon and structure the research using the constructs already established, therefore suggest using the theory as a template for research on technology-associated organisational change (Strong et al., 2014).

2.3.4 Affordance theory to explain IoT enabled servitization

In previous sections (2.3.2 and 2.3.3), the guidelines to use the affordance theory and evidence of its application to investigate technology-driven organisational change has been established. The theory has been used effectively to investigate contexts similar to IoT enabled servitization. The theory is driven by an intention to give due consideration to the technological (IoT) and the social (manufacturer) side when investigating the use of digital technology. Therefore, the theory is potentially a valuable tool for this study as it provides two key contributions, (i) actor-focused perspective and (ii) process-focused perspective.

Through an actor-focused perspective, affordance theory provides an opportunity to address the need for acknowledging the manufacturer's role in IoT enabled servitization by helping explain the diverse ways in which IoT is used by manufacturers. By applying the affordance theory to the servitization context, this study advances the existing literature's perspective of investigating the role of IoT in servitization and provide managers with the ability to manage the integration of IoT in their business. From an affordance perspective, IoT would be considered as a platform of opportunities that enable servitization, instead of being treated as an enabler of servitization by itself. This would shift the research focus from the technology to the manufacturer's perception of opportunities to achieve its goal to achieve outcomes that enable servitization (Frank et al., 2019; Suppatvech et al., 2018).

The process-focused perspective relates to the principle of the actualisation process, thus exploring how the manufacturer takes specific actions to realise these perceived affordances. Hence, while prior studies were satisfied with showing that use of IoT leads to *gathering insights about product-use* (Kamp and Parry, 2017), an affordance perspective would focus on how these opportunities are realised by the manufacturer. IoT-enabled servitization has not been studied to this level of granularity, yet, using the affordance theory. Furthermore, the bundling of services as a part of servitization (see section 2.1.2) will be investigated in practice through the principle of affordance dependency. This will allow visualising the use of IoT in the transformative process of servitization.

By applying the theory in the context of IoT enabled servitization, the study can contribute to the development of the affordance theory as the study will address specific gaps in the literature on affordance theory. Additionally, the theory will also be used to address the IoT as an artefact, while previous studies have focused on simpler IT systems (Wang et al., 2018; Strong et al., 2014; Volkoff and Strong, 2018). The study also provides the potential for the investigation of affordance dependency on a practical level, which has been called for previously (Strong et al., 2014). The use of affordance theory in literature presents specific gaps when it comes to the application of theory on an organisational level.

Investigating organisational transformation by using the affordance theory is limited in terms of the level of analysis that has been focused on individuals, such as employees (Strong et al., 2014; Wang et al., 2018). Majority of studies based on the affordance theory are presented as an individual's journey, more specifically, as an individual-level process of perceiving and actualising affordances (Seidel, 2013; Grgecic, 2015; Bygstad, 2016). Therefore, the theory suffers from a lack of understanding in differences between individual-level and organisational-level processes (Wang et al., 2018).

Strong et al. (2014) argue that their analysis introduces an organisational-level process by aggregating individual-level processes. However, Wang et al., (2018) have clarified that organisations manifest properties different from the sum of its individuals, which implies that aggregation of individual-level processes cannot be interpreted as an organisational-level process. They call for further research on the appropriate application of affordance theory organisational level. An organisational level of analysis also allows exploring actions on an organisational level and the type of technological features deemed useful by an organisation, as compared to an individual level focus from the extant literature.

Secondly, Strong et al. (2014) made a pivotal contribution to the theory development by conceptualising the principle of affordance dependency. However, they called for further development of this principle based on empirical evidence. Since the conceptualisation in 2014, there has been little exploration of affordance dependency in empirical research. This implies a limited scope of the existing literature to the identification of affordances, and the outcomes as a result of affordance actualisation (Wang et al., 2018). The identification of affordance dependency in a study would substantially contribute to the development of the theory while also explaining why particular affordances are perceived and actualised in a specific sequence (Strong et al., 2014). It would also highlight the actor’s role in this sequence, and thus result in crucial contributions for practitioners as well as academics.

2.4 Research questions

The review of the literature in this chapter has led to the identification of an overarching research question, which is further divided into three sub-questions that are based on individual research gaps. This section presents these gaps while also explaining the meaning of these gaps in terms of the affordance theory. Figure 4 visualises the derivation of the three sub-questions from the literature review that directs this thesis.

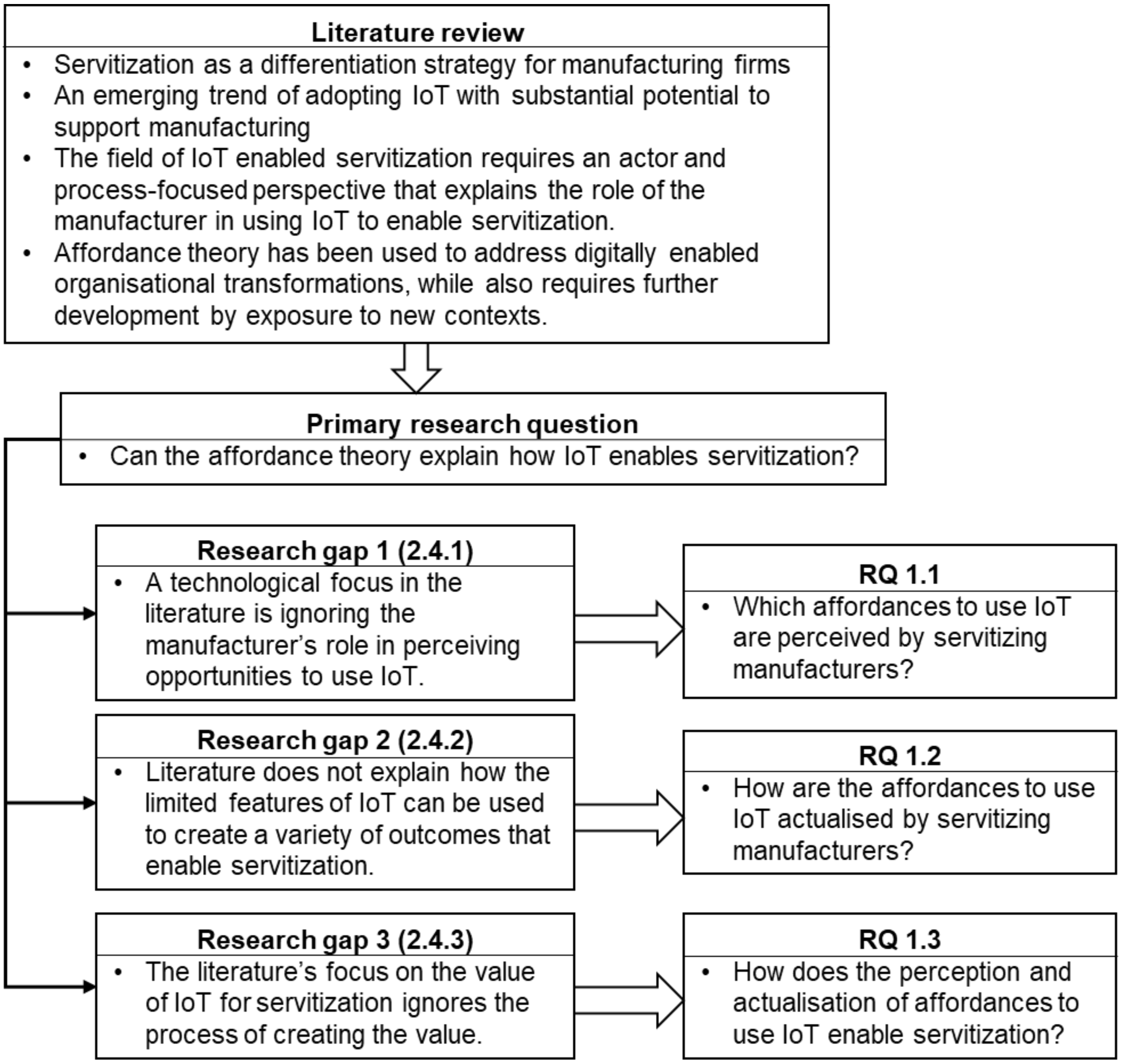

Figure 4 Research Questions

The literature review has established the intersection between the domains of servitization and IoT (section 2.2.5) and explained the suitability of affordance theory to allow the adoption of a new perspective to investigate IoT enabled servitization (section 2.2.6, 2.3.4). Specifically, manufacturers find achieving the desired outcomes from the use of IoT to be challenging, although the literature claims that IoT is a crucial enabler of servitization (Peilon and Dubruc, 2019; Simonsson et al., 2019; Zheng et al., 2019; Kohtamaki et al., 2020). This challenge can be attributed to the incomplete picture, presented in the literature, explaining the process of making goal-oriented use of IoT to enable servitization (section 2.2.6). By arguing that using the affordance theory to address this gap can contribute to a holistic explanation of IoT enabled servitization (section 2.3.4), the primary research question for the thesis is formulated as '*Can the affordance theory explain how IoT enables servitization?'* This question can be further divided into sub-questions that address three specific gaps in the research, thus providing more detail and setting the overall direction of this thesis.

The first gap (see section 2.4.1) identified is the lack of emphasis on the manufacturer's role in using IoT because the literature has focused on the phenomenon of digitalisation of using IoT and predicting its potential impact (Frank et al., 2019). This study argues for addressing this gap by adopting an actor-focused perspective of affordance theory, and thus advance the knowledge about IoT enabled servitization. In terms of the second gap (see section 2.4.2), the key IoT features, as identified in section 2.2.4, are limited by number, but their use creates numerous outcomes. The extant research inadequately explains the reason behind this diversity in outcomes which presents a significant gap for this research to address. The thesis argues that focusing on the manufacturers' unique goals when using the IoT can explain the diverse outcomes created by the use of limited IoT features. The third gap (see section 2.4.3) relates to the literature's focus on the outcomes of IoT usage for servitization, as such a focus ignores the actions from the manufacturer and the overall process required to create these outcomes. Such a gap can be addressed through a process-focused perspective of the affordance theory to explore the creation of these outcomes.

2.4.1 Manufacturer's role in IoT enabled servitization

Servitization literature has not adequately explored the role of the manufacturer when using IoT as it mainly focuses on IoT as the technological phenomenon responsible for enabling servitization (Ardolino et al., 2018; Turunen et al., 2018; Kohtamaki et al., 2019; Rymaszewksa et al., 2017; Zancul et al., 2016). Although in practice, this consideration is challenged as manufacturers do not quickly gain the benefits by embedding the IoT into their products (Tronvoll et al., 2020). The use of IoT to enable servitization in practice is found to be more complex and creative than the literature has stated so far (Coreynen et al., 2020). Therefore it is essential to explore *how IoT is used* rather than *what value is created* by IoT. This indicates focusing on the manufacturer's role as an actor in making goal-oriented use of IoT in servitization (section 2.2.6), as it allows exploring the creativity underlying the use of IoT to achieve specific goals (Lenka et al., 2018).

A focus on the manufacturer's role acknowledges the importance of their unique goals and actions to utilise IoT (Volkoff and Strong, 2018), and thus adds a new perspective to understanding how IoT is used in servitization. Therefore, this study argues that manufacturers perceive specific opportunities (affordances) to use IoT in alignment with their goals. Clear identification of these opportunities is the first step to exploring how IoT is used to enable servitization, which can be facilitated by the use of affordance theory (section 2.3.4). Therefore, the first sub-question for the research,

RQ1.1 Which affordances to use IoT are perceived by servitizing manufacturers?

2.4.2 IoT usage to achieve desired outcomes

As identified in section 2.2.4, IoT has limited features indicating its abilities such as remote monitoring, data analytics, and data sharing (Lee and Lee, 2015), but literature has identified a variety of complex outcomes from the use of these features (Bressanelli et al., 2018; Sjodin et al., 2018). This diversity in the outcomes from limited IoT features is inadequately addressed in the literature. This research argues that diversity can be explained by studying the use of IoT in the specific context of servitization because the manufacturers' unique goals for servitization can lead to the perception of different uses of IoT.

In terms of the affordance theory, the different uses of IoT can be attributed to the perception of diverse affordances perceived by the manufacturers. By exploring these affordances and their actualisation, the study can advance the knowledge on IoT enabled servitization and explain the creation of diverse outcomes from the use of limited IoT features (section 2.3.4) (Peillon and Dubruc, 2019; Paiola, 2017). Investigating the actualisation of these opportunities requires a focus on the manufacturer's actions to achieve the desired outcomes (Harison and Boonstra, 2009; Markus, 2004; Lenka et al., 2018). Therefore, this research can further enrich its investigation by focusing on the principle of affordance actualisation (section 2.3.1). To further substantiate this argument, the research will address the sub-question:

RQ1.2 How are the affordances to use IoT actualised by servitizing manufacturers?

2.4.3 Process of creating value through IoT usage

The examples of successful adoption of IoT to enable servitization, as described in section 2.2.5, are few (Rymaszewska, Helo et al. 2017)(Baines et al., 2014). This implies an overall lack of IoT adoption in practice, which can be attributed to lack of knowledge about the process of using IoT to enable servitization, as indicated in section 2.2.6 (Baines et al., 2017). Literature has primarily focused on exploring IoT's value to servitization (Kamp and Parry, 2017; Ardolino et al., 2016; Schroeder and Kotlarsky, 2015; Bressanelli et al., 2018; Ardolino et al., 2015) ignoring the overall process of using IoT that creates the potential value. Section 2.2.6 discussed that the extant literature does not explain the role of IoT in the transformative process of servitization, but only focuses on the outcomes created by the use of IoT. The process-focused perspective of affordance theory can help address this gap, as it has addressed similar research gaps in extant literature (section 2.3.3).

In terms of the affordance theory, this process of using IoT to create can be explained through the principle of affordance dependency, where the sequential perception and actualisation of affordances leads to the achievement of set organisational goals (section 2.3.1). Therefore, the use of affordance theory in this research can provide a clear focus on identifying the process of perceiving and actualising affordances to use IoT for enabling servitization (section 2.3.4). This focus can be substantiated through the sub-question,

RQ1.3 How does the perception and actualisation of affordances to use IoT enable servitization?

The three sub-questions (RQs 1.1, 1.2, 1.3) seek answers that are common to manufacturers in general without any specificity to manufacturer types. Therefore the research does not seek an in-depth investigation of a single manufacturer's use of IoT, but rather a comparison of multiple manufacturers in order to broadly explore how IoT is used in servitization, while also establishing common grounds across these manufacturers. The next step towards answering these questions is to develop a research design that adequately captures the perspectives of multiple manufacturers in their use of IoT.

2.5 Summary

This chapter has presented the contextual background of servitization, IoT, and their intersection; IoT enabled servitization. Section 2.1 presented the definition of servitization, different types of services within servitization, the manufacturers' motivations, and challenges in executing servitization. IoT was introduced as a technology with the potential to help address some of these challenges.

Section 2.2 explained the concept of IoT, its applications in different contexts, key technical features, and its association with servitization as described in extant literature. This review drove the development of the primary research question for this research. Further, the review indicated specific research gaps that helped to identify different foci for the research to answer the primary research question adequately.

In order to explore the phenomenon of IoT enabled servitization from a new perspective, the affordance theory was found as a suitable theory for this research. Section 2.3 explained the key principles and definitions involved in the affordance theory while also explaining the way it is intended to be used. The section also described how affordance theory could be used in the context of IoT enabled servitization. Additionally, the extant literature on the affordance theory was also reviewed to identify specific gaps in its application and how the application of affordance theory in the context of servitization will be able to address the identified gaps in affordance literature.

The literature review concluded with the identification of specific research gaps that will direct the framing of research in this thesis (Section 2.4). It was found that the extant literature on IoT enabled servitization has focused on the technical abilities of IoT, indicating that IoT by itself can enable servitization. Lack of focus on the manufacturer's role is a gap that this research will address. Another research gap identified indicates an inadequate explanation of the variety of outcomes created from the use of limited IoT features. This gap will be addressed by focusing on how manufacturers' make use of IoT in different ways leading to different outcomes. Finally, the research will also focus on identifying the overall process to use IoT to enable servitization as extant research has primarily focused on the value of IoT for servitization and thus ignoring how this value is created.

Figure 4 visualised the development of the research questions originating from the literature review and the alignment of each research question to the research gaps, and further to the primary research question. The following chapter will explain the research design and programme set for this study and choices made in order to make the design robust and reliable.

Chapter 3 Research design

The previous chapter discussed the development of research questions based on the research gaps identified in the literature review. This chapter describes the overall research design in order to address those research questions. The key aspects of the research design are summarised in Table 6, which include the aims and objectives (section 3.1), the underpinning research philosophy (section 3.2), the research strategy and type of study (section 3.3) and the design of a programme to conduct the study (3.4).

Once the research aim and objectives are developed, this chapter describes the commonly used research philosophies in the field of operations management before justifying the use of critical realism as a suitable philosophy for this research. In terms of research strategy, the chapter justifies the choice of deductive research strategy and a qualitative approach. It also explains why case studies are found as the most suitable type of study considering the type of questions raised in this research. Finally, a three-phase research programme is developed that demonstrates how the chapters contribute to the accomplishment of the research objectives.

Table 6 Key aspects of research design

Key aspects	
Research aim and objectives (section 3.1)	To use the affordance theory as an actor and process-focused lens to investigate the role of the manufacturer in the process of using IoT to enable servitization. - Designing and executing a robust research study with a foundation of the affordance theory to address the research questions. - Interpreting the manufacturers' accounts of perceiving and realising opportunities to use IoT and enable servitization. - Positioning the research findings in the servitization literature and explaining the academic and practical implications of the research.
Research philosophy (section 3.2)	Critical realism
Research strategy (section 3.3)	A deductive multiple-case study approach using qualitative data
Research programme (section 3.4)	A three-phase research programme: - Plan and implementation - Analysis and findings - Evaluation and conclusion

3.1 Research aim

The research gaps identified (section 2.4) are addressed in the thesis to advance the knowledge of adopting IoT to enable servitization, and resultantly simplify servitization for manufacturers. This is achieved through the provision of a better understanding of IoT's role in servitization, the manufacturer's role in using the IoT, and the process of using IoT in servitization. The literature review (section 2.3.4), identified affordance theory as a suitable theory to address this research, and based on this theory, research questions were developed for this study (section 2.4). In order to design the research programme driven by the affordance theory that successfully addresses the research questions, the aim of this research is:

"To use the affordance theory as an actor and process-focused lens to investigate the role of the manufacturer in the process of using IoT to enable servitization."

To achieve this aim, three individual objectives are specified that also play a crucial role in designing the research programme (section 3.4). The research objectives are:

1. Designing and executing a robust research study with a foundation of the affordance theory to address the research questions.
2. Interpreting the manufacturers' accounts of perceiving and realising opportunities to use IoT and enable servitization.
3. Positioning the research findings in the servitization literature and explaining the academic and practical implications of the research.

With the research aim in focus and research objectives developed, this chapter now presents the key elements of research design, including research philosophy, strategy, and the type of study. It describes the logical decisions made in designing the study that explains the researcher's stance when collecting and analysing the data.

3.2 Research philosophy

This section presents the research philosophies of positivism, interpretivism, and critical realism before explaining the choice of critical realism as a suitable philosophy for this research. It also describes how a critical realist stance interprets the reality of servitization as in this context.

3.2.1 Commonly used research philosophies

Research studies are strongly influenced by philosophical assumptions made during the investigation, and therefore make the philosophy of research the first important decision when designing a study. The philosophy defines the nature of society and the nature of knowledge as considered in the research (Burrell and Morgan, 2017). By identifying the philosophy, the researcher outlines the assumptions about the reality (ontology), the knowledge (epistemology), and the way findings can be obtained (methodology). A simplified categorization of research philosophies commonly identifies three approaches; *positivism, interpretivism,* and *critical realism* (Orlikowski and Baroudi, 1991).

Positivism is one of the most commonly employed philosophical approaches (Meredith et al., 1989). It is recognized as being based on similar assumptions as natural sciences. Epistemologically, positivist studies suggest a hypothesis which is tested using the data and is considered to be the depiction of reality if the hypothesis is confirmed by the data analysis. Ontologically, positivism assumes that a reality exists independent of the researcher, implying the world is completely natural, and it can be identified through research, thus being measurable (Guba and Lincoln, 1994). Positivist research often focuses on the generalisability of the hypothesis across the sample and understanding of a phenomenon by identifying individual components and explaining the effect of their relationships on the phenomenon. Positivist research is commonly based on quantitative methods of data collection and analysis.

On the other hand, interpretivism opposes positivism by taking an epistemologically subjective view on the social phenomenon. This means exploring the data without any prior assumptions and drawing conclusions solely from the patterns that emerge. On the ontological level, interpretive researchers assume reality to be a social construct which is created and reproduced through social interactions, meaning the reality is not entirely natural and open to interpretation (Orlikowski and Baroudi, 1991). Rather than creating generalisable theories from an objective distance, interpretive researchers aim to understand the perspectives of the individuals involved in the phenomenon, gain insights and derive explanations (Gioia and Pitre, 1990). Interpretivism looks for the meaning of responses from individuals involved and explanations of the phenomenon, instead of seeking repeatability or generalisability. Interpretivist research is often based on qualitative methods of data collection and analysis.

Critical realism (CR) uses components of both positivism and interpretivism to explore a phenomenon and provides a platform for scientists to make investigations based on the interactions between the objective knowledge and subjective knowledge. It works as a general philosophy for research but is not bundled with any specific methods. Researchers can use qualitative, quantitative, or a combination of both methods for data collection and analysis. CR primarily aims to identify causal mechanisms driving a phenomenon, as opposed to describing a phenomenon from objective reality (positivism) or explaining the phenomenon from the perspectives of involved individuals (interpretivism) (Bhaskar, 2016). The ability to engage in explanation and causal analysis (rather than engaging in the full empirical description of a given context) makes CR for this research as the research questions are directed towards identification of the mechanism underpinning the use of IoT for servitization (Fletcher, 2017). The following section (3.2.2) further explains the suitability of the CR philosophy for this research.

3.2.2 Critical Realism underpinning IoT enabled servitization

According to Fletcher (2017), any phenomenon, in reality, is arranged in three levels. The first level is called the *empirical* level, which is observable, hence objective. The level below the empirical is called the *actual*. In this level, events occur whether or not they are observed. These are real occurrences, although not clearly observed, which may be different from the observations at the empirical level. The bottom layer is called the *real* level*.* Causal mechanisms exist at this level of reality. These mechanisms are responsible for the empirical and actual levels of reality. Therefore, the identification of these causal mechanisms can explain the phenomenon concerning the empirical and actual levels.

The present study is focused on identifying the causal mechanism underlying the manufacturer's use of IoT to enable servitization. The critical realist view is suitable for the study as it allows exploration of this mechanism while acknowledging the empirical and actual levels of the phenomenon. In addition to this, the affordance theory also subscribes to a critical realist philosophy (Volkoff and Strong, 2013), making it the ideal choice for this study. The choice of this philosophy creates a suitable fit between the research questions identified for this study (section 2.5) and the fundamentals of research design. It creates a robust foundation for the study, ensuring the decisions made in the following sections of research design are aligned with the research questions and the philosophy.

In order to interpret what the critical realist philosophy means in terms of affordance theory and the context of IoT enabled servitization, consider the three levels of reality in the context of this study: the empirical level is represented by the outcomes of using IoT that can potentially enable servitization. The actual level is represented by the manufacturers making intentional use of IoT to enable their servitization goals. This level is subjective and requires investigation with a focus on the manufacturer's role.

The real level represents the unknown mechanisms that are responsible for the use of IoT and achieving the servitization enabling outcomes.

3.3 Research strategy and type of study

This section presents the research strategy and type of study found suitable for this research. To justify the choice of strategy and study, this section describes the types of strategies commonly chosen, followed by the justification of the chosen strategy of research. It is crucial to choose the strategy for this study, as the type of strategy also influences the type of study that can be chosen and the type of data that can be collected. Since critical realist philosophy is not directly associated with any specific strategy, type of study, or type of data, the choice of strategy needs to be made on other grounds such as the overarching context of the study. The context of IoT enabled servitization will play a crucial role in choosing the research strategy for this study.

3.3.1 Types of strategy

The first important step that frames the research methods used for this study is the choice of research strategy (Brewton and Millward, 2001; Gummesson, 2005). Commonly, the strategy is distinguished into inductive and deductive (Coolican, 1999). These two strategies are also related to the type of data collection and analysis methods, such as qualitative and quantitative methods. Positivist studies are often considered to have a deductive strategy where the study tests existing theory and hypothesis using quantitative data (Rose and Sullivan, 1996). Interpretivist studies are associated with an inductive strategy where research seeks to establish a new theory using more interpretive qualitative methods (Robson, 2002).

However, as a critical realist study, this research is not limited to specific methods (McAvoy and Butler, 2018). The research uses an existing theory and framework to explain the practical phenomenon (affordance theory), which means that the theory will guide the investigation rather than the data leading to the generation of a new theory, and therefore conclude with an interpretation of whether the theory can explain the phenomenon of this study or not. Such a strategy of study is understood as a deductive strategy. Deductive strategies interpret the results of a research-based on a preconceived theoretical standing.

Aiming to explore the mechanisms underlying the IoT enabled servitization of manufacturers, the study cannot depend upon measurable objective data available through quantitative methods. Objective data will only reveal the empirical layer of the phenomenon, as per the critical realist view (McAvoy and Butler, 2018). A mechanism is challenging to quantify as the measures to be quantified unknown. On the other hand, a qualitative approach provides a more in-depth, explorative form of data which is necessary for explorative elements in any research (Myers and Avison, 2002). Since the current study is primarily explorative and does not aim to establish generalisability, qualitative data is found to be suitable for this study (Creswell, 2007; Gray, 2019; Quinlan et al., 2019).

3.3.2 Type of study

After clarifying the strategy, Brewton and Millward (2001) recommend deciding on the type of study employed to address the research problem. The types of study commonly chosen in operations management (Voss et al., 2010) are commonly described in three classes:

- **The case study:** It involves the description of an ongoing event (e. g. organisational change) about a particular outcome of interest (e. g. use of IoT) over a fixed time in the 'here and now' (Brewerton and Millward, 2001, p.53).
- **The correlational design:** It involves quantitative correlational designs that attempt to explore the relationships between at least two variables within a given environment, although not to infer causes but to examine relationships and interrelationships between phenomena (Brewerton and Millward, 2001, p.57)
- **The experimental design**: It involves the manipulation of one variable (the independent variable) and the observation or measurement of the effects on another variable (the dependent variable). Such designs commonly involve controlling for external variables as far as is possible (Brewerton and Millward, 2001, p.58).

In the domain of servitization, case studies are the most common type of study used for research primarily due to the developing state of the research domain (Baines et al., 2018; Lightfoot et al., 2013). The next section delves deeper into explaining what case study research entails and the justification for its suitability as a type of study for this research.

A case study is formally defined as a study that examines a phenomenon in its natural setting, employing multiple methods of data collection to gather information from one or a few entities (people, groups, or organisations) (Benbasat et al., 1987). Benbasat et al. (1987) state that case study research has the following key characteristics:

1. **The phenomenon is examined in its natural setting:** This means that the researcher does not interfere or control any factors affecting the phenomenon, which is common to the experimental type of studies.
2. **Data is collected from multiple means:** Case studies often consist of data collected from different sources involved and related to the phenomenon, e.g., interviews of individuals, surveys, existing documents, and focus groups.
3. **One or few entities are examined:** Case studies can be used for examining different types of subjects such as people, organisation, and institutions.
4. **The complexity of the unit is studied with focus:** Case studies take an in-depth focus on the complex nature of the unit of analysis, identifying ingrained relationship and causal mechanisms.
5. **They are exploratory tools**: They are suitable for the exploration, classification, and hypothesis development stages of knowledge development, but overall the researcher should have a receptive attitude towards exploration.
6. **The results depend on the researcher's abilities:** The results derived depend on the integrative powers (ability to identify and analyse relationships between entities) of the researcher.
7. **They address how and why questions:** Case research is especially useful to study 'how' and 'why' type of research questions because of these deal with establishing operational links between entities, exploring phenomena and changes in relationships and entities over time rather than seeking frequency or incidence.
8. **The focus is on contemporary (current/present/modern) events**: Case studies are a commonly used tool for studying recent events as these events can be studied using multiple sources of data, unlike historical events which can only be studied through recollections and historical documentation.

Case studies can be found as either single or multiple case studies. A multiple case approach is widely common (Voss, 2010), but single cases have value in specific cases. Yin (2008) suggests single-case studies are appropriate if;

- It is a revelatory case, i.e., it is a phenomenon or source of data previously inaccessible to investigators.
- It represents a critical case for testing a well-formulated theory.
- It is an extreme or unique case.

Single-case study projects have been found most useful in the early phases of theory generation and late phases of theory testing, or phases of phenomenon establishment (Yin, 2008). A single case used for exploration is commonly followed by a multiple-case study. A single case may also be used to test the boundaries of a well-formed theory.

Multiple-case studies are desirable in more applications, such as when the intent of the research is exploration, description, theory building, or theory testing. Multiple-case designs allow for comparative cross-case analysis and the extension of the theory. The cross-case analysis allows the researcher to find patterns between the cases, indicating causal mechanisms (Voss, 2010). Majority of servitization research based on case studies employ multiple case study approach in order to explore the phenomenon further and compare various manufacturing firms and their servitization.

3.3.3 Suitability of case studies in this research

This research focuses on exploring IoT enabled servitization, for which very few systematic descriptions and explanations were found in the literature (Martin-Pena et al., 2018). The research questions set for the study are of the 'how' type which is already established as a suitable scenario to use case studies. To further reinforce the choice of a case study for the present research, literature has increasingly indicated the suitability of case studies for new research areas:

> *"Particularly well suited to new research areas or research areas for which existing theory seems inadequate. This type of work is highly complementary to incremental theory building from normal science research. The former is useful in early stages of research on a topic*

or when a fresh perspective is needed, while the latter is useful in later stages of knowledge" (Eisenhardt 1989, p 548-549)

Also, the above explanation of case studies is relevant to the present study specifically to address point 8 of section 3.3.2. It means that while the phenomenon of IoT enabled servitization is contemporary (Baines et al., 2013b), it is also very complex. Servitization as an organisational transformation is found very complex to investigate (Baines et al., 2018), while the integration of IoT in this context further adds to the complications (Ardolino et al., 2016).

Servitization is a phenomenon that has emerged through practice and not through theory (Vandermerwe and Rada, 1988). Therefore, to investigate servitization, it is essential to consider the contextual conditions and the nature of the involved organisation, which is a servitizing manufacturer or manufacturers. These specific characteristics of the present study align appropriately with those of case study research (point 4). Therefore, a case study is found to be the best-suited type of study for this research.

The intention of the present study is aligned with the explorative capacities of multiple case studies as well as allowing theory testing to a certain extent. The exploratory part of the research corresponds to the IoT enabled servitization phenomenon, and the theory-testing part corresponds to the adoption of the affordance theory in the new context of servitization. A single case design would not be suitable for the study as it would not be able to draw upon a cross-case analysis to identify the common opportunities provided by IoT to enable servitization or the common features of the IoT important in this context. Additionally, the multiple-case study research approach is commonly adopted in operations management (Voss, 2010) and corresponds with the range of philosophical assumptions represented by critical realism (Fletcher, 2017).

3.4 Research programme

To achieve the research aim, Robson (2002) recommends designing a research programme that will accomplish critical stages of the research through various steps that will be taken throughout the research. Mainly, the research programme should be developed after the following components are established for the research; *purpose,* *theory, research questions,* and *methods.* The purpose of the study is described in Chapter 1, and research questions have been established through section 2.4. Section 2.3 presents the affordance theory as the 'theoretical framework that successfully links with the phenomena being studied' (Robson, 2002, p.81), thus proposing a suitable choice of theory for the study. The foundation of research methods for this study is clearly explained through sections 3.1, 3.2 and 3.3.

Robson (2002) suggests a research programme should be developed that precisely reflects the objectives of the research. Therefore, for this study, a research programme was developed that follows three clear phases. Figure 5 is an illustration of the research programme with the thesis structure, as presented in Figure 2. Phase 1, termed as *Plan and Implementation*, focuses on developing the research programme, designing the study, collecting the data, and compiling the cases. This phase represents the first objective: *Designing and executing a robust research study with a foundation of the affordance theory to address the research questions.* This chapter has allowed developing the programme based on the key decisions around research design. The next two chapters (4 and 5) mark the completion of Phase 1 by describing the case study design aspects and the execution of the study.

Phase 2, named *Analysis and findings*, focuses on the analysis of the results on an individual and cross-case level and presenting the findings of the analysis. Chapters 6 and 7 contribute to the completion of this phase. Phase 2 represents the research objective: *Interpreting the manufacturers' accounts of perceiving and realising opportunities to use IoT and enable servitization.*

Phase 3, named *Evaluation and conclusion,* focuses on discussing the findings in comparison with the literature and stating the implications and contributions of the research in general. Chapters 8 and 9 contribute to the completion of this phase. Phase 3 represents the research objective: *Positioning the research findings in the servitization literature and explaining the academic and practical implications of the research.*

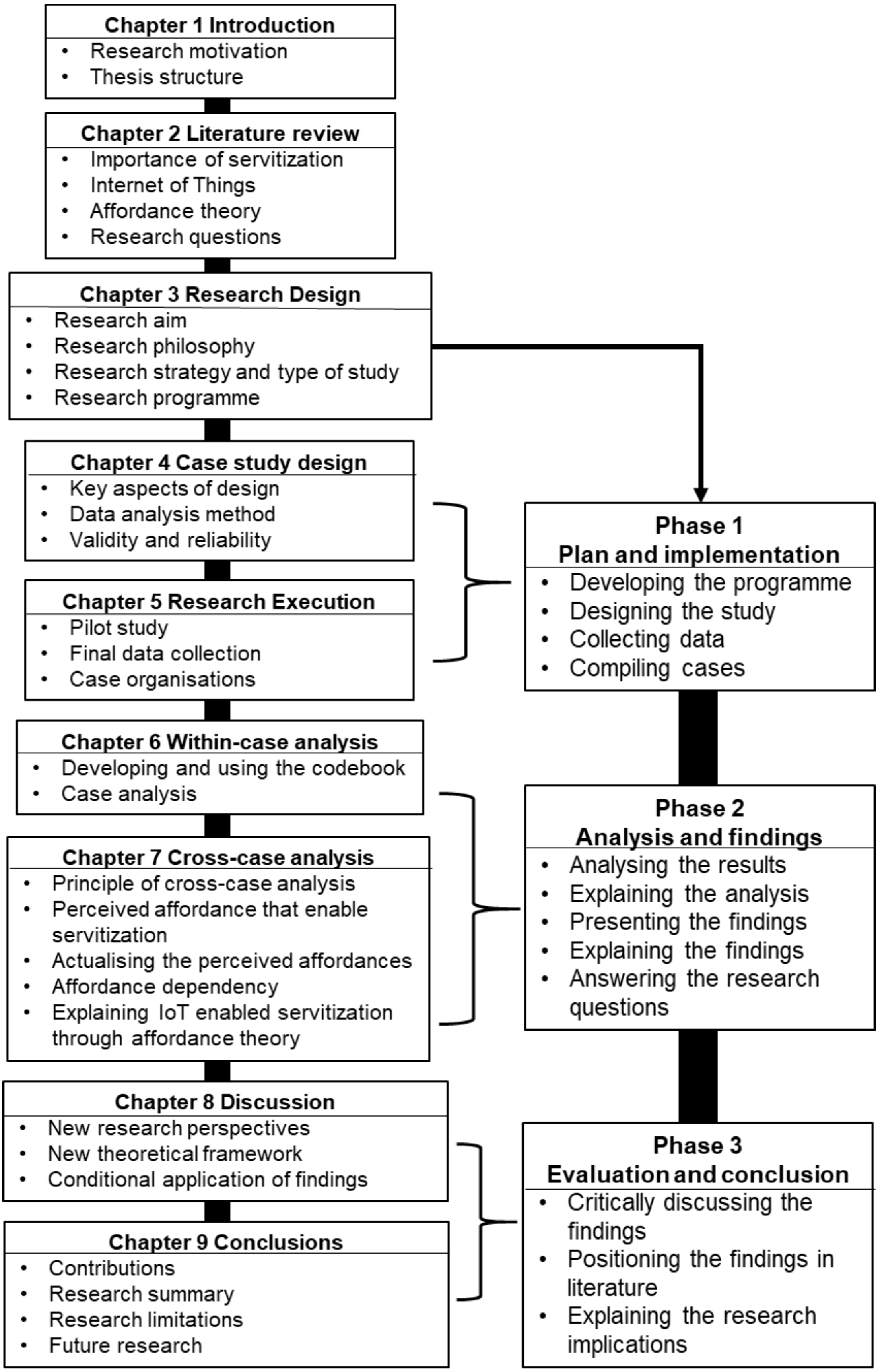

Figure 5 Research Programme

3.5 Summary

This chapter has explained the process of research design. It started with clearly articulating the aim and objective of the research (section 3.1). The research philosophies commonly underpinning research in operations management were also described before justifying the choice of critical realism as a proper philosophical stance for this research (section 3.2). Next, the chapter explained the deductive research strategy adopted in this research, along with the choice of qualitative data while describing the types of studies commonly chosen (section 3.3). A multiple case study approach was found the most suitable for this research. Finally, a three-phase research programme was presented as a navigation tool for this research (section 3.4). The three phases include *Plan and implementation, Analysis and findings,* and *Evaluation and conclusion*. The next chapter marks the commencement of Phase 1: Plan and implementation.

Chapter 4 Case study design

The research programme developed in the previous chapter (section 3.4) states that the next step for Phase 1 involves designing the case study. This chapter describes the case study design, data collection process, and the data analysis methods chosen for the research. The chapter will explain the key aspects to be considered for case design (section 4.1), the suitable data analysis method for this research (section 4.2), and the validity and reliability considerations for the case (section 4.3).

In terms of the key aspects, the chapter presents the unit of analysis for the case study research, which was identified as the *IoT usage instances* (section 4.1.2). This is followed by the development of three case selection criteria for this study (section 4.1.3). Next, the chapter explains the choice of interviews as the suitable type of data for this study followed by the development of interview design (sections 4.1.4 and 4.1.5) and description of documentation as a secondary source of data (section 4.1.6). Further, the chapter explains the fundamental principles of data analysis adopted for this study (section 4.2.1) followed by explanation and justification of the deductive thematic analysis technique chosen for this research (sections 4.2.2 and 4.2.3), in alignment with the research strategy (section 3.3.1). The chapter concludes with explaining the construct, internal, and external validity considerations taken in this research (section 4.3.1) along with the considerations for ensuring reliability (4.3.2).

4.1 Key aspects of case design

Case design includes making decisions on certain theoretical aspects of case study such as the research phenomenon, research questions, case selection criteria, unit of analysis, and sources of data (Sayer, 2004). According to Yin (1994), the case design is a useful and essential step to establish the links between the research questions and the investigations made in the field. More specifically, the research questions present *what needs to be found*, while the case design decides *what needs to be studied* and *how it needs to be studied* in order to answer the research question. Table 7 provides a summary of the key aspects of the case design for this study.

Table 7 Key aspects of case design

Key aspects	
Research phenomenon (section 2.2.5)	IoT enabled servitization
Research questions (section 2.4)	- Which affordances to use IoT is perceived by servitizing manufacturers? - How are the affordances to use IoT actualised by servitizing manufacturers? - How does the perception and actualisation of affordances to use IoT enable servitization?
Unit of analysis (section 4.1.2)	IoT usage instances
Case selection criteria (section 4.1.3)	- A manufacturer that produces physical goods for sale. - A manufacturer offering bundles of physical products and complex services as opposed to purely making product sales. - A manufacturer using IoT to enable the provision of the bundles of products and services.
Sources of data (section 4.1.4)	- Primary source: Interviews - Secondary source: Documentation

4.1.1 Research phenomenon and questions

The first theoretical aspect in research design is the phenomenon of research. Clearly defining the phenomenon of research is essential to focus the enquiry in multiple-case research (Miles and Huberman, 1994). The phenomenon of research has been established through the literature review (sections 2.1 and 2.2). To summarise, this study investigates the role of the manufacturer in making goal-oriented use of IoT to enable servitization. The phenomenon of IoT enabled servitization is defined in section 2.2.5. The study is conducted in the business context of the manufacturer and its relationships with the IoT. This context involves the nature of the manufacturer's business and its market industry in which they sell their products and services.

The second task is to formulate the research questions. The research questions allow the investigator to link a study to practical and theoretical contributions (Dube and Pare, 2003). The research questions in multiple-case research must seek causal mechanisms of the phenomenon, instead of purely measuring or analysing the phenomenon or its impact (Sayer, 2000; Yin, 2008). The research question for this research was developed as a result of the literature review of the phenomenon and the affordance theory as a suitable choice of theory (section 2.4): *Can the affordance theory explain how IoT enables servitization?*

4.1.2 Unit of analysis

The unit of analysis is a vital part of the case design. It defines what will be studied in the research (Yin, 2005). Sayer (2000) argues that selection of the unit of analysis is usually given less attention than it commands as a large part of the study depends on how we view a concrete object or phenomenon from a single lens. In operations management, the unit of analysis can often be an organisation, a process of change, or a specific technology, but it is not limited to these examples (Voss, 2010).

In this study, the research questions (section 2.4) focus on the manufacturer's use of IoT to enable servitization. The questions aim to investigate the opportunities to use IoT, the actions to realise those opportunities, and the relation between realising multiple opportunities and enabling servitization. This relates to investigating the overall use of IoT in servitization. Therefore, to answer the question of '*what needs to be studied?',* focusing on the process of using IoT is found suitable. Drawing upon the deductive strategy of the study (3.3.1), the unit of analysis will be driven by the affordance theory. In terms of the affordance theory, the process of using IoT will include the perception of affordances to use the IoT and the actualisation of these affordances to achieve the desired outcomes. This process encapsulates the IoT usage instance of a manufacturer. The IoT usage instances across cases are different as the goals of the manufacturers are different. Deeper insights arise when the IoT usage instances in different cases are analysed comparatively. Therefore, the unit of analysis for this study is the **IoT usage instances** of a manufacturer.

4.1.3 Case selection

The next key aspect of case design is selecting the cases for multiple case study research. Multiple-case research is often considered analogous to multiple traditional experiments when it comes to the selection of sites (Hersen and Barlow, 1973). Based on this view, Yin (2003) proposes two criteria for selecting potential sites. First, sites, where similar results are predicted, may be used as "literal" replications. Second, sites may be chosen for "theoretical" replication, i.e., chosen such that contradictory results are predicted.

Literature suggests that case selection can extend beyond these two types (Fletcher et al., 2018). Specifically, research on organisation-level phenomena requires site selection based on the characteristics of firms as these characteristics are critical to answering the research questions (Yin, 2008). These characteristics often include the industry, company size, organisational structure, profit/not-for-profit status, public or private ownership, geographic coverage, degree of vertical or horizontal integration, and so on. Researchers interested in specific technologies should consider these characteristics when selecting a site (Voss, 2010). The phenomenon of research can be one of the critical criteria for selection of cases.

Based on the identified research questions, this research is expected to focus on manufacturers that are transforming through servitization and use IoT to enable this transformation. To guide the selection of cases further, the cases are filtered through a set of inclusion criteria. The cases will include:

- A manufacturer that produces physical goods for sale.
- A manufacturer offering bundles of physical products and complex services as opposed to purely making product sales, i.e. a servitizing manufacturer.
- A manufacturer using IoT to enable the provision of the bundles of products and services, i.e. a manufacturer using IoT to enable their servitization.

Those manufacturers that use IoT to improve the production efficiency purely were not considered to be servitizing as they did not aim to use IoT to develop and deliver services. Manufacturers using IoT for similar activities such as monitoring in-house manufacturing processes and developing new in-house manufacturing process were also excluded as such activities deviated from the third criterion.

The case organisations selected for the study were also participants of two industry-academia collaboration projects run by the Advanced Services Group, Aston Business School, UK. The first project was a consortium of large multinational manufacturing organisations that are traditionally production- focused and now in the earlier stages of exploring, developing and deploying advanced services. The second project was a European Regional Development Fund supported programme bringing together a group of 80 manufacturing SMEs and providing guidance and support in their servitization journeys. Since both the projects were focused on manufacturing organisations, the first criterion was immediately fulfilled.

All manufacturers involved in these two projects were transforming through servitization, which ensured that the second criterion was fulfilled. To ensure that the third criterion was fulfilled, the researcher performed a preliminary analysis of the manufacturers' offerings to determine whether the manufacturer used any form of IoT and if yes, then what was the role of IoT in the manufacturers' organisations. The researcher examined publicly available data such as websites, videos, brochures, and news articles to identify those manufacturers that used IoT in their servitization. Additionally, attending the meetings on both the projects allowed the researcher to gather supporting information from the manufacturer's presentations, discussions, and provided a platform to have conversations with them.

Overall, 22 manufacturers were found to fit the selection criteria, which were later reduced to 18 based on the exclusion criteria. These 18 manufacturers were formed the preliminary list of candidate manufacturers.

The candidate manufacturers were engaged, starting with the two industry-academia collaboration projects and the research group's workshop activities. The manufacturers were sent official invitations to participate in the study, along with a consent form and an information sheet. The consent form included permissions to conduct interviews, record interviews, and use the data for research purposes (Appendix 2). The information sheet included an introduction to the aims and objectives of the research and the participants' rights within the study (Appendix 1). Out of the 18, 5 organisations did not respond to the invitations to participate in the study, and one organisation denied the invitation due to time constraints. This resulted in a final list of 12 cases that were suitable and agreed to participate in the study. The 12 final cases demonstrate a suitable pool of cases for a multiple case study, as suggested by Eisenhardt's (1989) who recommended a sample size of 10 or more.

4.1.4 Sources of qualitative data

With the case selection complete, the next important decision is to choose the sources of data that is to be collected to develop the case studies and how this data will be collected. The research strategy was set out to be a deductive strategy with a qualitative approach towards data collection. Therefore, in alignment with the research strategy, the type of data to be collected is qualitative.

The goal of the data collection is to obtain rich data addressing the specific research issue, as well as capturing the contextual complexity (Saunders et al., 2009). The researcher is expected to have a detailed idea of the data sources to be gathered before conducting the site visit. The data to be collected depends on the research questions and the unit of analysis. Multiple data sources can be used, and are commonly recommended, in case of research as they support triangulation of the findings (Benbasat et al., 1987).

The goals of planning the data sources are to ensure proper coverage of the research questions, efficient use of time spent collecting data, and a guide for the researcher to follow. As the project unfolds, the plan can be revised according to the researcher's judgement, unexpected observations, or limitations and opportunities for collecting data (Miles and Huberman, 1994).

Commonly, case study research that uses qualitative data combines evidence from two or more data sources to support the research findings (Yin, 2008), for example;

1. **Documentation -** Written material ranging from memoranda to newspaper clippings to formal reports. For example, brochures, news articles, websites, case studies, videos, podcasts, and blogs.

2. **Archival records** - Organisation charts, service, personnel or financial records.

3. **Interviews** – Structured, semi-structured, or unstructured conversations with participants. These are commonly collected by the researcher with questions addressing a specific research problem. Such interviews are not reused for other investigations, unlike other types of data.

4. **Direct observation** - Absorbing and noting details, actions, or subtleties of the field environment. This type of data is commonly used in a participant observation approach towards research where the researcher articulates their observation of the phenomenon from the field.

5. **Physical artefacts -** Devices, outputs, tools. These are used in mostly technological research that involves critical analysis of a physical artefact and its ability to achieve desired outputs.

Interviews are found to be the most suitable sources of data, out of the five sources discussed. Direct observation is not suitable as it would be time-consuming and result in a longitudinal study which is not the aim of this research. Similarly, archival records are not suitable as the study of organisational charts, or financial records would not provide insights into the use of IoT to enable servitization. Physical artefacts were not relevant to the study as the investigation of the product or IoT would lead to a technological focus for the research, whereas the research is aiming to adopt an actor-focused perspective. Therefore, the primary source of data was the interviews conducted with the officials of the manufacturing organisation. The documentation was chosen as a secondary source of data to verify the interview responses and provide technical details about the manufacturer, their product, and the IoT artefact. The secondary sources include the manufacturer's website, product or service brochures, videos, news articles, and supporting case studies.

4.1.5 Primary source of data

In operations management, interviews are one of the most commonly chosen types of data used by researchers conducting case study research (Flynn et al., 1990; Voss, 2010). Interviews are defined as face-to-face verbal exchanges in which one person, the interviewer, attempts to acquire information from and gain an understanding of another person, the interviewee (Rowley, 2012). The interviewee is invited to talk about their attitudes, beliefs, behaviours or experiences, as a citizen, user, consumer or employee. In research in organisational studies, the selection of the interviewee is critical. They may be selected either as an individual employee or as a representative of their team, organisation, or industry.

The general purpose of interviews is to enable the researcher in collecting "facts", or gaining insights or understanding of opinions, attitudes, experiences, processes, behaviours, or predictions (Bryman, 2001). For example, in conducting interviews with members of an organisation in order to identify the capabilities required to transform the organisation's focus, the interviewer might be seeking "facts" such as which activities were of prime importance in this transformation, what new knowledge was gained to transform the organisation, stories of any particularly negative or positive experiences, and the interviewee’s predictions as to the future of the organisation’s capabilities. Interviews allow the collection of these facts from either with one person or with a group of people (Rowley, 2012).

For this study, the specific focus on the IoT/servitization intersection required access to interview participants that have specialisations, insights, and exposure to both perspectives. In circumstances where specialist knowledge is required to answer the research questions, it is necessary to identify individuals who are in critical positions to understand, experience, and describe a phenomenon (Trinczek, 2009). This strategy of choosing the interviewees is called expert interviewing (Meuser and Nagel, 2009). For example, key individuals could be the managers responsible for implementing a corporate strategy in the transformation of an organisation. Explanation of the decisions behind the organisation’s transformation cannot be provided by other individuals of the organisations who were not part of that process, although its result may have affected them. In this case, interviews are preferable because they provide more details and insights, but also because the key informants are likely to provide a very detailed and expert perspective of the phenomenon under investigation.

Expert interviews

Bogner and Menz (2009) identify two crucial dimensions of expert interviews, namely ‘know-how’ and ‘know-why’. These dimensions make the experts more attractive because they are knowledgeable of the functional aspects of the phenomenon (therefore having know-how) and they are also in a position to operationalise their ideas about the phenomenon into practice thus directly influencing the phenomenon. Therefore, they can explain why the phenomenon can lead to specific outputs (implies having know-why).

Using the expert interviewing method has multiple advantages compared to interviewing a broader population of stakeholders that is also valid for the present study. Firstly, talking to experts is a more efficient and concentrated method of gathering data for an exploratory study rather than participatory observation or surveys (Bogner et al., 2009). Conducting expert interviews can serve to shorten time-consuming data gathering processes, mainly because the experts are banks of practical insider knowledge and are interviewed as surrogates for a full circle of players. Expert interviews also lend themselves to those kinds of situations in which it might prove difficult or impossible to gain access to a broader number of respondents (as is the case, for instance, with an organisation's managerial board). Expert interviews are useful in cases where only a few individuals hold the knowledge required to answer the interview questions.

In the present study, the experts to be interviewed are decision-makers responsible for the integration of IoT, development of the servitization initiatives, and the services provided as a result. By targeting them as representatives of the manufacturers, the data collection is not diluted with the responses of individuals that are not related to the specific decisions related to the IoT enabled servitization (Table 9, section 5.3). By contacting these experts, the researcher was also able to shorten the data gathering process and tackle the uncertainty of gaining access to a broader group of respondents which may not have resulted in focused answers. Additionally, expert interviews are also a commonly used interview technique in the servitization literature (Story et al., 2017; Stantchev et al., 2015; Coreynen et al., 2017; Smith et al., 2014).

The study required the respondents to provide a business focussed account of the IoT usage for servitization, which implies possessing expertise in a business-technology intersection. This need of the research meant that the sources of data were limited to one or two interviews commonly. Only a few decision making individuals within the organisations were found suitable for the study. In addition to this, the range of organisation sizes addressed also contributed to the challenging respondent selection and access. The smaller organisations, categorised as SMEs, did not have more than one person who could provide a holistic perspective on the decisions made around the use of IoT to enable servitization. In organisations larger than the SMEs, generally categorised as MNCs, the experts responsible for operationalising IoT enabled servitization was not more than 2 or 3. For ensuring the reliability of the data, secondary sources of data, as explained previously, were used.

Interview Design

The interviews were designed to be semi-structured, which means the interview did not use a specific set of questions but rather involved certain themes of questions (Miles and Huberman, 1994). This technique is specifically useful for exploratory research as it allows the interviewee to provide their account of the phenomenon within the boundary of the themes set, but without being restricted by concrete questions similar to a survey. The questions could be adjusted the specific case but would still be addressing the set themes that are related to the research. This allows the results of the data collection to be not limited by the structure of the questions set for the interview and also allows capturing the variety in the context of the manufacturers (Miles and Huberman, 1994). Therefore an interview theme was set instead of using a concrete structure of questions.

The theme was derived from the research question and the objectives set for this study. Table 8 presents the interview themes which directed the questions in the interviews. Probing questions within each theme are listed in the second column. The third column presents the purpose of the theme and it’s proving questions with respect to addressing the research questions and other important information. The table is followed by a detailed discussion of the purpose of each theme.

Table 8 Interview themes

Interview Theme	Probing questions	Relevance to research
What are the products and services offered by the manufacturer?	- Which new services are being offered? - Which products will be offered through services?	Contextual information
What is the goal behind transforming the organisation through servitization?	- What benefits are expected from servitization? - What led to decision of moving to a service-focus?	Organisational goal, contextual information RQ 1.1
Why does the manufacturer use IoT in their offering?	- Which features of IoT are found most useful? - How does IoT help the manufacturer with its services? - How did the manufacturer see different opportunities to use IoT? - What did the individual features help the manufacturer achieve?	RQ 1.1, 1.2, 1.3
What steps were required to integrate the IoT in the offering?	- How was IoT integrated in the product and the overall business? -How did the manufacturer act upon the opportunities to use IoT? - What was the immediate outcome of using IoT for services?	RQ 1.2, 1.3
What other forms of technology would the manufacturer seek?	- Were the features chosen for IoT enough to enable services? - Which other features are found valuable to increase value of IoT?	Contextual information, identifying common features of IoT

What are the products and services offered by the manufacturer?

The role of this theme was to understand various offerings of the manufacturer and their general nature. This allowed the researcher to identify the specific servitization initiative within all the different offerings, which would become the focus of the remainder of that interview. This identification often led to probing-questions about the type of customer that were targeted through the offerings.

What is the goal behind transforming the organisation through servitization?

This theme seeks answers regarding the concepts within the theory. This specific question provided insights into the 'manufacturer's goal'. It also gave an understanding of the manufacturer's understanding of servitization. However, the cases were chosen based on the researcher's understanding of servitization and established definitions in section 2.1.1. As a step to ensure that the definition of servitization does not create conflict between the researcher and respondents, the adopted definition was stated in the information sheet provided to respondents. Probing-questions led to clarifying the goal and what efforts were made by the manufacturers to achieve this goal.

Why does the manufacturer use IoT in their offering?

This theme opened the discussion about the use of IoT by allowing the researcher to identify the specific features of IoT relevant to the manufacturer, how these features combine to create the IoT artefact, and why those specific features of IoT were chosen. Similar to the previous theme, the definition of IoT adopted for this research (section 2.2.1) was specified in the information sheet supplied to the respondent. Probing questions were able to identify the specific opportunities manufacturers perceived to use the IoT. Further, it also led to questions answering the uses of specific IoT features that would eventually enable the manufacturer to achieve their goal.

What steps were required to integrate the IoT in the offering?

This theme allowed the researcher to understand the specific actions taken by the manufacturer to use the IoT system to achieve the outcome from each of its features as described in the previous theme. This would uncover a basic idea of the mechanisms in place to enable servitization through the use of IoT. This theme would also shed light on the outcome of these actions.

What other forms of technology would the manufacturer seek?

This theme would allow the researcher to identify the features of IoT that are missing from the current IoT system in use and what other features appear essential to the manufacturer that they would aim to integrate in the future. By identifying these features, the researcher compared them across cases and identified the common features. This helped to acknowledge the features used by manufacturers and those that manufacturers would want shortly.

4.1.6 Secondary source of data

Documentation material is considered a valuable source of secondary data since it is stable, can be repeatedly reviewed and collected (Yin, 2005). In this study, the manufacturer's website provides first-hand information about the description of the products and services provided by them and clarifies underlying claims and statements about the products and services offered. This was crucial in identifying the candidate cases during the preliminary levels of analysis. Secondly, the product and service brochures provide detailed information on the technical specifications of the products and services, along with necessary information on the use of IoT in the products and services. Information regarding the manufacturer's business and the customer base can also be found from these documents. This was important in the latter parts of the analysis to verify the interviewee's responses.

This section has explained the key aspects of case design which included the unit of analysis, case selection criteria, and the sources of data. The next step is to identify the method of data analysis that are suitable for this study while maintaining the alignment with the deductive research strategy.

4.2 Data analysis method

This section explains the fundamental principles of data analysis adopted for this research, followed by the explanation of thematic analysis as a suitable method for this study and explains the benefits of using this method. Next, the section also describes the codebook approach towards thematic analysis that ensures a deductive approach to thematic analysis of the case studies.

4.2.1 Fundamentals of analysis

In operations management, the most common way of analysing case studies is conducting a two-step process; Individual (within-case) and Cross-case analysis (Meredith, 1998; Voss, 2010; Barratt et al., 2011). Individual case analysis allows the identification of emerging patterns of events and causal mechanisms on the case level. The cross-case analysis allows the researcher to compare the cases and find the differences, while also allowing the cause and extent of these differences to be explored (Voss, 2010). This helps to find commonalities and therefore suggests generalizations based on these identified patterns and causal mechanisms on a broader level (Eisenhardt, 1989).

The within-case analysis is usually used to explore each case in detail, providing the necessary observations, whether made inductively or deductively (Barratt et al., 2011). Next, these observations are then compared using cross-case analysis concerning the research question or problem under focus for the study (Johnston, 2003). The cross-case analysis consequentially leads to finding the answers to the research questions and thus generating the key research contributions.

The present study follows this two-step process of analysis by first studying the cases individually with a deductive approach, identifying the key constructs of the affordance theory in the data (Table 5). This is followed by a comparison of the cases to address the three sub-questions developed in section 2.4. The within-case analysis starts with detailed case descriptions followed by coding of the data, on an individual case level. This is important for the reduction of data into themes relevant to the research (Miles and Huberman, 1994). In this study, the detailed case descriptions have been provided in chapter 5 (section 5.3), and the coding of the data is explained in chapter 6 (section 6.1.1).

The cross-case analysis used the findings of the within-case analysis for comparison and identifying trends across these findings. The affordances and actions identified in different cases were categorised to find commonalities between them and answer research questions. The categorisation was conducted iteratively in an inductive way, which are demonstrated in Tables 22 and 23 (sections 7.2 and 7.3). These categories were later used to identify underlying patterns between the categories (section 7.4). The cross-case analysis is described in more detail through Chapter 7.

4.2.2 Thematic analysis

In operations management, the most common way of coding is a three-step process of thematic analysis; open coding, axial coding, and selective coding (Miles and Huberman, 1994). Although this is the most commonly used technique of qualitative coding data in operations management, it is effectively an inductive approach towards coding. An inductive approach generates a vast amount of codes and then condenses it into sub-categories and categories which is a very time-consuming process and bears the risk of drowning the researcher in the data (Hsieh and Shannon, 2005). On the other hand, a deductive approach to coding adopts a pre-structured route to analysing qualitative data. The deductive approach to coding is better suited to the current study due to the deductive research strategy of this study (section 3.3.1).

Thematic analysis is regarded as a flexible qualitative method of analysing and coding textual data. It is a widely used technique of analysis in social sciences; however, most commonly based on an inductive approach (Braun and Clarke, 2006). The specific approach to thematic analysis chosen by a researcher varies with the theoretical and practical interests of the researcher and the problem being studied.

A deductive approach to thematic analysis uses a pre-defined or theoretically derived framework for labelling the data with codes (Braun and Clarke, 2006). The data is compared to theoretical constructs of the framework and extracts of data are matched against them. This method is also commonly referred to as directed content analysis and used mainly in psychology and medical studies (Potter and Levine-Donnerstein, 1999). However, deductive thematic analysis has also been successfully used in previous servitization studies (Baines et al., 2011; Raddats et al., 2016; Story et al., 2016; Cenamor et al., 2017; Zhang and Banerji, 2017).

The present study addresses the phenomenon of IoT enabled servitization deductively with the theoretical framework of affordance theory (Figure 3, section

2.3.2). The use of the pre-existing theory to explain a particular phenomenon requires the researcher to illustrate the theory's ability to address similar phenomena (Braun and Clarke, 2014). Once the fit between the theory and the phenomenon is illustrated, deductive thematic analysis can be used. In the present study, the ability of the affordance theory to address organisational change was demonstrated in section 2.3.5. This approach provides the present study with a more structured and focused method of analysis than a conventional coding approach (Hsieh and Shannon, 2005), while also establishing alignment with the set research strategy.

Using this technique of analysis has multiple benefits for the research. Respondents cannot be expected to answer the interview questions with complete clarity and relevance to the underlying research question as they primarily may not be aware of the research question or do not necessarily understand the theoretical significance of their responses (Mayring, 2000). This would result in some of the responses repeating information about the phenomenon or information that does not directly relate to the research questions (Vaismoradi et al., 2013). A deductive thematic analysis allows the researcher to focus on the parts of the interviews, which are directly relevant to the research. This is achieved by developing a codebook and focusing the coding process within this codebook.

4.2.3 Codebook for thematic analysis

The codebook is a guiding tool for the researcher to label parts of the data according to a theoretically derived framework and then replicate this process multiple times when analysing different cases (Braun and Clarke, 2016). Essentially, the codebook helps to reduce the data to a more manageable form that can be used to derive conclusions. However, in order to develop the codebook, the theoretical framework for the analysis must be established. This section describes the basics of the codebook and justifies its suitability for this study. Section 6.1.1 further explains the specific use of the codebook for analysis in this study while presenting the case analysis simultaneously.

For developing the codebook for this study, the framework of affordance theory (Figure 3) was adapted to the context of this research. This meant modifying the constructs involved in the framework. The organisational goal is more precisely termed as the manufacturer's goal to accurately capture the manufacturer's role in the use of IoT. The features of the artefact are referred to as IoT features as in the context of IoT enabled servitization, the IoT is the artefact in focus. The interaction between the manufacturer's goal and IoT features leads to the perception of an affordance, as suggested by the original theoretical framework. Next, the manufacturer takes actions to realise the opportunity presented by the affordance, resulting in a desirable outcome.

Having established the theoretical framework, the key constructs under focus are; *manufacturer's goal, IoT features, affordances, actions,* and *outcomes.* These constructs have been previously defined in section 2.3.2, Table 5. These constructs are then used to draft the codebook. The codebook is a detailed account of codes identification, their description, criteria, and examples (Braun and Clarke 2006). Essentially, the codebook provides clear instructions for the researcher about which constructs need to be identified, the selection criteria for them, examples, and the theme to be captured at the end of the coding process.

The themes are the researcher's interpretation of the meaning behind the identified code (Ryan and Bernard, 2000). The themes help reduce the identified code and project that interpretation on a generalized level. The generalized level of themes helps the researcher to perform a comparative analysis of the entire collection of themes across the case. It is often found that codes from different cases can be referring to the same occurrence or activity and this similarity can be acknowledged when interpreted as a theme as the themes identified are the same (Braun and Clarke, 2006). Identification of repeating themes across cases can lead to the identification of patterns that form the essence of the cross-case analysis (Boyatzis, 1998).

For example, using the codebook, the research could code a section of the interview; 'We realised that by using a few sensors, we could capture crucial parameters about the product that indicates its health' as an affordance. The next step for the researcher would be interpreting these coded data and develop a theme. The interpretation of this theme that adequately represents the code of affordance would be 'Understanding product condition'. Similarly, the researcher can identify other codes within the data and then interpret these codes to develop particular themes.

The codebook developed to analyse the individual cases is presented in chapter 6 (section 6.1.1, Table 10). The codebook consists of code definitions, code examples as identified in a sample case, and theme examples as interpretations of codes. Followed by the explanation of the method of data analysis chosen for this study, the chapter addresses the validity and reliability considerations in the next section.

4.3 Validity and reliability

Researchers must pay attention and take active measures to ensure validity and reliability in any type of research case study research (Voss et al., 2002). Ensuring validity and reliability is key for demonstrating rigour in research, which is especially challenging in case study research (Gibbert et al., 2008).

Validity is commonly divided into three types; construct validity, internal validity, and external validity (Yin, 1994; Campbell, 1963; Eisenhardt, 1989). However, these concepts have originated from a positivist paradigm of measuring the validity of quantitative data and quantitative analysis. When research is driven by a critical realist philosophy, these concepts of validity do not hold. Therefore, these concepts have been redefined for better suitability in the measuring validity of critical realist research.

4.3.1 Validity

The first type of validity to be considered is construct-validity. It is defined as the quality of conceptualisation or operationalisation of the revenant concept (Yin, 1994). This needs to be considered during the data collection phase. More specifically, construct validity refers to the extent to which the case study investigates what it aims to investigate (Denzin and Lincoln, 2008; Voss, 2010). However, in critical realism, construct validity is redefined as a measure concerned with whether the data gives insights about the actual outcome caused by the generative mechanisms of a phenomenon (Johnston and Smith, 2010).

To ensure this construct validity, establishing a logical connection between what can be observed empirically (say, an answer to an interview question) and what some community agrees (consensually) to be the actual event, occurrence or experience (Johnston and Smith, 2010) is recommended. In this research, the construct validity was ensured by clearly identifying the meaning associated with servitization from the literature and ensuring that the manufacturers fit this definition by assigning clear criteria for case selection (section 3.2.3).

Internal validity checks whether the phenomenon is caused by the factors being measured through the data rather than other external factors (Yin, 1994). For the critical realist research, on the other hand, internal validity is concerned with establishing that the generative mechanism is the cause of the phenomenon observed in the study (Johnston and Smith, 2010).

To ensure internal validity, the generative mechanism should be clearly explained, and it should operate consistently in multiple examples, and any alternative explanations are eliminated (Bunge, 2015). Internal validity was ensured in this research by providing a clear explanation of the identified mechanism and examples to illustrate the same (section 6.4). The study also aligned the investigation with key principles of affordance theory; perception, actualisation, and dependency, which allow structure the explanation of the mechanism (section 2.5.2). This eliminates any alternative explanations to the identified mechanism.

External validity or generalizability is generally conceptualised as the extent to which the findings from the study can be generalised to other types of people, settings and times (Voss, 2010). This is based on the belief that findings must be shown to account for the phenomena not only in the specific study but also in other contexts (McGrath and Brinberg, 1983). From a critical realist perspective, such a conceptualisation is bogus, because it conflates the visible traces of the phenomenon with the mechanism causing the phenomenon. The critical realist view of external validity, therefore, is that it represents the likelihood that the generative mechanism that caused the actual phenomenon within the boundaries of the study can be extrapolated more widely in the problem domain (Johnston and Smith, 2010).

To ensure external validity, it is recommended that the mechanism that explains the phenomenon as investigated in the research but also explains the phenomenon beyond the study (Baskerville, 2003). In this research, external validity was ensured by clearly discussing the conditions of applying the mechanism in other cases of IoT enabled servitization. This helps correctly using the mechanism to explain the phenomenon of servitization beyond the study (section 8.3).

4.3.2 Reliability

Reliability is the extent to which a study's operations can be repeated yielding the same results (Miles and Huberman, 1994). Although this concept is based on the physical sciences where the majority of the research is conducted using quantitative data, it is considered good practice to make sure qualitative research is reliable as well. Yin (1994) recommends the creation of a programme that clarifies how the study was designed and conducted. For this study, a research programme was developed, which describes in detail the three phases of the research aligned with the research aim and objectives (section 3.4). The programme allows for a clear demonstration of the design, execution, and evaluation plan for the research, thus making the study's operations as transparent as possible.

4.4 Summary

This chapter has described the key aspects of case design that include decisions on choosing the unit of analysis, developing the criteria for case selection, and choosing the sources of data. Next, the chapter also described the data analysis method found suitable for this study, followed by the validity and reliability considerations.

The IoT usage instances were found as a suitable unit of analysis (section 4.1.2), as it reflects the focus of the research questions of this study. Next, three criteria were developed to ensure the case organisations that are chosen for the study are manufacturers, transforming through servitization and use IoT to enable their transformation (section 4.1.3). The common sources of qualitative data were also described before choosing interviews as the primary source of data, and documentation as the secondary source of data (sections 4.1.5, 4.1.6). In section 4.2, the thematic analysis method of analysing qualitative data was described along with an explanation of the deductive approach towards thematic analysis that is adopted for this study (section 4.2.2). The development of codebook for deductive thematic analysis was also explained in this chapter (section 4.2.3). The chapter concluded with demonstrating the construct validity, internal validity, external validity (section 4.3.1), and reliability (section 4.3.2) considerations taken in this research.

Chapter 5 Research execution

Based on the research programme, this chapter expands upon the execution of the designed research. The research started the execution by conducting a pilot study (section 5.1) using two case organisations, intending to verify the relevance of the interview themes (section 4.1.5). Next, the chapter explains the data collection (section 5.2), which involves conducting the interviews and collecting the required data along with the process of ensuring the confidentiality of the participants. The chapter concludes by describing all the case organisations that contributed to the multiple-case study research (section 5.3).

5.1 Pilot study

In order to test whether the interview design is suitable and collects the appropriate qualitative data, a pilot study was conducted before the overall data collection commenced. Pilot studies are a highly encouraging step in research because they allow the researcher to test the research design for the study, as well as allowing the researcher to understand how interviewees respond to questions, what to expect when visiting the interviewees, and identifying any need for changes to the interview design (Creswell, 2007; Guba and Lincoln, 1994; Miles and Huberman, 1994).

For the pilot study, cases Sigma and Eta were chosen as they were diverse in their ways of using IoT. Eta used IoT to support simple business activities such as product dispatch and delivery tracking, whereas Sigma used IoT to deliver product capability and monitor uptime. These cases helped ensure that the interview design can capture responses irrespective of how crucial IoT is to the case manufacturer's business. Representatives from Case Sigma and Eta agreed for interviews at their manufacturing facilities.

5.1.1 Pilot study execution

Before the interview started, the interviewees were presented with a research information sheet (Appendix 1) and the consent form (Appendix 2). The research information sheet presented the motivations and objectives of the research, the interviewee's rights to withdraw from the study, guarantees of confidentiality and anonymity, as well as a description of the researcher's intention to use the responses for research purposes. The consent form requested permission from the interviewee to use their responses as research data in this study and associated research articles, and a confirmation that they understand the contents of the research information sheet. The consent form also asked for permission to record the interview through an audio device.

After the respondents signed the consent form, the interview started and lasted for 45-90 minutes. The interviews were recorded on an audio device and later transcribed and prepared for preliminary analysis. Any mention of organisation’s name, offering’s proprietary name, respondent’s name, other members’ names, competitors’ names, customers’ names or any other information that may lead to the identification of the organisation or the respondent were anonymized.

The researcher conducted a preliminary analysis of the transcripts to identify IoT usage instances to enable servitization in line with the unit of analysis (section 4.1.2). To further ensure the relevance of the interview theme as per Table 8, descriptive elements of the manufacturer’s business such as the nature of the business, the product, their customer, and the IoT artefact were also identified. The secondary data sources, such as product brochures and corporate websites, were used to verify the interviewees' responses about these descriptive elements. The case descriptions were compiled by arranging these descriptive elements to provide an overview of the case in the context of IoT enabled servitization. This preliminary analysis confirmed that the interview questions generated responses relevant to the study.

5.1.2 Pilot study findings

As a result of this pilot study, it was found that the interview design was able to collect the relevant data and resulted in productive responses from the interviewees that are relevant to the research. The interviewees often deviated from the interview themed, but that is expected from a semi-structured interview design (Miles and Huberman, 1994). The researcher asked probing questions to ensure the responses were focused on interview themes and to ensure that detailed descriptions are captured. The study found that although Eta was initially identified as a suitable case through the selection criteria, it did not meet criterion 3 (i.e. *a manufacturer using IoT* *to enable the provision of the bundles of products and services*) in practice. Eta has multiple product and service offerings out which only one service offering can be considered to be relevant for their servitization, and this specific offering does not use IoT. IoT is used in other product offerings within Eta's portfolio which were the cause of confusion. As a result, Eta was not considered eligible for the remainder of the study.

Overall, the pilot study achieved its objective of testing the interview design and concluded that the interview design was suitable for the study. The study also helped the researcher gain confidence in conducting interviews and prepared the researcher to ask probing questions that bind the interviews to the set interview themes. As Eta was no longer considered suitable for this study, the number of cases for the data collection was reduced to 11. On the other hand, Case Sigma was found to be profoundly insightful in describing its use of IoT to enable servitization and thus crucial for this study. Therefore it was used as a case for the research along with the remaining ten cases. As criterion 3 was found to be challenging to operationalise, the remaining 10 cases were re-examined to ensure that the offering that would be investigated for this study was enabled by IoT to avoid future omission of cases.

5.2 Data collection

After the pilot study, the remaining case manufacturers (10) were approached for the interviews, and the interviews were conducted based on the interviewees' availability. The data was collected based on the steps similar to the pilot study (as described in section 5.1.1). Some interviewees were not located within the UK, which then required the interview to be conducted electronically. If the interviewee was located within the UK, the researcher interviewed at the manufacturer's office location. The interviews lasted for 45-90 minutes, with a possibility of follow up interviews or communication if required. Interviewees, in a few cases, recommended the researcher to interview other individuals within their organisations that they believed to possess additional relevant information. This resulted in multiple interviewees within the same case, further strengthening the data.

Secondary sources of data such as product and service brochures, websites, news articles, and videos were also collected during these interviews. Table 9 (section 5.3) indicates which sources were used for each case. As described in section 4.1.6, these sources of data were used to cross-check and verify the interviewees' responses in terms of the technical specifications of the IoT artefact and the manufacturer's products and services. This also ensured triangulation in cases where only one interviewee was found suitable expert for the study (section 4.1.5). Analysis of cases Beta, Delta, Epsilon, Zeta, Theta, and Omega was supported with publicly available case studies (indicated as an *e*-type secondary source in Table 9) conducted with them about their use of IoT. These case studies were also used to verify the responses of the interviewees and later to compare the individual case analysis. These case studies disclosed the manufacturers' identities and therefore, are not referenced in this thesis as that would compromise the confidentiality agreed with the participants in this study.

With all the data collected, the cases were ready to be analysed. The next section provides a brief description of each case organisation, which is followed by chapter 6 that presents the case analysis on an individual level.

5.3 Case descriptions

This section describes each case based on preliminary analysis and identification of descriptive elements such as the nature of business, product, and customers. Table 9 provides a summarised introduction of the case manufacturers. It presents the international reach of the manufacturers, where 6 of the 11 cases manufacturers serve an international market whereas the rest serve local markets within the UK. The manufacturers represent a wide range of industries through their products such as communication systems, cleaning equipment, and medical technology. Additionally, the table also presents the position of interviewees within the company and the type of secondary sources of data gathered from each manufacturer.

All of the interviewees, considered as suitable experts for this study (section 4.1.5), had an engineering background with several years of experience in leading the development and delivery of the servitized offerings investigated. Besides, the interviewees operated jointly with the IoT development teams. This provided them with insights about the interaction between IoT and the development of service offerings.

Table 9 Case summary

No.	Case	Market	Product	Interviewee position	Secondary data
Legend: a-website, b-brochure, c-videos, d-news articles, e-external case studies					
1	Alpha	International	Heating equipment	-VP Innovation -MD, UK division	a, b, d
2	Beta	British	Automation and monitoring systems	-Director of Operations	a, b, e
3	Gamma	International	Medical technology	-Director of Connected Solutions	a, b, d
4	Delta	International	Automation and processing equipment	-General Manager of Advanced Services -Operations manager	a, b, d, e
5	Epsilon	British	Cereal processing equipment	-Managing Director	a, b, d, e
6	Zeta	International	Filtration equipment	-VP Innovation -Director of IT - VP product marketing	a, b, c, d, e
7	Theta	British	Packaging products	-Manager of Business Development	a, b, e
8	Kappa	International	Environmental and ventilation automation	-Managing Director	a, b
9	Lambda	International	Cleaning equipment	-VP Global Services -IoT program director	a, b,
10	Sigma	British	Communication systems	-Director of Operations	a, b
11	Omega	British	Light-based disinfection, curing, and inspection equipment	-Managing Director	a, b, e

5.3.1 Case Alpha

Alpha is an international manufacturer of a wide range of heating equipment. It is part of a broader group that has a presence in more than 100 countries worldwide with leading positions in Russia, Europe, North America, Turkey, and China. The group employs over 6500 people and turned over EUR 1.8 billion in 2018. The UK division themselves employed more than 300 people and had a turnover of more than £20 million. The case under discussion is the UK division of the manufacturer. This division is responsible for the production, sale, and aftersales services for the heating equipment in the UK and Ireland. Their products are not equipped initially with IoT, but Alpha is in the process of retrofitting the legacy equipment with IoT and launching new IoT integrated equipment.

Alpha serves domestic, commercial, and industrial customer groups. It has different capacities of equipment for each of these groups. Currently, Alpha sells the product directly to the customer groups, or through a distributor. In terms of services provided, Alpha currently provides reactive maintenance and repair services, and a protection plan. The customers can subscribe to a protection plan which allows them guaranteed support for a fixed period during which the manufacturer conducts periodical maintenance visits and responds to the problems as soon as possible for no extra cost. In case the customers do not subscribe to the protection plan, the customer can request for a reactive maintenance and repair service.

5.3.2 Case Beta

Beta is a manufacturer of automation and monitoring systems based in the UK. It designs and manufactures power press monitors, production recording systems, assembly-machine process monitors and software for networked measurement and data-logging systems. The product is equipped initially with IoT. The systems provided by Beta can be integrated into a variety of other equipment used by the customers. It is a manufacturing firm classified as an SME by the British government. It had a turnover of less than £1 million in 2018 and employed four people.

Majority of its customers belong to the automotive sector while it also serves defence and aerospace sectors in the UK. These customers are often suppliers to automotive, defence, and aerospace industries, such as suppliers of metal parts and products.

Beta’s servitization initiative in focus involves the integration of their products in load presses and hydraulic presses used by these suppliers. Its applications support automation in the manufacturing sector. This involves recording the usage of the presses and the performance statistics of the press. It also provides spare parts, repair and maintenance services for the systems it manufactures. Beta signs service-level agreements with its customers which involve periodic maintenance visits, next-day visits in cases of breakdowns, and telephonic support. It also provides services including calibration, test work, breakdown support, consultation and training.

5.3.3 Case Gamma

Gamma is a global manufacturer of medical technology. It is a publicly listed manufacturing firm with a turnover of 1.82 billion (2017). It employs more than 10,000 people worldwide with operations in 40 countries and sales in more than 135 countries. This case discusses explicitly the European division of the manufacturer where it is the industry leaders. It has a wide range of products that are supplied to hospitals and life science centres.

Gamma's key customers are European hospitals, clinics, and medical laboratories that purchase the products, commonly in large numbers. It can supply these sectors with all the equipment required for medical procedures, including everyday tools, to more complicated machinery for examinations and treatments. This case focuses on their servitization initiative on the sophisticated medical equipment and machinery. Gamma also provides repair and maintenance services for all of their products. It provides the required consumables for their products, software support, and business intelligence services, equipment monitoring and connectivity, and patient flow management services. Commonly, these services are offered on long-term contracts.

5.3.4 Case Delta

Delta is an international manufacturer of food automation and processing equipment. It is a family-owned business with a significant presence in Europe, Asia, the Middle East, and Africa. Delta majorly supplies in the Asian and European market. This case focuses specifically on the European division of Delta. It had a turnover of £115.9m in the year 2017 with more than 600 employees.

Delta's major customers are a large business in the food and beverage industry. More specifically, the customers commonly deal in fresh and snack foods during the processing of which, Delta's products are used. Therefore, Delta plays an integral part in their customer's business. It provides a range of sophisticated equipment starting from weighing scales to automated pick-and-pack systems. It also provides proprietary software support to the customers, project management services, and turnkey contracts involving their equipment as well as third party equipment. The servitization initiative in focus is their provision of services based on a fleet of packaging products and material handling equipment driven by their proprietary software support.

5.3.5 Case Epsilon

Epsilon is a manufacturer of cereal processing equipment in the UK. It has four employees and a turnover of more than £400,000 in 2018. It manufactures its products in partnership with other companies in Europe and Asia.

The critical customers for Epsilon are large milling businesses that employ numerous cereal milling machines. Majority of their current customer base is located in East and South-East Asia. Epsilon offers the product, spares and parts, and repair and maintenance services. It also provides business intelligence and optimization services. Their servitization initiative involves providing product capability as a service driven by the use of remote monitoring technology.

5.3.6 Case Zeta

Zeta is a publicly listed international manufacturer of filtration equipment. It has a presence in 25 countries and manufacturing facilities in 12 countries across five continents. It has more than 2000 employees and a turnover of £350 million in 2018. The current case discusses the European division of the manufacturer.

Zeta serves a wide range of customers that are commonly operating in automotive, woodworking, material processing and handling industries, machining, and emergency stations. It also has customers in the food industry, healthcare, and laboratories. Business in any industry seeking filtration equipment to comply with government standards opt for Zeta’s products. It provides a range of filtration equipment that can handle gases, liquids, and solid particulate material. It also supplies spare parts, repair and maintenance services along with software support. It has also developed service contracts that cover all of these services and the product over a long-term. Their servitization initiative relates to offering services and management of product fleets using their proprietary digital tools.

5.3.7 Case Theta

Theta is a manufacturer of packaging products made of timber and corrugated materials. It is a family-owned manufacturing firm with more than 100 employees and made a turnover of £11.08 million in 2018. The manufacturer is based in the UK and supplies locally.

70% of Theta's customer base operates in the automotive sector, and other customers are local flooring manufacturers and glass product manufacturers. It also provides bespoke products to select customers such as aerospace suppliers, and logistic companies. Theta offers customised packaging products to its customers, along with stock management services. It also provides design services for packaging complex parts such as engines and transmission blocks. It is recently offering services to guarantee the delivery and safety of the customer's products. Their servitization initiative in focus for this study relates to the provision of comprehensive asset monitoring using a new IoT artefact.

5.3.8 Case Kappa

Kappa is an international manufacturer of smoke and natural ventilation, and window automation systems. Their primary manufacturing facility is located in the UK; however, their products are sold globally. It has other offices and presence in Asia and Africa. Kappa made a turnover of £20 million with more than 150 employees.

Kappa provides its offerings to large commercial, industrial, and community building projects that require ventilation and exhaust automation systems. This involves housing, universities, manufacturing plants, office spaces, and shopping malls. It provides products such as automated emergency ventilation, windows, exhaust systems, and automation retrofits using IoT controllers and actuators. These products can also be combined with installation services, repair and maintenance. It also provides bespoke designing services for new constructions along with remote digital services.

5.3.9 Case Lambda

Lambda is an international manufacturer of industrial cleaning equipment. It has manufacturing locations in East Asia, Australia, South America, the USA, and

Europe. As a group, it has made a turnover of £850 million with 4300 employees. This case discusses the European division of the manufacturer.

Lambda serves a range of 14 industries, some of which are healthcare, education, automotive, manufacturing, aviation, warehousing, and retail. Commonly, the customers purchase a fleet of products from 15 broad types of products that Lambda offers. It conducts product sale, repair, maintenance and spare part sales. It also sells refurbished and pre-owned equipment and recycling services for the equipment batteries. It also offers four tiers of long-term service contracts. As their servitization initiative, this case will focus on their effort to provide fleet management and guaranteed uptime on the range of their products using their IoT artefact.

5.3.10 Case Sigma

Sigma is a British manufacturer of communication products and systems. It manufactures the products in collaboration with design and manufacturing partners in Finland and Taiwan. It has 20 employees and made a turnover of approximately £1 million in 2018.

It provides services to Emergency services, Public utilities, and Public transport sector. NHS is the biggest customer for Sigma, where the products are purchased in large numbers and deployed across multiple NHS units. Sigma offers communication products, software support, part replacement, and maintenance services. It also provides vehicle location and resource tracking, workforce management, and incident data recording services. The customers purchase the bundle of product and services on long-term service contracts. Their servitization initiative under focus in this study is the provision of communications systems with a 100% uptime guarantee.

5.3.11 Case Omega

Omega is a British manufacturer of light-based inspection, curing and disinfection equipment. It manufactures and supplies locally in the UK and made a turnover of approximately £1 million with a team of 10 employees. It manufactures some product lines in collaboration with its suppliers which are also based locally in the UK.

Majority of Omega’s customer belongs to the automotive, aerospace, food handling, and healthcare sectors. In the automotive and aerospace industries, the frequent use of Omega’s product is inspection and curing of special paint and surface treatments. Disinfection is the primary use of their product in food handling and healthcare sectors where the product performs non-intrusive disinfection aligned with government regulations.

More specifically, the products can perform a surface inspection, paint curing, bacterial disinfection. Omega also provides the spare parts and maintenance services required for these products. Other services include process monitoring, consultancy on the choice of products, and safety training. Safety training is a critical service which is bundled with most of their sales as improper use of the products can be a health hazard and can also damage the customer’s assets. Their servitization initiative under focus in this study involves the provision of guaranteed uptime of its paint curing product line.

5.4 Summary

This chapter has marked the completion of phase 1 of the research programme: Plan and implementation. It described the execution of case design as developed in chapter 4. As a first step, the interview design was tested through a pilot study (section 5.1) that validated the interview themes. The process of collecting the data was described by explicitly focusing on logistics of conducting the interviews, the structure of data collection, ensuring the respondent consent and confidentiality, and collection of secondary data. Case Eta was found to be unsuitable for the study as it did not satisfy the case selection criterion 3 accurately. This resulted in the final number of cases to be reduced to 11.

The data collection was executed after these validations using the same process as used for the pilot study (section 5.2). The 11 cases that were compiled as a result of data collection are described in this chapter with detailed information on the nature of their business, products and services, their customer base. These cases were analysed based on the identified IoT usage instances described in the interviews. The next chapter presents the case level analysis of these processes using the affordance actualisation framework.

Chapter 6 Within-case analysis

This chapter marks the start of Phase 2 of the research programme; Analysis and findings. It presents the results of case compilation and then analyses the cases on an individual basis. The chapter presents the first of the two-step process of analysis; within and cross-case analysis (section 4.2). It specifically relates to the within-case analysis and explains *how were the cases analysed using the theoretical framework* (section 6.1), and *how each case relates to the theoretical framework* (section 6.2). The chapter also describes the development and application of the codebook for analysing cases in this study (section 4.2.3), followed by the compilation of findings from the coding in tabulated forms.

The objective of the within-case analysis is to provide a foundation to conduct the cross-case analysis. It does not answer the research questions as all the questions refer to servitizing manufacturers in general rather than individual manufacturers in their industrial contexts. Answering the questions requires a comparison between the cases, which is also the rationale behind choosing the multiple case study method (section 3.3.2). Therefore, the within-case analysis is an essential step towards answering the research questions by laying the foundation for cross-case analysis (chapter 7).

6.1 Developing and using the codebook

The first step to individual case analysis is coding the data. The study adopts a deductive strategy (section 3.3.1) that influenced the choice of deductive thematic analysis (section 4.2.2) involving the development of a theoretically derived codebook. This section describes how the codebook was developed and then used for individual case analysis. The resulting individual case analysis allowed the identification and explanation of the IoT usage instances to enable servitization.

6.1.1 Codebook

For this study, the codebook was developed based on the theoretical framework presented in Figure 3 (section 2.3.2). The coding started with a sample case (case Lambda) to create a point of reference for the coding of other cases. Case Lambda was chosen as it was compiled early during the research and provided a wide range of IoT usage instances to be identified. This made the coding process more straightforward for the remaining cases as the researcher became familiar with coding a wide range of IoT usage instances (unit of analysis, section 4.1.2) through Case Lambda. The researcher identified five codes which include *manufacturer's goal, IoT features, affordances, actions,* and *outcomes* using fixed definitions derived from the theory (Table 5, section 2.3.1). These codes were identified in the transcripts by highlighting sections that related to the code definitions. These quotes were then reduced to themes (the researcher's interpretation of the meaning behind the quote) (Braun and Clarke, 2006). The researcher identified the themes and continuously compared them in order to identify any similar themes and reduce overlaps, which also allowed developing the themes on a generalized level (Braun and Clarke, 2006). Using this process, the researcher populated the codebook with the codes, their definitions, example quotes, and the themes (see Table 10).

Table 10 Thematic analysis codebook

Code	Definition	Example quotes (Case Lambda)	Example themes
Manufacturer's goal	The reason behind the manufacturers' decision to servitize (Raddats et al., 2016).	'Well, we say we provide them with data that allowed them to manage their business better, so, and their field better, so it's really about providing data, and the data we give them is utilisation data.'	Improve customers' product utilisation
IoT features	A distinctive attribute, aspect, or ability of the IoT (Strong et al., 2014).	'Information about the location of the machine. So, where it's located. It's not through GPS, but through cell phone triangulation which means it's not just very, it's perfectly accurate.'	Location monitoring
Affordance	An opportunity for action arising from the relation between a manufacturers' goal and features of IoT (adapted from Strong et al., 2014).	'A lot of our customers have multiple sites, they move the machines, especially contract cleaners, move machines around a lot because they move from one contract to another or they swap machines between sites.'	Ensure authorised machine movement
Actions	The actions taken by the manufacturer to take advantage of the affordances through its use of IoT (adapted from Strong et al., 2014).	'So, keeping track of their machines is critical for them.'	Monitor and record data of machine movement across customer sites
Outcomes	A specific expected outcome from actualisation that is viewed as useful for realising the overarching motivation to servitize (adapted from Strong et al., 2014).	'So, through the system, they can locate the machines and, when they move, they get an alert that the machine is being moved, moved away, outside the zone, so the triggers an action too.'	Customer notifications when a machine changes sites or is lost

After the codebook was drafted, the coding process was replicated for all cases to maintain consistency of codes and themes. The coding was conducted using NVivo, a qualitative data analysis software. NVivo has many advantages and may significantly improve the quality of research (Wong, 2008). Analysis of qualitative data is more accessible through NVivo and yields more professional results as it reduces a significant number of manual tasks such as preparing physical transcripts and marking the codes on paper and gives the researcher more time to discover patterns, recognize themes, and derive conclusions. Also, NVivo is considered as an ideal technique to ensure transferability and external validity of the research (Hilal and Alabri, 2013).

In this research, NVivo was precisely used to manage data efficiently. NVivo was used as a platform to store the interview transcripts and secondary data where it was coded. NVivo also allowed viewing the data from the perspective of each code across all the cases, which made the cross-case analysis easier and more transparent. NVivo is an increasingly used analytical tool due to its abilities to organise and report data effectively (Bazeley, 2007).

6.1.2 Compilation and tabulation of data

The next step of the within-case analysis is to compile the key themes together (Voss et al., 2002). A typical starting point is to create a visualisation of the data that presents information systematically so that the researcher can either draw conclusions or make further analysis (Miles and Huberman, 1994), e.g. tables, figures, and flow diagrams. The themes identified in this study were compiled in the form of tables to visualise the data. They were arranged based on the theoretical framework of affordance theory (Table 5). The idea is to become intimately familiar with each case as an individual entity and allow unique patterns of each case to emerge as the visualisations are compared across multiple cases (Voss, 2010). Essentially, this described how the manufacturer perceived an affordance due to the interaction between its goal and IoT features, and which actions helped create the desired outcome.

6.2 Case analysis

The following section describes the analysis of the 11 cases, individually, using the affordance actualisation framework. Table 10 presents a summary of the highlights of each case. For each case, the table states the type of product that the case is developed around, the goal to servitize, and the specific uses of IoT made by the case manufacturer. The following sections explain how the instances where manufacturers used IoT were analysed using the affordance actualisation framework.

The description of each case follows a specific sequence. First, the manufacturer's goal to servitize for each case is identified, followed by a description of the IoT artefact used by the manufacturer. Next, the instances of IoT usage are described, along with an accompanying quote. The themes are then presented in a tabular form that summarises the findings of the analysis for each case[1]. The individual tables are then compared in the cross-case analysis, with a specific focus on the constructs that address the three research questions. These comparisons are further explained in sections 7.2 and 7.3.

Table 11 Summary of within-case analysis

Cases	Product	Goal	Highlights of IoT usage
Alpha	Heating equipment	Create value by capturing performance knowledge	Used IoT to understand product health and performance, reduce repairs and predict breakdowns, and provide better visibility of product usage.
Beta	Automation and monitoring systems	Gaining and maintaining a competitive advantage	Used IoT to prevent product damage, provide predictive maintenance, protect customer equipment, estimate productivity, ensure quality of output, and capture new markets.
Gamma	Medical Technology	Reducing customer proximity	Used IoT to collect product usage data, develop prediction models, and estimate product condition using a range of internal and external factors.
Delta	Automation and processing equipment	Delivering maximum return on investment for the customer	Used IoT to understand product usage, improve data presentation, provide centralised data access to customers, improve responsiveness to faults, understand product condition, improve resource allocation to solve errors, detect errors in live operations, guarantee uptime, provide remote support, and demonstrate delivered uptime.
Epsilon	Cereal processing equipment	To be a bigger part of customer’s business	Used IoT to accurately identify fault locations, identify external factors that affect productivity, provide assured uptime, compare multiple machines and develop best practices, share product information transparently, generate predictive performance models, reducing faults from operator errors.
Zeta	Filtration equipment	Develop a closer relationship with the customer	Used IoT to understand product condition and usage, predict product condition, provide transparent data access, provide customised services and compliance standards, notify sudden changes to operational settings, and provide performance data and alerts to customer.
Theta	Packaging products	Reduce customer proximity by providing services to help customer’s business	Used IoT to understand product usage, evaluate product condition, improve the information on customer’s stock, provide visibility of product in transit for customer
Kappa	Environmental and ventilation automation	Differentiating from the competition	Used IoT to understand product usage, identify faults, guarantee availability, detect urgency of problems, predict breakdowns, and inform customers about product status.

[1] The analyses of cases Alpha and Beta are presented identically. To avoid repetition, the descriptive elements of each IoT usage instance relating to the identification of individual codes are omitted. This identification is expressed through the tables for each individual case.

Lambda	Cleaning equipment	Improve the product utility and return on investment to the customer	Used IoT to collect product usage data, provide transparent access to data, identify faults, predict maintenance, improve predictive models, reduce maintenance costs, provide product security, improve product utility for customer, and provide performance advisory services.
Sigma	Communication systems	Expanding the target market using technical expertise	Used IoT to collect location data of the product, provide customer asset security, provide controlled access to customer assets, and transparent data access to asset location and usage.
Omega	Light-based disinfection, curing, and inspection equipment.	To deliver reliability and uptime to the customer	Used IoT to monitor product usage and condition, predict maintenance, guarantee uptime, and guarantee performance.

6.2.1 Case Alpha

Manufacturer's goal

Alpha's **goal** to servitize is identified as 'Create value by capturing performance knowledge'. Alpha wanted to develop a better understanding of the product performance and usage in the customer's environment. It also wants to improve its customer support using this knowledge. It wants to use the protection plan as an offering to achieve this goal.

> *"We want to maintain, you know, well understood, obviously, as the Cloud and other big data enable these things to become possible, there's a strong belief that we, in order to maintain a position of strength in the value chain, we should own the primary data from our appliances. And, actually, we can create value by knowing our appliances and the performance of our appliances better than anybody else."*
>
> *(Managing Director)*

The IoT artefact

To enable the goal, the manufacturer has developed an IoT artefact that combines wireless sensor technology embedded in the product along with software and communication technology. This IoT artefact is retrofitted to the legacy range of products and in-built in the new range of products. It collects and analyses the data centrally at its manufacturing plant. Alpha uses this IoT artefact to monitor the product usage, identify faults remotely, optimise the maintenance schedules based on the fault identification, identify the fault causes, and shares the information collected from the product with the customers.

Alpha's IoT usage instances

Alpha had four specific IoT usage instances that indicate the perception of four unique affordances from the interaction between their goal and the different IoT features. Next, each of the instances of IoT usage that lead to the perception of the affordances is described based on the identification of the IoT features, the perceived affordance, the actions taken, and the outcomes created. Table 12 presents the visualisation of the individual case analysis followed by the description of the four affordances. Each explanation can be traced to the table according to the instance numbers in the first column.

Table 12 Case analysis: Alpha

Instance No.	**Goal: Create value by capturing performance knowledge**			
	Perception		**Actualisation**	
	IoT features	**Affordances**	**Actions**	**Outcomes**
1	Remote monitoring	Understanding the health of the product	Monitor the product usage and identify faults	Collection of usage data Accurate knowledge of faults
2	Data analytics	Reducing repairs and visits	Analyse collected data and identify the source of the problem in product or environment	Knowledge of fault's cause Efficiency in the dispatch of engineers Customer notified about the cause
3	Data Analytics	Avoiding breakdown	Comparatively, analyse usage data of multiple products to develop predictive trends	Prediction of faults
4	Data sharing	Providing visibility	Share access to product's usage data through an app	Better control of product Better visibility of product usage

Instance no.1

First, Alpha decided to integrate the IoT artefact as it found a potential use in improving the reactive maintenance and repair services provided to the customer. The manufacturer can identify the correct part of a product that requires maintenance, therefore reducing the need of the engineer to spend time conducting any diagnosis on site. The engineer can be deployed equipped with the correct parts and resources to fix problems in a minimum number of visits.

> *"So today we send an engineer to repair a boiler, he might not have the right part. Today we send an engineer to repair a boiler, he might find out that he needs an hour and he's been allocated 30 minutes and he'll have to arrange a further visit and go back."*

(VP Innovation)

Based on this instance, Alpha described that it monitors the usage data from the product regularly, which helps them identify the faults of the product. Therefore, 'Understanding the health of the product' was identified as the theme of the **affordance**. The remote monitoring feature of IoT helps them collect this data. As a result, it has an accurate knowledge of the usage data based on the collection from the products. Therefore, the **feature of the IoT artefact** identified as 'remote monitoring'. 'The manufacturer continuously monitors product usage and identifies faults. This is identified as an **action**, further resulting in the identification of **outcomes** as 'collection of usage data' and 'accurate knowledge of the faults'.

Instance no.2

The manufacturer can also identify whether the problem lies within the product or the external environment of the product based on the analysis of the data, in which case the customer can be informed accordingly. This was important because Alpha often had to send engineers for a visit and realise that the fault was not in their equipment. This contributed to a loss of resource.

> *"We should be able to prevent some visits because it's not the boiler and we can say, Mrs Smith, I think you need to check your gas or Mrs Smith, you might have a leak on a radiator."*

(VP Innovation)

Here, Alpha refers to analysing collected data and identifying the root cause of the product fault. Therefore, the data analytics **feature** of the IoT artefact was used by Alpha. In interaction with the goal, led to the perception of an opportunity to reduce the engineer visits to diagnose the fault causes. Therefore the **affordance** was identified as ‘Reducing repair and visits’. The manufacturer took **action** to analyse collected data and identify the source of the problem. This resulted in an **outcome** of better knowledge of faulty parts that would also improve efficiency in the dispatch of service engineers and customer being notified about the cause of problems. Similar to the first two affordances, the other instances of IoT usage in the case were analysed to identify the IoT features, affordances, actions, and outcomes.

Instance no.3

Alpha also analyses the usage data collected by the IoT artefact across multiple products and identifies trends that indicate the conditions of the product when a fault occurred. This allows them to predict the maintenance of a machine to a certain extent.

> *“Monitoring the data points and then taking the data points, what they were doing before a fault condition happened, combining that over hundreds of thousands of assets installed over the field to then determine, okay, we know if these conditions are present then x will happen. We can stage an intervention and make sure we perform some preventive maintenance work before the asset goes down.”*

(VP Innovation)

This instance indicates that Alpha perceived **affordance** of ‘Avoiding breakdown’ based on the data analytics **feature** of the IoT artefact. This affordance was actualised by taking **action** to compare the usage data of multiple products and develop trends to predict breakdowns by analysing the data. This resulted in an **outcome** of prediction of faults before the product breakdown.

Instance no.4

Additionally, Alpha provides access to the usage data and control over the product usage to the customer through a mobile app. By providing transparent access, Alpha can educate their customer about the energy being used by the equipment and push suggestions that reduce consumption and improve operational practices.

> *“So it means that people can have an app on their phone to control the heating. It’s smart because it talks to your boiler rather than just turning it on and off, it learns a little bit about your home usage*

> *patterns and makes recommendations and energy-saving suggestions."*

(Managing Director)

The last **affordance** perceived is 'Providing visibility' to the customer' based on the data-sharing **feature** of the IoT. Alpha took **action** to provide the customer with access to the product and usage data through a mobile app. This resulted in an **outcome** of better visibility and control over the product usage for the customer.

6.2.2 Case Beta

Beta's goal is identified as 'Gaining and maintaining competitive advantage'. Beta wanted to serve and lock-in the customers higher in the supply chain to the automotive and defence industries. These customers are keen to gain more value from the data and appreciate services more as compared to lower-tier suppliers.

> *"We obviously find the higher up the food chain you go they're very keen for advanced services, they want the data from the press, they want to analyse as much data to try and predict problems before they happen. Whereas the smaller press shops are very reactive, so they buy a more simple system, they don't care about the data coming off […]. So we have to cater to the Tier 1s and the OEMs that want all-singing, all-dancing, all bells and whistles."*

(Director of Operations)

Beta developed an IoT artefact to support their goal that comprises of numerous sensors such as load sensors, vibrations sensors, and pressure sensors. It collects usage data of the presses and their performance statistics. The artefact also includes communication devices to relay the data back to the manufacturer and centrally located analytical tools to interpret this data. This artefact is integrated into the new products sold by Beta.

Beta described six different IoT usage instances and therefore indicated that six unique affordances were perceived from the interaction between their goal which was 'gaining and maintaining competitive advantage', and different features of the IoT artefact. Table 13 presents the visualisation of the individual case analysis, which is described next.

Table 13 Case analysis: Beta

No	Goal: Gaining and maintaining a competitive advantage			
	Perception		Actualisation	
	IoT feature	Affordances	Actions	Outcomes
1	Remote monitoring and data analysis	Avoiding catastrophic failure	Collect and analyse tool placement and machine usage data	Collection of usage data Prevention of product damage and failure from a motor breakdown
2	Data analysis	Providing predictive maintenance	Analyse live usage data with reference to a historic baseline and spot anomalies	Analysed usage data Improved availability and output from the load press
3	Remote monitoring	Protecting the tooling and the press	Monitor the load pressure readings and flag anomalies	Protection from damage Ensured output quality
4	Data analysis and data sharing	Estimating productivity of the press	Analyse usage data and develop OEE reports	Reporting press productivity for the customer
5	Remote monitoring	Ensuring quality in press output	Monitor the placement and fitting of tools and components	Accurate fitting of components without any damage to the press or product
6	Data analysis	Capturing service market from 3rd party	Analyse motor vibrations for insights into machine health	Complete service agreement Customer needs addressing

First, Beta uses their IoT artefact to collect data on how the load presses put stress on different materials and monitor the trajectory of the stress as the press subjects the material to increasing load. Any anomalies in the trajectory indicate that operational parameters have changed, which may result in a poor quality output of the press or damage to the tooling. This allows Beta to raise alarms or stop the press to avoid damage to the customer's equipment and final product.

> *"Yes, so with the load monitor we put an electric transducer onto the press, we're monitoring the stress through the frame. So as the press forms a part, you get the signature through the frame, so you get a curve […] we analyse that curve throughout the cycle and if that signature is different from a blow to blow we stop the press and say there's an issue, something's changed in the operation. […] It's quality of the part, protecting your tooling, protecting the press."*

(Director of Operations)

In this instance, Beta perceived the **affordance** of ‘Avoiding catastrophic failure’ from the remote monitoring and data analytics **features** of the IoT artefact. It took **action** to collect tool placement and machine usage data and analyse it. This resulted in an **outcome** of a collection of the usage data and prevention of product damage and failure from motor breakdown.

Beta provides process monitoring services where it monitors pressure when different components are being fit together. If the components are prepared correctly, the force required to fit them together should not have any irregularities. The occurrence of irregularities indicates that the components are not prepared correctly. Applying excess pressure to fit improper components can cause damage to the tooling and the components. Beta makes sure such damage can be avoided.

> *“Process monitoring, that’s normal for an insertion process. So you’ve got for example a hub on a car and you want to push the bearing to the hub, so what we’re monitoring is the force that’s required to push the bearing into the hub. So is the hub machined correctly, is it oversized obviously there’ll be not enough force, if it’s undersized there’ll be too much force. […] So that’s process monitoring.”*

(Director of Operations)

It perceived the **affordance** of ‘Providing predictive maintenance’ from the data analytics **feature** of the IoT artefact. It took **action** to analyse live usage data in comparison to historical baselines to spot anomalies that could indicate changes in product condition. This resulted in the **outcomes** of Analysed usage data’ and Improved availability and output from the load presses.

If the press stops running, Beta has designed its system to integrate the reason for a breakdown as fed by the operator. It collates the information and presents it back to the customer. It also provides OEE reports based on the same data and gives estimates of the productivity of the press. This helps educate the customer about the performance and operational practices on the press, thus reducing breakdowns in the future.

> *"Production recording, it can be if the press stopped running, why is the press not running? So then we look at […] and the operator has to enter reasons why the press is not running. That information is all collated back in a central database where the managers can analyse that data […]. And we can also produce OEE reports off the back of that.*

(Director of Operations)

Beta perceived the **affordance** of 'Protecting the tooling and the press' from the remote monitoring **feature** of the artefact. It took **action** to monitor the load pressure readings and flag any anomalies. This resulted in the **outcome** of protection from damage and ensured the output quality of the load press.

Beta also monitors the positioning of tooling when the customer is processing products involving different types of sheet metal. This helps them avoid damage to tooling and the metal by making sure that the tooling is accurately positioned to carry out the work. Similarly, it also monitors temperature and vibration in the motors where it can estimate any anomalies that determine if the component is going to fail and take measures to stop that.

> *"On a basic, you might just be cropping a sheet of metal, so simple cropping is not going to do any damage but some tools are really, really complex. tools […] if you're a millimetre out and you send the press over you're really going to do some damage to the tool which can cost tens of thousands to repair. And then other sensors like pressure sensors and temperature sensors, that's more to do with looking after the machine more than the material. So if my temperature is going up on this bearing obviously the bearing is about to fail so it's trying to catch that before. On a motor we're starting to do vibration analysis so again, if you're starting to see a trend if something is changing, […] obviously you want to catch that failure before the catastrophic failure."*

(Director of Operations)

Beta also perceived the **affordance** of 'Estimating productivity of the press' from the data analytics and data sharing **features** of the artefact. It took **action** to analyse the usage data and developing OEE reports. This resulted in the **outcome** of reporting press productivity for the customer.

Beta analyses trends of parameters that indicate the condition of the press components such as bearings and other movable parts. This allows them to highlight problems and chances of failure before it occurs, therefore predicting maintenance requirements of the press.

> *"So again, to try and catch trends. So on our unit, we'll have parameters that say if you go over this value, stop the press […]. We've got a slight uptake here, but why is that happening? And then start to plot it, then try to highlight a problem way before our unit would. […] Yes, predictive and preventative maintenance, analysing trends more intelligently rather than just saying, okay, my bearing has just broken, the temperature flew up. Obviously, at that point, it's too late."*

(Director of Operations)

Beta perceived the **affordance** of 'Ensuring quality in press output' from the remote monitoring **feature** of the artefact. It took an **action** to monitor the placement and fitting of tools and components which resulted in an **outcome** of accurate component fitting without damage to the output of the press.

Beta identified an opportunity to provide more services by analysing data required by the customer. A customer currently employs a 3rd party to analyse the data recorded by Beta's monitoring system every quarter. Beta decided to extend their offering by providing real-time analysis of the collected data, thus capturing a new market as well.

> *"Yes, so vibration analysis of motors […] one of our customers pays an external company to come in, analyse their data for a short amount of time, say ten minutes every month, so they've got a service level agreement around that. What I want to do is put a vibration sensor permanently on the machine […] So I want to analyse that data 24/7. The way I want to sell that is you won't need to have this service level agreement with the company anymore, you're constantly analysing the data."*

(Director of Operations)

Finally, beta also perceived the **affordance** of 'Capturing service market from third party' from the data analytics **feature** of the artefact. It took **action** to monitor motor vibrations which indicate the machine health. This resulted in **outcomes** of capturing service market through complete service agreements and meeting customer needs.

6.2.3 Case Gamma

Gamma's goal to servitize was identified as 'Reduced customer proximity'. Through servitization, Gamma wants to ensure that their customers are locked-in with the products and services provided, and the value is captured through all-inclusive service contracts. This helps them differentiate themselves from the competition and develop a sustainable competitive advantage.

> *"Well, the ability to tie in our customers to our products and our solutions and our service contracts, even the capital sales model that we have, is a very critical benefit. And, once we have those customers on, we really want to drive customers onto our all-inclusive agreements, and then it becomes a matter for us to drive down our costs to run that all-inclusive service contract."*

(Director of Connected Solutions)

To enable their servitization, Gamma has integrated an IoT artefact in their products which comprises of a combination of sensors that remotely monitor crucial product parameters. This data is transmitted and collected at a central data bank using communication technology and then analysed off-site. It extracts the data selectively to avoid the collection of patient data and employee data in compliance with GDPR. Only product usage and status information are collected and analysed.

Based on four IoT usage instances, Gamma perceived four unique affordances from the interaction between their motivation to servitize, 'reducing customer proximity', and different features of the IoT artefact. Table 14 presents the visualisation of the individual case analysis, which is described next.

Table 14 Case Analysis: Gamma

No.	Goal: Reducing customer proximity			
	Perception		Actualisation	
	IoT feature	Affordances	Actions	Outcomes
1	Remote monitoring	Recording the product usage data	Embed a monitoring and control system	Collection of product input, output, and operational changes
2	Data analytics	Developing a predictive model to identify breakdowns	Analyse collected data to predict significant events in the operation	A helpful tool for service engineers to prepare and avoid breakdowns.
3	Remote monitoring and data analytics	Improving the accuracy of the predictive model	Collate and analyse data from other sources such as maintenance records	Accurate prediction of the exact components that will experience a breakdown
4	Remote monitoring	Accounting for environmental factors affecting product condition	Add new sensors to measure environmental factors	Accurate estimation of product condition and causes of failure or damage

Gamma measures all the parameters of the products in analogue and digital form during the input and output phases, which are then communicated back to their central system. The IoT artefact also allows them to capture periodic snapshots of the machine status, which is transmitted back to their central system.

> *"So, we're measuring all the analogue input and all the analogue outputs, and all digital inputs and all digital outputs that are controlling some parts of the machine, or measuring a part of the machine. And, we have that as snapshots per second, where we're picking up, this is one big image of how the settings were or the [IOs were], and that is then shipped off to our system."*

(Director of Connected Solutions)

Gamma has collected vast amounts of user data from their products over time which is stored centrally. This data is being logically analysed, resulting in predictions of events likely to occur with the products. This can be made available to their service engineers and thus make their onsite work more efficient.

> *"We have built the legacy part on 13 million processes, so that data model is built on that, and 20 million file entries on top of that. So, really big datasets running, I don't know, how many virtual machines in Amazon, that are continuously just unpacking data and storing it into different databases, so that we can apply the logic to it. What we had realised until now is, a fairly simple prediction engine that is running already in our front and also we haven't freed it up to our service engineers yet. And, we can predict already that something is about to happen fairly clearly and fairly with a high probability."*

(Director of Connected Solutions)

In these two instances, Gamma perceived an opportunity of recording the product usage data using remote monitoring. It embedded a monitoring and control system in their product. This resulted in the collection of product input and output data and operational changes. Next, Gamma wanted to develop a predictive model to identify breakdowns using data analytics. It analysed the collected data to predict significant events in product operation. This resulted in a helpful tool for service engineers to prepare for and avoid breakdowns.

Gamma also compares the stored data with other forms of data, such as maintenance records and notes. This helps them accurately identify fault causes and thus inform their service teams about the tasks involved during their onsite visits.

> *"If we don't know when the gasket is changed, we can't really predict if it's new or an old, so we need to have that as a correlation in terms of what the service data is saying. Because, if it was just recently changed and it takes a long time to inflate it, then we probably have a leakage. If it was not replaced more recently and it takes a long time to inflate it, that may be just because it's torn, and we have to go and replace the gasket. So, that's the two different generalities, and it's really two different things that you have to go and do. One thing is to adjust the speed to the chamber valve, and the other thing is changing the gasket."*

(Director of Connected Solutions)

It also wants to capture more data from the product's environment. This includes parameters such as quality of the utilities being supplied, environmental conditions of the product, and the external pressure exerted on the product. This will help them make more accurate predictions and estimations about their product and also clearly identify the source of the problems.

> *"Yes, there would be a lot of data points. Unfortunately, we have not yet succeeded to apply those additional parts. We should have incoming utilities just to measure what is the general water pressure coming to the machines because then you can correlate a lot of other things. The altitude at which the machine is located is also a very important factor. The weight of the load that goes into the machine, so there's a lot of things, to put a scale into the machine would actually be really beneficial, also. I could probably come up with a few more, but yes, more sensors outside of the machine would be a good thing."*

(Director of Connected Solutions)

In these two instances, Gamma perceived an opportunity of improving the accuracy of the predictive model using remote monitoring and data analytics. It collated and analysed data from other sources, such as maintenance records. This resulted in an inaccurate prediction of the exact components that might breakdown. Finally, Gamma saw the opportunity of accounting for environmental factors affecting product condition using remote monitoring. It added new sensors to measure environmental factors. This resulted in accurate estimation of product condition and causes of failure or damage.

6.2.4 Case Delta

Delta's goal to servitize was identified as 'delivering maximum return on investment to the customer'. Through their journey of servitization, Delta wants to gather more knowledge about the equipment, to determine what measures need to be taken so that it delivers maximum availability and value for the customer. Visibility of the machine usage is crucial for Delta to maintain efficiency and the customer to estimate their return on investment.

> *"They've spent let's say £0.5 million on a machine, they want that machine to work 100%. It will never do that. But the closest it can get to that and for the most amount of time that they're operating their shift […] so it needs to be doing the best it can do. So it gives visibility for us and the customer as to what that machine needs to be able to maintain that efficiency as well."*

(General Manager of Advanced Services)

Delta has developed a proprietary IoT artefact which involves a combination of sensors that monitor operational parameters of the product as well as specific environmental parameters that affect its performance such as temperature and humidity. The artefact also includes connectivity through standard communication channels to the central control system of the manufacturer where the monitored data is analysed. The analysed data is presented to the customer through a central-access portal where it can interact with and monitor the products.

Delta perceived ten unique affordances from the interaction between their motivation to servitize, ‘delivering maximum return on investment to the customer’, and different features of the IoT artefact. Table 15 presents the visualisation of the individual case analysis, which is described next.

Table 15 Case Analysis: Delta

No.	Goal: Delivering maximum return on investment for the customer			
	Perception		Actualisation	
	IoT feature	Affordances	Actions	Outcomes
1	Remote monitoring and data sharing	Understanding and recording product usage data	Monitor and collect usage data of the machine and present it through reports	Collection of usage data Development of efficiency and availability reports
2	Data analytics	Simplifying data analysis and presentation	Capture and analyse data in periodic snapshots and present data in a simplified form	Better understanding and presentation of the information
3	Data sharing	Developing central information access	Add all the information collected and reports created from usage data to a central portal and share access	The customer informed regarding the availability and efficiency of the machine
4	Remote monitoring and data analytics	Identifying the cause of the error	Develop algorithms to diagnose the cause and the machine component at fault	The quick and accurate response to faults
5	Remote monitoring and data analytics	Understanding product condition	Analyse the collected data to estimate the condition of the product and diagnose faults remotely	Information on product condition and recurring faults that can be fed back to product design
6	Data analytics	Prioritised resource allocation	Develop a rule engine to categorise the identified errors	Prioritised allocation of resources to solve

				errors based on urgency
7	Data analytics	Detecting errors occurring in live operations	Identify problems and errors in operation and flag them	Development of a bank of error codes and quick identification of faults
8	Data analytics	Providing guaranteed uptime	Analyse the usage data to diagnose, detect, and solve faults	Improved customer satisfaction through the delivery of proactive remote assistance
9	Remote monitoring and data sharing	Supporting the customers remotely	Share live monitoring data to assist the on-site service teams	Improved customer satisfaction due to effective support to service teams
10	Data sharing	Demonstrating delivered uptime	Monitor the input and outputs, and changes to the settings of the machine. Develop reports	Provision of reports demonstrating the delivery of uptime and factors that stop the fulfilment of guarantees

Using the IoT artefact, Delta wants to gather detailed information about the usage of the product on demand. It wants continuous access that allows them to monitor and collect the usage data. This helps them develop performance and efficiency reports about the product and share it with the customer through a central access platform where the customer can log-in.

> *"Okay, so all of our machines or all of our newly produced machines have the ability for an ethernet connection into the machine. We use that ethernet connection through our customer's firewall. Primarily that gives us the ability to take data from the machine and produce efficiency reports, performance reporting, literally looking at what the machine is doing over a period of time and that is a web-hosted platform the customer can log into and they can see that on any device. So that gives them immediate access to what's happening with the machine from anywhere in the world."*

(Operations Manager)

Delta captures the patterns developed through the machine output instead of capturing every single output in order to manage and simplify the data better and provide an aggregate overview to the customer. It also helps them understand whether the machine performance is satisfactory overall, or there needs to be an intervention, which is an estimate that is not possible through monitoring of every single output.

> *"The way the system works, […] we don't record every bag because the data volume would be ridiculous. We're looking at trend data because that's really going to give us over time that global view of what's going on with the machine. So we take a snapshot every minute, so we can't say how many packs the machine has produced but we're pretty accurate with it, and that overview data is what is valuable to the customer. It is just a very simple dashboard to just say, this is what your machine is doing. Is it good, is it bad, does it need somebody to go and look at it? That's really all it is, it's almost a traffic light system."*

(General Manager of Advanced Services)

In these two instances, Delta wanted to understand and record product usage data using remote monitoring and data sharing. It monitored and collected usage data of the machine and presented it through reports. This resulted in the collection of usage data and development of efficiency and availability reports. It wanted to simplify data analysis and presentation using data analytics. It captured and analysed data periodically and presented it in a simplified manner. This resulted in a better understanding of the information provided.

Delta does not have complete control over the machine operations but feels the need to demonstrate that the guarantees of availability were delivered as per contract. It achieves that through OEE reports. This helps them substantiate their claims of the deliverables by accounting for factors that are out of their control.

> *"So they are looking at the OEE, so the overall equipment efficiency, so it's the availability of the machine, the quality and the uptime of the machine. So they're looking at that figure although there are lots of outside influences that can affect that for our machine. Obviously, whatever is coming into the machine that we don't have control of and then later down the line where the product goes as well. So we can obviously monitor our machine and make sure that's running as effectively as it can […]. So if we are in a position where the customer said well I want 99% efficiency from you, why haven't you*

> *delivered it, the data can at least say well we haven't delivered it because of x, y, and z."*

(Operations Manager)

Delta analyses the collected data and flags errors, identify faults or detect breakdowns in the product operations. It was able to inform the service engineer about the cause and the potential repairs that need to be conducted on the product. Using this information, the engineer is equipped to solve the fault in the least amount of time and visits resulting in maximum uptime of the machine and high quality of service for the customer.

> *"So then we can start to flag errors that happen with a machine, for example, a motor overheating gradually over a period of time, we can start to identify what those faults might be, […] they have a breakdown they can contact us to connect to the machine and rather than fly very often an engineer halfway around the world […] potentially repair the machine if it's a software issue, or at the very least diagnose what the problem is. And if we still need to send somebody out to the field they will be aware of what the problem is and quite often they have the spare part with them to repair the machine as well. So it gives us a huge opportunity to maximise the uptime of the machine and give that added level of service to the customer."*

(Operations Manager)

In these two instances, delta saw the opportunity of identifying the cause of errors using remote monitoring and data analytics. It developed algorithms to diagnose the cause and the machine component at fault. This resulted in a quick and accurate response to faults. Delta also wanted to understand product condition using remote monitoring and data analytics. It analysed the collected data to estimate the condition of the product and diagnose faults remotely. This resulted in information on product condition and recurring faults that can be fed back to product design.

It was able to capture and use the data internally from the customer's site and gain awareness of the usage of the product, identify repair and maintenance requirements, and additionally inform their future product developments. It found that capturing performance data led to substantial benefits in general.

> *"And although we probably didn't know it at the time, we knew there was some value from the data that we were going to collect. Initially, in giving performance data, that visibility is a benefit immediately. The secondary is obviously to be able to repair and diagnose and support the customer to a higher level. And thirdly, which is probably one of the most difficult areas to capture is pulling that information internally to advise and inform future developments as well […]. We knew there would be benefits from having that data."*

(Operations Manager)

Delta has become more proactive in supporting its customers and providing services to maximise the product uptime. The analysis of the performance data has allowed Delta to address numerous problems, often those that the customers were not aware of. This helped them demonstrate the value being delivered to the customer and show that the problems have been addressed proactively.

> *"So we have to work towards maximum uptime now to even get in with a chance of moving on with those service propositions. But the system definitely helps with the uptime, and also the fact that we're able to proactively provide a service to the customer to just improve their uptime a small amount proves valuable. We've got a number of customers that while we've been looking at the data that comes through we've noticed problems and we've reacted to those problems and we've addressed them for the customer and told them that we've repaired a problem that they probably didn't even know they had. So that's really obviously gold from a marketing perspective to ring your customer and say, we're that proactive we've repaired a problem you didn't even know you had.*

(General Manager of Advanced Services)

In these two instances, Delta further saw the opportunity of prioritised resource allocation using data analytics. It developed a rule engine to categorise the identified errors. This resulted in a prioritised allocation of resources to solve errors based on urgency. Delta saw the opportunity of supporting the customers remotely by data sharing. It shared live monitoring data to assist the on-site service teams. This resulted in increased customer satisfaction due to active support to service teams.

Delta also provides notification services where it informs the customer about the machine operations through daily email reports or preferred channels as per request.

It also feeds this data into their analytical software to determine the urgency of some problems.

> *"We also send email reports if the customer wants them every day, once a week and once a month which aggregate that data into those trends. And again, the customers find that very valuable, it's easy, it's in an Excel sheet, they can manipulate the data, we're not trying to be too fancy with it, it just gives them useful information. That is very much the customer end, that is what the customer sees. We are developing newer methods to give us more scope in the future but again we've used technology that has been around for quite some time. We pull that data in, our control team when they developed the software put in lots of triggers to identify what an error should be, is it a bad error, is it something we need to look at now, is it something that is not really that critical?"*

(Operations Manager)

Delta's customers are downsizing their on-site service teams. Delta uses this opportunity to provide support services with technical competency, using remotely monitored data along with remote support on call whenever required by the customer. This gives assurance to the customer that it has access to expert support whenever required.

> *"Some of those customers have very skeletal maintenance teams, for example, a lot of them are looking to try and downsize as much as they can in terms of their site support. So the ability for us to remotely monitor and react and support with a high level of technical competency from here […] because they need that reassurance that there's always an expert at the end of a connection that can fix the machine for them."*

(General Manager of Advanced Services)

Delta uses the remote monitoring capabilities of the IoT artefact to detect problems quickly to avoid significant damage to the customer's business. Their IoT artefact raises alarms based on the designed tolerance limits and informs the technical desk when action is required.

> *"So we have very rapid heaters in that machine to do that function and lots of motors to drive it and it could be that over time the machine is wearing and it's been used, one of those heaters takes a fraction of a second longer to come up to temperature and we'll pick*

> *that up in the system, […]. Then there are tolerances within the system, this has all been developed in the system, it will say once it goes over a certain tolerance it will go red and that's a trigger for somebody on our technical desk to look at it and see, there's probably a problem here."*

(General Manager of Advanced Services)

Delta has experience in understanding the severity of issues flagged by their system, which allows them to develop a priority list of how the identified problems need to be addressed. It can also determine the urgency of a particular problem based on the frequency of its occurrence.

> *"We know that a lot of error codes means something needs to be done but it's not going to make the machine fail but it's just something you need to look at, it's not critical. And I think we've got … I think it's three levels, it might be more, of initial error, medium error, critical alarm, and they've all been classified. It's obviously time to do that, but each error has been classified as what's the severity of that issue? So we have that level but then we also count how many times that happened within a period of time […]. If you have that error happening five times in an hour it's probably something a little bit more serious."*

(General Manager of Advanced Services)

Finally, in these four instances, Delta decided on providing guaranteed uptime using data analytics. It analysed the usage data to detect and solve faults. This resulted in improved customer satisfaction through the delivery of proactive remote assistance. Additionally, delta wanted to demonstrate delivered uptime using remote monitoring and data sharing. It monitored the input, output, and changes to operating settings to develop reports. This resulted in the provision of reports demonstrating the delivery of uptime and factors that step the fulfilment of guarantees. Finally, delta decided upon detecting errors in live operations using data analytics. It identified problems and errors in operation and flagged them. This resulted in the development of a bank of error codes and quick identification of faults.

6.2.5 Case Epsilon

Epsilon's goal to servitize is identified as 'to be a bigger part of the customer's business'. It wants to make the cereal processing equipment more accessible and efficient to run by taking more control of the operations. It can use the expertise in running the equipment to reduce the waste that is generated by the inefficient use of milling machines.

> *"[Epsilon] leads the world in the production of healthy cereal and the delivery of a simplified sustainable approach to cereal milling. We address the real challenges faced by millers today, not those of hundreds of years ago. To change the embedded culture of an entire industry is a significant challenge and we are working with our partners to challenge the established norms and achieve this change"*

(Website- Epsilon)

Epsilon has designed an IoT artefact that has a combination of sensors integrated into the product along with communication devices to transmit the data captured by the sensors. The data is sent back to the manufacturer where it is analysed centrally. The manufacturer has developed analytical tools based on performance and usage trends from historical data.

Using this IoT artefact, Epsilon perceived seven unique affordances from the interaction between their motivation to servitize, 'to be a bigger part of the customer's business', and different features of the IoT artefact. Table 16 presents the visualisation of the individual case analysis, which is described next.

Table 16 Case Analysis: Epsilon

No.	Goal: To be a bigger part of the customer's business			
	Perception		Actualisation	
	IoT features	Affordances	Actions	Outcomes
1	Remote monitoring and data analytics	Identifying the exact component at fault for poor output	Collect and analyse usage data to identify trends that indicate the exact component at fault	Collection of usage data Efficient and quick response to faults
2	Remote monitoring	Identifying external factors that affect productivity	Monitor humidity and temperature of the feed	Accurate information about the input to the machine
3	Remote monitoring	Estimating the health of consumables accurately	Estimate condition of belt drives to avoid breakdown	Assured uptime of machine by timely maintenance
4	Data analytics	Comparing the performance of multiple machines	Collate usage data from multiple machines and plot performance trends	Development of error logs and best-operating guidelines
5	Data sharing	Providing information transparency to customers	Develop and share access to a live information portal	Transparent information display for customers with access to live usage data
6	Data analytics	Generating a predictive performance model	Analyse historical data to predict the parameters that can affect the performance	Optimised operations and performance of machines
7	Remote monitoring	Keeping track of changed settings and set of consumables	Identify the set of consumables associated with different types of inputs	Reduction in faults when processing different inputs in the machine

It uses the trends of product performance to identify when the product is not creating the expected output. Similarly, identification of the specific faulty container within the product is possible and therefore allows Epsilon to intervene without hampering other containers.

> *"As soon as you have an issue with the machine the bran scale will be the first thing to reflect it. You probably also see power blip on the machine that's got a problem, or the torque will change, all these are parameters that we can instantly real-time analyse.*

But by putting a little accelerometer on each of the chambers we can now determine which chamber has got the problem, we can do that automatically. Now traditionally if we have a chamber that's gone bad on a machine we shut the whole machine down and we lose 12 chambers."

(Managing Director)

Epsilon uses the combination of sensors to monitor the quality of the cereal feed and any other environmental factors which may affect the cereal processing. This helps them accurately account for the conditions of the feed that affect the output of their product.

We know that if you have rice in a [day bin] which has been there for some time it'll be dryer than rice that's been in the storage bins which tends to be slightly wetter. So they'll run the day bin down, then they'll bring in a load of wet rice and dump it in that day bin. Over a period of time it will dry out again but that first surge of rice there'll be a step-change in how that rice performs and how the machine would have to be adapted to cope with that change in rice.

(Managing Director)

In these two instances, Epsilon saw the opportunity of identifying the specific component at fault for reduced output using remote monitoring and data analytics. It collected and analysed usage data to identify trends that indicate the specific component at fault. This resulted in the collection of usage data and efficient and quick response to faults. Next, Epsilon wanted to identify external factors that affect productivity using remote monitoring. It took measured humidity and temperature of the feed. This resulted in inaccurate information about the input to the machine.

Epsilon uses remote monitoring abilities to identify broken belts on the motor and combines multiple data points to improve the accuracy of fault identification. This allows them to identify the faults without stopping the machine and schedule the repair activities during the times that it is not used.

"Now the other things that we can do is by better monitoring the machine and understanding how the machine is working then we can potentially extend with greater certainty […]. So we're just looking for light spots through the belt. So without stopping the machine, we can determine this belt has holes or this belt doesn't have holes. If the

belt doesn't have holes and the join is intact then no need to stop it. It's only when it has a problem. And again, if you're looking at the data profiles that we're producing from the torque and the motor data and then we superimpose that with the rice data you can see this has happened and with a number of hours this is likely to happen so we can flag up in advance."

(Managing Director)

It collates the data collected from multiple machines and compare them to develop best practices of operating the machines and identify changes to operating conditions. This makes sure that the operational settings of the machine are not changed by the operators whenever it takes control.

"So if I have ten machines in a factory, I can then compare machine to machine and identify if there's an issue. […]. And again, we can look at comparative data, mill on mill, machine on machine, operator on operator, and one of the big bugbears in the rice mill right now is that the operator, as soon as the operator changes, the new guy who comes on thinks the guy who's just left doesn't know what he's doing and he goes around and adjusts everything."

(Managing Director)

In these two instances, Epsilon decided on estimating the health of consumables accurately using remote monitoring. It estimated the condition of belt drives to avoid breakdown. This resulted in assured uptime of the machine by timely maintenance.

Further, Epsilon decided upon comparing the performance of multiple machines using data analytics. It collated usage data from multiple machines and plot performance trends. This resulted in the development of error logs and best-operating guidelines.

Epsilon provides the customer with access to the data collected and insights generated from the data through a central dashboard. This helps to provide transparent control to the mill owners.

"Now by bringing a dashboard of real-time or near real-time data you're putting the miller in control pre-emptively, you're putting the mill owner into some sort of control so he can understand what's happening in his mill, how that is impacting on his profitability."

(Managing Director)

It is analysing large sets of historical usage data to develop algorithms to optimize the performance for different types of feeds in different conditions. This helps them make the machine suitable for a wide variety of cereals and ensure its efficiency across the different feeds.

> *"Lots and lots of testing. Laborious, boring, mind-blowingly boring testing. Counting bits of rice. So we run the machine at different speeds. So if we look at capacity and we look at speed, the faster we go to a point it will produce more then it will flatten out, it can't produce any more. We know that the brokens for any given setting will be like this. So we're looking for that point there. But what we know is and once you've found the settings for a particular rice type they don't change. So we built a database of, I want to mill basmati, this is the setting, you want that orifice, that chamber setting, that belt."*

(Managing Director)

Epsilon can keep track of the belt drives, and operational settings used different types of feed and allow reconfiguration of the machine based on this information. This helps to ensure the maximum performance from a belt-drive and therefore reducing the customer's costs of replacing the belts.

> *"One of the things we looked at in the past was making smart belts or ID in the belts, putting an RF tag on the belts so each belt has a unique number. So you can take a belt off if you were changing rice, put a different belt on. You can put that belt back on, we know where that is in the belt life cycle so we can set the machine according to the use of that belt. So again, it's all about maximising the performance of the belt and that is related to the speed and the speed is set simply by changing the parameter in the register."*

(Managing Director)

Finally, in these instances, Epsilon saw the opportunity of providing information transparency to customers through data sharing. It developed a live information portal and shared access. This resulted in a transparent information display for customers with access to live usage data. Epsilon also wanted to generate a predictive performance model using data analytics. It analysed historical data to predict the parameters that can affect performance. This resulted in optimised operations and performance of the machine. Epsilon also decided upon keeping track of changed settings and consumables using remote monitoring. It identified the set of consumables associated with different types of inputs. This resulted in a reduction in faults when processing different inputs in the machine.

6.2.6 Case Zeta

Zeta's goal to servitize is identified as 'develop a closer relationship with the customer'. Through servitization, Zeta wants to become a closer part of the customer's business process and reduce proximity to the customer. It decided to integrate digital technology into their products to drive this change.

> *"So, for most of our customers, we are, sort of, a secondary process in their manufacturing process. And, they are not experts in what we sell to them if you get my point. So, what we decided, two years ago, was that we wanted to pilot if we could digitise our solutions so that we became more relevant to our customers and be able to, sort of, have a more forward-looking relationship on our installed base going forward."*

(VP Product Marketing)

Zeta has developed their proprietary IoT artefact that includes a combination of monitoring sensors, communication technology to transmit the data, a central data collection and analysis tool, and an online access tool for the customers and service engineers. It can connect to their complete range of products through this IoT artefact and extract data as and when required.

Zeta perceived six unique affordances from the interaction between their motivation to servitize, 'develop a closer relationship with the customer', and different features of the IoT artefact. Table 17 presents the visualisation of the individual case analysis, which is described next.

Table 17 Case Analysis: Zeta

No	Goal: Develop a closer relationship with the customer			
	Perception		Actualisation	
	IoT features	Affordances	Actions	Outcomes
1	Remote monitoring	Understanding product condition and usage	Monitor product usage and performance metrics	Collection of usage and performance data Estimation of the product condition and usage
2	Data analytics	Predict product condition and breakdown	Analyse the performance and usage data to predict the condition	Faster response to product breakdown and predictive maintenance
3	Data analytics and data sharing	Providing better access to and understanding of performance data	Develop a rule engine to interpret the data and send alert notifications to customers	Information transparency and improved customer proximity
4	Remote monitoring and data analytics	Customizing operations according to the customer's industry	Develop new rule engines and flag alerts and errors according to industry standards	Customised services and compliance standards for customers
5	Remote monitoring	Detecting and notifying accidental changes to operational settings	Monitor and detect any abnormal settings in filter operation and send alerts	Notifications to the customer regarding any sudden changes to filter operations
6	Data sharing	Providing transparent access to analysed data and information	Develop and present a central access portal to customers with live and historic information and alerts	Improved customer satisfaction and proximity through transparent data access

Zeta uses the monitoring sensors in their IoT artefact to monitor the product performance and identify patterns to predict product condition. This also opens more avenues for them to provide new services to the customer using this data.

> *"We are able to do remote monitoring, and we can see how the different filters are performing, and how the process is behaving in the customer side. That allows us to build, you could say, various service packages around that so, of course, we hope that that could be a revenue generator going forward. But, it's also a new way of engaging with our customers so that we can actually sell various*

services so that a customer can ask us to survey, or monitor, their filter on a regular basis and we can do predictive maintenance, so we can let them know if we see any patterns in their processor in their filter system that are abnormal, and we could not do that before."

(VP Innovation)

It also assists the customer in reducing process breakdowns due to faults in the filtration equipment. It can identify the need for maintenance before the breakdown and ensure that the customers' business process does not lose uptime.

"We are also reducing risk, so for most factories and factory management and maintenance people they are basically measured on uptime, so their goal in life is to avoid that the production stops. So, what we are now able to do is, we can help them with the risk management, we can do predictive maintenance, and that, basically, indirectly gives them the security of uptime."

(VP Innovation)

In these two instances, Zeta saw the opportunity of understanding product condition and usage using remote monitoring. It monitored product usage and performance metrics. This resulted collection of usage and performance data, and estimation of the product condition and usage. Next, Zeta decided to predict product condition and breakdown using data analytics. It analysed the collected data and predicted the condition. This resulted in a faster response to product breakdown and predictive maintenance.

Zeta provides the customer with access to filter performance and sends notifications about reduced performance or faults. It also provides the customer with access to specific tools where operational thresholds and tolerances can be set, resulting in various rules and alarms. These help the customers control the overarching process better.

"We can also look at historical data, with the cloud and the app we have today, we can give the maintenance people and their factory and plant management, tools so that they can constantly look at how the system is performing. And, they can set various rules and alarms, meaning that if a fan gets hot, or if a pipe gets full of dust, or if something is working at normal, we can set limits to the measures,

so they get alarms into their control room, or to their iPads, or even to their mobile phones."

(Director of IT)

Zeta develops different rule engines for different industries to help them comply with their standards. This helps them extend their services to different industries and also ensure that the output of their machine is directly relevant to the customer business.

"It's a mix of both, so you can say I talked about the fact that you could set limits and get alarms, for each industry we try to, sort of, set a set of tolerances. So, you know that if the temperature or if the level of dust, or the airflow, things like that, if they exceed or go below a certain limit then you get an alarm. Each industry has limits where you can say, if the temperature goes up in a chimney, or if the temperature in a filter gets too high, then you can risk a local explosion, or that the filter starts burning, stuff like that."

(Director of IT)

These two instances show that Zeta wanted to provide better access and understanding of performance data using data analytics and data sharing. It developed a rule engine to interpret the data and send alert notifications to customers. This resulted in information transparency and improved customer proximity.

Further, Zeta saw the opportunity of customizing operations according to the customer's industry using remote monitoring and data analytics. It developed new rule engines to flag errors and send alerts according to industry standards. This resulted in customised services and compliance standards for customers.

It also identifies and highlight changes occurring accidentally in the operational settings. This helps avoid any accidents or faults that may occur due to negligence and thus reduce customer's costs.

"Exactly, it's to prevent downtime and accidents, and basically, you know, see if something needs to be changed. Or, sometimes, factories or factory workers change something, even without knowing, maybe they change the temperature or the airflow. Maybe a new person is not aware, or they do something, if they do a change to their process, we try to capture that in our data, so if we can see something that is abnormal."

(VP Innovation)

Through the access portal, Zeta provides its customers with access to the usage data, alerts, crucial information and other operational details. This allows the customer to have transparent access to all the parameters that affect the performance of Zeta's products and thus affect the customer's business. It can also make informed decisions about maintenance and repair based on this information.

> *"Well, of course, we have a dashboard that allows the simple realisation of the data, both with real-time values and some graphic presentation of historic data and stuff like that, but that's just pure presentation. And then, we have an alarm function, or we call it a rule engine, where you can make complex rules to say that, if a certain combination of sensors reaches certain threshold values for more than a certain amount of time then it's an impression that something is wrong."*

(Director of IT)

These last two instances describe how Zeta also decided upon detecting and notifying accidental changes to operational settings using remote monitoring. It monitored and detected any abnormal settings in operation and sent alerts. This resulted in notifications to the customer regarding any sudden changes. Finally, Zeta saw the opportunity of providing transparent access to analysed data and information by data sharing. It developed and presented a central access portal to customers with vital and historical information and alerts. This resulted in improved customer satisfaction and proximity through transparent data access.

6.2.7 Case Theta

Theta's goal to servitize is identified as 'reduce customer proximity by providing services to help customer's business'. Through servitization, Theta wants to be closer to their customer by providing solutions focused on improving the customer's business and helping their gain more value. It wants to position themselves as service provides before manufacturers of packaging products.

> *"Fundamentally, we manufacture and supply products, however, we see ourselves as service providers first and foremost. Our aim is to provide each of our clients with a solution that delivers optimum value for both their business and across their wider supply chain."*

(Manager of Business Development)

Theta uses an IoT artefact manufactured by a third party that is a combination of sensors and communication devices that transmit the data collected by the sensors. It collects data on global positioning, acceleration, tilt, humidity, temperature, and moisture. This artefact can be retrofitted to any of their packaging products or bespoke products. It can be removed and reused once the packaging has arrived at its destination or returned to the origin.

Theta perceived four unique affordances from the interaction between their motivation to servitize, ‘reduce customer proximity by providing services to help customer’s business’, and different features of the IoT artefact. Table 18 presents the visualisation of the individual case analysis, which is described next.

Table 18 Case analysis: Theta

No.	**Goal: Reduce customer proximity by providing services to help customer’s business**			
	Perception		**Actualisation**	
	IoT features	**Affordances**	**Actions**	**Outcomes**
1	Remote monitoring	Understanding the customer’s usage of products	Monitor the stock usage and suggest restocking	Collection of usage data Improved customer lock-in and relationship.
2	Remote monitoring	Evaluating the condition of the product	Monitor the impact taken by the product and the journey travelled	Developed a track record of how the product has travelled over the period of time.
3	Remote monitoring	Integrating with the customer’s IoT strategy	Connect to customer’s IoT system and monitor the data shared	Improved information on the customer’s packaging stocks and needs.
4	Data sharing	Informing the customer about the details of the package journey	Present the data back to the customer through a report of the journey and the points of handling	Transparency in the transit process and increased customer satisfaction.

Theta uses their remote monitoring abilities of the IoT artefact to monitor the packing product stocks and manage it remotely. It also monitors the weight exerted on the product and keeps track of the stress on the product.

“Yes, things like remote monitoring, so obviously a lot of the time … because the packaging is a low-value thing it’s very difficult to attach that kind of level of technology to everything. Now we are looking at doing things like RFID tagging to manage stock electronically, which we have done. But also looking at ways to use pallets to turn it into a bit of weighing equipment, by putting sensors in there. When you put the load in there it’s able to … what weight that pallet is carrying.”

(Manager of Business Development)

It tracks the shock absorbed by their product in transporting various items and the location. Overlapping this data allows them to understand where the product could have experienced damage. This helps them inform the customer about expected damage to their product and the location where it may be damaged.

“So if we were shipping from here to Scotland for the sake of argument, and we want to design packaging to go through the rigours of that journey […].

So what we can do is gauge a picture of what happens and where the points along that journey are, where it’s got more chance of being damaged by rough handling and all that stuff. That’s kind of where we use remote monitoring as well, rather than looking at how a certain product is used in action every day.”

(Manager of Business Development)

Also, it provides a full report of the product journey, highlighting where the product stopped, or was handled, or damaged. It uses the data about product shock, location and other parameters to make accurate estimates of the product’s journey. This allows Theta to help its customer prepare for any damages to their packaged item and reduce a negative impact on their business.

“But with remote monitoring in packaging, what you’re doing is taking away the unknown to a certain extent because generally, they just packed their product into a timber case, put it in the back of a truck, and they didn’t see it again until it arrived at the other end. They wouldn’t know until it got to the other end and it’s damaged. If you had remote monitoring in there you could say, okay, this has been subjected to 2 Gs of shock on this lab, we’re either going to need to check it before it goes over or quickly ship another one out so we’d rather have two there than one that doesn’t work. But that kind of data and that kind of information is valuable to the customer and that’s what it enables us to do.”

(Manager of Business Development)

In these instances, Theta wanted to manage the customer's stock of packaging products using remote monitoring. It monitored stock usage and suggested restocking. This resulted in a developed track record of how the product has travelled over some time. Next, Theta decided upon plotting the shock absorber and the journey of the packaging using remote monitoring. It monitored the impact taken by the product and the journey travelled.

Using the connectivity of the IoT artefact and aligning that with the customer's IoT strategy, Theta shares the information directly and combines the systems with the customer to initiate proactive services. This helps them gather replacement orders proactively and lock-in the customers.

> *"And if we're part of their supply chain, if we've got the knowhow to be able to integrate with their IoT strategy as well I think there's going to be a lot of value in that in the future because like I said, it's a low-cost item but it's critical to their supply chain. So for example, if they've got a machine that's churning out parts, if there's a way of calling off, I don't know, if 50 of those parts go in a cardboard box, is there a way of their machine telling our packaging that we've just made 50 of them, we need a cardboard box. I think will become more and more prevalent in our supply chain."*

(Manager of Business Development)

Theta tracks the location and movement of their product, carrying an item and shares the live data with the customer to allow the customer to track the progress of their item throughout the journey. It can also track other parameters that can affect the condition of the packaging.

> *It's GPRS tracking but we can put GPS tracking in as well so it will tell you where it is on a map and what kind of shock it's been subject to or measure vibration, moisture, temperature, humidity, that kind of stuff.*

(Manager of Business Development)

Further, Theta wanted to integrate with the customer's IoT strategy using remote monitoring. It connected to the customer's IoT system and monitored the data shared. This resulted in improved information on the customer's packaging stocks and needs. Finally, Theta saw the opportunity of informing the customer about the details of the package journey by data sharing. It presented the data back to the customer through a report of the journey and the points of handling. This resulted in transparency in the transit process and increased customer satisfaction.

6.2.8 Case Kappa

Kappa's goal to servitize is identified as 'Differentiating from the competition'. Kappa has chosen to servitize in order to differentiate themselves and stay ahead of the competition. It finds that the type of products it supples are being commoditised by increasing emergence of low-cost suppliers.

> *"I would say it's driven by the need to develop competitive advantages. It wasn't customer-driven, it's an internal drive to constantly keep ahead of the competition."*

(Managing Director)

Kappa has developed a proprietary IoT artefact which includes a combination of remote sensors, communication devices to transmit data, a central data analysis tool, and a cloud-based platform for the customer to access data and reports. This IoT artefact is present on all of their products. However, customers can opt not to have them, which involves physically removing the IoT artefact from the products.

Kappa perceived seven unique affordances from the interaction between their motivation to servitize, 'Differentiating from the competition', and different features of the IoT artefact. Table 19 presents the visualisation of the individual case analysis, which is described next.

Table 19 Case analysis: Kappa

No.	Goal: Differentiating from the competition			
	Perception		Actualisation	
	IoT features	Affordances	Actions	Outcomes
1	Remote monitoring	Understanding the usage and current status of the product	Monitor the usage and performance of the system	Collection of usage data Guaranteed functionality of the system
2	Remote monitoring	Identifying the maintenance spots and faults	Monitor and analyse usage data to identify the exact need for maintenance	Informed service engineers about the parts to be replaced or repaired.
3	Remote monitoring	Ensuring system availability	Monitor the power supply and power levels of the ventilation systems	Guaranteed availability of the system
4	Data analytics	Identify the urgency in solving anomalies	Analyse usage and performance data along with historical records to develop priorities	Effective solving of problems based on priority towards system availability
5	Data analytics	Predicting part breakdown	Analyse performance and usage data and to predict maintenance requirements	Provision of predictive maintenance
6	Data sharing	Informing stakeholders about system status	Share the gathered system information in an understandable format	Informed internal stakeholders and customer

The first two instances show that Kappa collects performance data from its ventilation system and ensures its availability. It also conducts diagnostic analysis to identify the exact maintenance requirement that assists the service engineers. This helps them reduce the cost of maintenance visits.

> *"By embedding technologies and data generation inside our products, that we can then harvest, in the first instance from the life safety point of view, we can remotely make sure that that system is fully functional to operate all the time. From a reducing cost, reducing the ongoing running costs of that building, we can make sure that before we make a maintenance visit on that system, for instance, that we've got a full diagnostics to check on that on all the components in that building, such that some may be coming to the end of their life and need changing."*

(Managing Director)

It monitors mission-critical parameters such as power levels and power supply to ensure the availability of their systems. It also develops profiles of the system performance to identify changes and predict maintenance. This helps them approach the customers with recommendations for repair and replacement of parts that are likely to fail.

> *"So, for instance, some of our systems, our smoke ventilation systems are life safety products, and so they have primary and secondary power supplies. We've got the technology to real-time monitor that secondary power supply to ensure that it's always ready to work when it needs to. But, to do that, that sounds very simple, but the data characters, the characteristics that we have to monitor and understand, are actually quite complex. And, it is the ability to put the sensors in and the algorithms to understand what that data means, that's the really interesting proposition that we get out of that.*
>
> *And, in addition to that, because we sell mechanical devices, we can profile the performance of those products, such that when we start to see a change in the profile of that performance, we know what that change in profile indicates. For instance, it might be a drive coming to the end of its life, or whatever, that's where we can proactively we can approach the client and say, you need to address this device because it's at the end of its life, that type of scenario."*

(Managing Director)

First, in these three instances, Kappa saw the opportunity of understanding the usage and current status of the product using remote monitoring. It monitored the usage and performance of the system. This resulted in the collection of usage data, and guaranteed functionality of the system. Next, Kappa decided upon identifying the maintenance of sports and faults using remote monitoring. It monitored and analysed usage data to identify maintenance requirements. This helped them inform their service engineers about the parts that need maintenance or replacement. Further, Kappa saw the opportunity to ensure system availability from the remote monitoring feature of the artefact. It monitored the power supplied to the ventilation system to make sure that the system is always available for usage.

Kappa also analyses the collected usage and performance data to develop alarms and notifications sent to the customer and engineers. This helps them optimize the allocation of resources based on problem severity.

> *"Well, quite the opposite, they don't have to look and spot those anomalies, we do that automatically with our algorithms, and we then push out to their relevant parties, the stakeholder, we can expect there will be a problem in x amount of time or there is a real-time problem now, there is an activation, whatever it is, that needs addressing instantly."*

(Managing Director)

Additional steps to improve their prioritisation, Kappa also overlap the live data with the product's historical performance data. This helps them accurately deploy engineers to solve urgent problems and start a maintenance process where faults are being predicted soon.

> *"Absolutely, absolutely, and the degree of that solution, as I said, it might be, right, there's a critical failure here, go out and send an engineer to one of these sites to rectify that immediately. Or, it might be a much longer-term that says, okay, we're noticing there's a deterioration in the performance of this product, and therefore contact the client, prepare a quotation for a replacement, for instance."*

(Managing Director)

Kappa analyses the data collected and presents it in a simple format. This is important for transparency within their organisation and for the customer who can access data as required.

> *"So, we capture all this data and there is a considerable amount of IP that sits behind processing this data. And, that data is turned into a simple usable format that is available, depending on the tiered level, at a high-level user level, which is generally just internally. But then, it can be broken down to a much simpler level, whereby an end client or an intermediate engineer might wish to access this data."*

(Managing Director)

Here, the instances start with describing how Kappa also saw the opportunity to prioritise the maintenance based on the urgency of the problem through the data analytics feature. It analysed the usage and performance of their product along with historical records to develop priority lists. This helped them manage maintenance requests more effectively. Kappa perceived an opportunity to predict the breakdown of products through the data analytics feature. It analysed performance trends and live usage data to predict maintenance requirements, and thus deliver predictive maintenance to the customers. Additionally, it saw an opportunity to inform the stakeholders about the status of the ventilation system. It collated and shared the gathered data in formats understandable to everyone involved.

6.2.9 Case Lambda

Lambda's goal to servitize is identified as 'Improve the product utility and return on investment to the customer'. Through servitization, Lambda has a goal to provide the maximum utility of their products and a high return on investment for the customer. It finds the ability to track the performance and usage of the products is essential to substantiate the return on investment.

> *"If you invest in a machine which can cost between, let's say, €2,000 and €40,000, of course, it's sometimes a very important investment so you want to make sure that that is really being used, and that you have the best return on investment by really having also very good usage day by day and track that."*

(VP Global Services)

Lambda has developed its proprietary IoT artefact that includes a combination of remote sensors, communication devices, a central data analysis tool, and a cloud-based access platform. It collects various parameters, such as battery power, battery health, product runtimes, consumable levels, and product locations. Customers can log into the platform to use the collected data, receive notifications, and monitor product usage.

Lambda perceived nine unique affordances from the interaction between their motivation to servitize, 'Improve the product utility and return on investment to the customer', and different features of the IoT artefact. Table 20 presents the visualisation of the individual case analysis, which is described next.

Table 20 Case analysis: Lambda

No.	Goal: Improve the product utility and return on investment to the customer			
	Perception		Actualisation	
	IoT features	**Affordances**	**Actions**	**Outcomes**
1	Remote monitoring	Gathering information about the product usage	Monitor product usage, performance, and location data	Collection of product usage A comprehensive record of the product's utility in the customer environment.
2	Data sharing	Providing complete transparency to the customer	Share the usage and performance data with the customer through a portal	Informed customer about the usage, location, and performance of the product.
3	Data analysis	Identifying the faults correctly	Analyse data collected with other sources and develop fault codes	Accurate identification of the faults and their causes.
4	Data analysis	Predicting maintenance requirements	Analyse multiple forms of data to accurately predict breakdowns, wear, and repair opportunities.	Accurately developed predictive maintenance models.
5	Data analysis	Improving the predictive maintenance models	Analyse fault codes to identify patterns of occurring faults	Triangulation of predictive model and fault codes patterns resulting in improved predictive maintenance
6	Remote monitoring	Reducing maintenance costs for the customer	Monitor the battery charging patterns of the customer and advise improvements	Reduction in battery replacement and repair costs for the customer
7	Remote monitoring	Providing security to the products	Monitor the location of the product and develop authorised geo-fences for the customer	Assurance of the safety and location of the fleet of products for the customer
8	Data analysis	Helping customer to improve product utility	Analyse usage patterns across the customer's fleet and advise on better product choices	Improved customer satisfaction and proximity through performance advisory

9	Data sharing	Presenting the product usage data to demonstrate optimization opportunities	Share the usage and performance data and schedule advisory meetings	Customised performance advisory services.

Using the IoT artefact, Lambda collects usage, location, and battery charging data of their products onsite. It gathers this data and presents it to the customer through an access portal, which helps the customer manage the fleet of products it has purchased efficiently.

> *"Okay. Because, since about two years and a half we've really been very proactively promoting a fleet management system, and that fleet management system, in summary, the management system is really built around a very user-friendly portal. But, what it is being set with is usage data, location data, and the battery charging data, and that's something that we make available to the customer. We are also trying to build, on the same portal, an overview of service-related data."*

(IoT Program Director)

Lambda uses their access portal to provide reports to the customers about product usage and then have meetings where suggestions to improve the usage can be offered. Educating the customer and providing performance advisory helps Lambda ensure maximum utility and demonstrate a high return on investment for the customer.

> *" So, that kind of partnership thing, based upon data that we take from the portal, which are on the portal but not immediately visible, but still relevant and important to the customer. And, a second possibility we see there is, could we maybe organise this kind of reporting with service and the salesperson for that specific region. Then, they have a meaningful conversation or set up a meaningful conversation on a regular basis with the customer, helping them in their region too, either optimise the usage of the machines. Or, make sure that they can do some proactive initiatives and actions on service, that they can avoid machine breakdowns, and that they can do very efficient planning for the service operations or the maintenance operations."*

(VP Global Services)

In these two instances, Lambda first perceived the opportunity to gather information about product usage from the remote monitoring feature. It monitored the product in use and collected data on its performance and location. This helped them create a collection of data and create records of the product status. Lambda also saw the opportunity to provide useful information with the customer. It shared the usage and performance data with the customer through a portal which resulted in the customer informed about the product status.

It also collects data on various fault codes that it has developed and assigned to specific faults based on their historical knowledge of fixing the products. This data helps Lambda to differentiate and accurately identify a broad range of faults.

> *"Apart from that, there are also some data that we capture in the machine. Just to give you an example, we have the possibility to collect close to 100 different fault codes that the machine generates, and that could be any kind of technical fault or indication that the machine tells us."*

(IoT Program Director)

Lambda analyses multiple forms of data to develop a predictive maintenance model and plan maintenance activities efficiently. It combines the usage data, the life cycle data and the service record to make accurate decisions about problem-solving.

> *"But, the point there is that if we can use the usage data that are being captured […], if we would combine that with our service knowledge being, for example, the best practices that we explain in a user manual or in a maintenance manual, saying that after I don't know, 200 or 300 hours these specific elements of the machine need to be replaced or revised.*
>
> *If we would combine the usage data, the age of the machine, with this kind of service milestones, we would be able to go into a predictive model saying, like, okay, given these elements, given this information, we know that in one month's time that specific machine will need a service technician to go on-site and do this, and this, and this operation."*

(VP Global Services)

It also analyses the fault codes and identifies patterns in the occurrence of these fault codes, which can be related to other data to predict breakdowns and thus avoid them. These patterns can be interpreted by the service engineers to help make informed decisions about faults and accidents before it happens.

> *"So, what we came up to with the conclusion is, if we would be able to single out of these 100 codes the five really critical ones that, of course, could give us already some possibilities to be more proactive. And, the second element is, if we would be able to put some effort in trying to analyse for a certain time period the sequence of a number of fault codes if they would be appearing after each other within a given timeframe. So, for a very experienced service expert or technical expert from our side, knowing that, okay, this could be an indication that this or this critical fault or accident is going to happen."*

(IoT Program Director)

In these instances, Lambda perceived the opportunity to identify faults. It analysed collected data with other sources to develop fault codes. This resulted in accurate identification of faults and causes. Lambda then saw the opportunity to predict maintenance requirements. It analysed multiple sources of data and identified maintenance and repair requirements, which resulted in the development of predictive maintenance models. Further, Lambda saw the opportunity to improve predictive maintenance models. It analysed the occurrence of fault codes to identify patterns which resulted in more accurate predictions.

Lambda also monitors the battery charging techniques used by the customer and advises the customer to optimize the battery use and reduce replacement costs. It found that a recurring cost for the customer is the cost of replacing batteries because it has not been charged correctly, therefore reducing their life. By monitoring the charging techniques of the operators, Lambda raises alerts and educates the operator about the best practices in charging the batteries to maximise utility.

> *"An example, a traditional battery should not be charged like you charge a mobile phone, meaning opportunity charging whenever you find a socket, and whenever you feel that the power is not high enough that you just do it a short load. With a traditional battery, you have a limited number of charging cycles, so that's the lifetime of your battery […]. So, in that respect, battery charging and tracking that is, of course, an important element. Because, some of the most intense and frequent discussions we have within contracts, or within the warranty of our machine is, well, the battery is gone and who is*

to blame, you as a manufacturer, or you as a customer. And then, this data provides you, first of all, some proof around the charging attitude, let's say. But also, it allows you to be proactive and see that, after two weeks, if the machine is really charged in a very bad way by certain operators, that you can take action and say, okay, these people need to be educated that they should change their ways."

(IoT Program Director)

It provides a geofencing feature in their offerings where the location of the product is monitored, and managers can manage the machines across multiple sites and reduce theft. Managers can mark their sites as geofences, and if the machine leaves the geofence for any reason, the manager will be alerted immediately.

"Once again, if you've invested in a machine of €20,000 and that disappears somewhere, and that your phone around and nobody knows where it is, well, it's convenient that you have a signal coming from the machine saying, well, I am in that zone where I should be. Meaning, geofencing is, of course, the principle of you determine a zone and it could be a quite wide zone from something like two to three kilometres around, and if the machine is in that zone, well, then we're safe because the machine is where it should be.

(VP Global Services)

Another element that is important there is, of course, if you as a manager see that a machine is not fit for that site, you make a decision to ask someone to transport it to another site. Well then, it's very convenient for you to see, after a week, did the machine arrive then at the new site, and does it give its new location."

(IoT Program Director)

In these instances, Lambda saw the opportunity to reduce maintenance costs for the customer. It monitored the battery charging behaviour of the operators and advised the customer resulting in reduced costs of the replacement and battery repair. Lambda also perceived the opportunity to provide security of the product. It monitors the location and movement of the product and develops geofences that have authorised access according to customer requirements. This resulted in the assurance of safety and control for the customer.

Lambda also provides advice to the customer about which products have been heavily used and which have been underutilised in order to provide increased return on investment. This helps them ensure that the correct type of product is chosen for a specific job so the utility of the product is also maximised.

> *"So, we promote it not as a service offering, we promote it as a solution, a solution for a customer with multiple machines and multiple sites to really keep track of the usage of the machine and to optimise that. For example, we have a KPI which says which machines are being used very frequently and very heavily, as opposed to in the same graph to see that there are some machines which are really used very, very poorly, or very few, or not frequent at all. And, that is the way we also bring value to the customer saying, like, you can see in your fleet if there's over or under utilisation of machines and take action to redeploy. Or, even to decide that a certain machine is maybe not fit for that site, and when we should discuss what might be a better fit."*

(VP Global Services)

It monitors the functioning of the product based on parameters beyond essential powering on-off functions to provide a detailed utility report. This involves recording actual operational parameters such as specific timeslots of the day and specific functions chosen on the machine by the operator during those timeslots. This helps managers monitor machine usage accurately.

> *"No, it's even more sophisticated than that. So, yes, the time measured between a machine being switched on and off is measured, but also the time when the brushes of the machine were active. When the real cleaning has been going on, also that is measured. And, with the latest software version that we launched, you even are capable not only by seeing day by day, okay, there was so much run time and so much scrubbing time, you can even see the detailed usage on all these elements, like, did the machine run, did the machine scrub, even within the timeslot of the day. We really get a visual graph saying, this machine has been cleaning in short sequences, five short sequences between 7 and 8 o'clock, for example. And then, it was charged between 9 and 11 o'clock, that kind of details are available."*

(IoT Program Director)

In these last instances, Lambda perceived the opportunity to help the customer in improving product utility. It analysed usage patterns across the customer's and provided advice on better product choices. This resulted in improved customer satisfaction through performance advisory services. Finally, Lambda saw the opportunity to present the usage and performance data to the customer and demonstrate optimization opportunities. It shares the information and schedules advisory meetings with the customer. This resulted in customised performance advisory services.

6.2.10 Case Sigma

Sigma's goal to servitize is identified as 'Expanding the target market using technical expertise'. It wants to use its expertise in running communication systems and provide services to expand into different industries. It has gathered substantial expertise by providing products and services to the emergency services, which can be transferred to other industries that require monitoring and communication of mission-critical information.

> *"What we wanted to do, was take some of our knowhow of mission-critical comms and build that into a solution for our customer and then run the service to other industries. That was our original strategy, we can do all the hard work about radios and SIMs and connectivity, encryption, and everything else that we have to do for reliable service and let's see if we can apply that to another industry as a partner so that we can help them."*

(Director of Operations)

As part of their communication products, Sigma has integrated monitoring sensors, communication devices to transmit the data from the sensors and a central data analysis tool. It collects the usage and communication data of the products, monitors the power supply and location of the product. This IoT artefact is an integral part of the product, without which the product cannot perform at all.

Sigma perceived four unique affordances from the interaction between their motivation to servitize, 'Expanding the target market using technical expertise', and different features of the IoT artefact. Table 21 presents the visualisation of the individual case analysis, which is described next.

Table 21 Case analysis: Sigma

No.	Goal: Expanding the target market using technical expertise			
	Perception		**Actualisation**	
	IoT features	**Affordances**	**Actions**	**Outcomes**
1	Remote monitoring	Understanding the condition and location of the product	Monitoring the location and connectivity of the product	Collection of communication data and location logs Assurance of the connectivity of product
2	Remote monitoring	Providing security assurances to the customer	Monitoring the customer's asset and providing controlled access for customs officers	Security assurances for the customer regarding the location and access to their asset
3	Remote monitoring	Providing controlled access to the customer	Monitoring access to the customer's asset and provide secure access to employees	Controlled access to the asset for the customer's employees
4	Data sharing	Informing the customer about the location and accessing personnel	Share the location and access data for the customer's asset with the customer through a central portal	Customer provided with records of the employees accessing the asset and the location of the asset.

Sigma collects location data of the customer's asset to which the communication devices are attached to and also add control to the asset access remotely to ensure asset security. This information is critical for the customer's business as it allows them to ensure that their business process dependent on the asset is performing efficiently.

> *"So there you have a complex and expensive set of maintenance tools which are built into a big thing they call a tool chest. […] They have 2 problems, one is the guys who are using these tools lose the tools, second is, when they ship these tool chests to somewhere like Africa, South Asia, or Indonesia, or Australia, sometimes it doesn't arrive at the other end. The expensive tools are locked into the tool chest and the customs guys can't pass the tool chest through customs because they don't know what's in it. SO (a customer) approached us and asked if we could provide them with secure telemetry, mobile data kind of connectivity, to the tool chest, so they can always tell where the tool chest is though GPS tracking and they*

> *can control the access to the tool chest from within the chest. SO the customs guy wants to see what's inside the chest, so they can give him one-time access to open the tool chest. And when the tool chest is outside they can see who has accessed the tool chest, so if the tooling is lost then they know who is responsible."*

(Director of Operations)

It also extended the secure access feature to the customer's employees so that the customer is informed about the employees accessing the asset and identifying if any parts are lost or damaged. The customer is provided access to this data through a portal. Loss of the tools in the chest contributes to substantial costs in replacement and unavailability of any maintenance and repair activities. Therefore, the customer must be able to monitor the use and access to the tool chest.

> *"We make a box. Similar to that box there, has GPS in it, lock controls to unlock doors and effectively a GSM phone all built into a box the size of a cigarette packet and the GPS aerial is built into the top of the tool chest because the chest is also a tool bench. So what happens is that guys look at the systems through the internet."*

(Director of Operations)

In these two instances, Sigma perceived the opportunity to understand the condition and the location of the product. It monitored the location and quality of connectivity of the product. This resulted in a collection of communication data and location logs with the assurance of continuous connectivity to the product. Next, Sigma saw the opportunity to provide security assurances to the customer. It monitored the customer's asset and provided controlled access to other individuals. This allowed the customer to be informed of the location and access to the asset.

Sigma also monitors the condition of the communication device to make sure that it is communicating continuously. It maintains the availability of a spare communication terminal that is always running. It also monitors when the system has failed to perform and read the error signals from the product.

> *"Right, we run a diagnostics tool that we look at in this building which has some pie charts that gives you average message latencies and including a number of failures. And we have the technical skill that we can judge, and tell when the system is operating correctly or there is a problem. It also has some traffic light indicators where you*

> *can tell if mobile network no.1 is up, no.2 is up, connection to command and control centre is up and it's all replicated so it's done twice and you can tell, one of the issues we have is we have a full replicated solution that can get down to the vehicle through any one of two channels and one channel breaks. As long as you can get through the 2nd channel, the service you see is the same. You don't know that there is something wrong because it is designed to be fault-tolerant. Until the 2nd channel also fails and then you got a problem."*

(Director of Operations)

Sigma also provides the customer with access to a portal where all the collected information and logs of an employee accessing equipment and assets are recorded. It can provide an in-depth status update on the product to the customer through this portal.

> *"So we have provided a web server, a portal is probably a good word. They access the location of their tools and the record about who has opened the tool chest through our web service which we host here in this office. What we did is, all of the technicians already have an ID card and in that card is an RFID which allows them to get into the building and sorts. So we built a card reader into our box so when the technician wants to gain access to the tool chest, they take their card to the tool chest and if their ID is allowed, we unlock the doors and they are allowed to open the tool chest."*

(Director of Operations)

In these two instances, Sigma saw the opportunity to extend the controlled access to other applications for the customer. It provided encrypted access to customer's employees and monitored access entries. This allowed the customer to make sure only authorised employees accessed the asset. Finally, Sigma saw the opportunity to inform the customer about the asset status in general. It shared a comprehensive set of data with the customer resulting in the customer being aware of the exact details and operations of the asset at all times.

6.2.11 Case Omega

Omega's goal to servitize is identified as 'To deliver reliability and uptime to the customer'. Omega decided to servitize as it recognized the need for providing reliability and uptime to the customer. Their customer's businesses have processes that cannot sustain breakdowns; therefore, continuous uptime of Omega's products is process critical.

> *"It was, really, because we're very much aware of the need for reliability and the need for uptime, and it's so process-critical, so we felt that we could better offer that if we had the remote monitoring in place."*

(Managing Director)

Omega recently embedded an IoT artefact into a specific range of their products. This included remote monitoring sensors and communication devices to transmit the data. It collects usage data, power intensity data, and other conditional parameters such as temperature. This data can be viewed as live centrally by the manufacturer and shared with the customer.

Omega perceived four unique affordances from the interaction between their motivation to servitize, 'To deliver reliability and uptime to the customer', and different features of the IoT artefact. Table 22 presents the visualisation of the individual case analysis, which is described next.

Table 22 Case analysis: Omega

No.	Goal: To deliver reliability and uptime to the customer			
	Perception		Actualisation	
	IoT features	**Affordances**	**Actions**	**Outcomes**
1	Remote monitoring	Understanding the operating conditions of the product	Monitor the temperature of the product in usage and take measures to reduce it	Collection of product usage data Controlled temperature and feedback for product design.
2	Remote monitoring and data analytics	Predicting the wear and tear of the product	Monitor the power intensity passing through the product along with usage patterns	Components of the product can be fixed or replaced before they breakdown.
3	Remote monitoring and data analytics	Guaranteeing uptime of the product	Monitor environmental parameters of the product to ensure reduced breakdown from factors outside the product	Guaranteed uptime of the product through reduced breakdown from overheating
4	Remote monitoring and data analytics	Guaranteeing the performance of the product	Monitor the performance of the product in the context of curing applications	Assured delivery of the curing performance

Omega monitors the temperature of its product and control cabinets to ensure that it does not overheat. It customises the product surrounding to help with this problem. After noticing a high frequency of overheating, Omega also changed the product design to reduce fault occurrence.

> *"Yes, the whole curing equipment itself, we've retrofitted on their production line. And, we've got remote monitoring, so we'll be using digitalisation, I guess, all embedded in it, so we can, for example, see what temperature the UV lights are running at, what's the temperature inside the electrical control cabinet. It was interesting because, as part of the installation, we changed the design as we went along because we could monitor it, we could see it was getting too hot in certain parts, at certain times of the day and certain … But, we put compressed air into the bottom of the cabinet, just to cool it down."*

(Managing Director)

Omega also monitors the power passing through its product to understand its usage and predicts the wear and tear of the product. It can monitor the temperature of their product as well and make informed decisions about the type of product suitable for specific applications.

> *"Definitely, yes. So, we can monitor current, for example, the current that the lamp is drawing tells us how well the lamp is running. We can monitor how many hours the lamp has done, so we know when to change the bulbs. We'll be able to look at the temperatures, and when we compare different systems we can look at, oh, this one runs at this temperature, this one runs at this, okay, this cures better, or this one the lamps last longer, and things like that."*

(Managing Director)

First, in these two instances, Omega saw the opportunity to understand the operating conditions of the product. It monitors the temperature of the product in usage and take measures to reduce it, which resulted in a collection of product usage data and controlled temperature and feedback to improve product design. Next, Omega saw the opportunity to predict the wear and tear of the product. It monitored the power being supplied to the product along with usage patterns. This allowed identifying components that need repair before the product breaks down.

It also monitors other parameters such as air pressure, equipment housing temperature, and cooling fans to make accurate decisions about the safety and uptime of the equipment. If the sensors measure parameters beyond set thresholds, an alarm is raised for Omega to take immediate action.

> *"So, we've got temperature sensors measuring the temperature of the air, the temperature of the lamp housing themselves, the air pressure switches to make sure the fans are running, if the fans aren't running they need to turn them off quickly otherwise it will melt the system down. These lamps run at 900 plus degrees centigrade, and 24 kilowatts per lamp, so they're big 1.2 metre long lamps. Shutter systems, so we've got sensors which show if the shutters are open or closed, depending on what part of the cycle they're at you've got to get that the right way around. Because, when the shutters open the lamps go from half power to full power, when the shutters close they go form full power to half power, and you've got to get that right and make sure the shutters are in the right place. If anything*

went wrong then there would be a sensor which sends an error signal."

(Managing Director)

Omega monitors the product curing intensity to ensure that the right level of curing is delivered to the customer's product. This helps Omega to demonstrate the value of the product for the customer's business process.

"We can go further, by we can continuously monitor the UV lights radiance, so the strength of the UV light, and then we could make sure it's within the tolerances of the process parameters."

(Managing Director)

In the final two instances, Omega perceived the opportunity to guarantee uptime. It monitors the environmental parameters of the product to ensure reduced breakdown from factors external to the product. This allowed them to ensure that the product does not breakdown. Then, Omega saw the opportunity to guarantee product performance. It did this by monitoring the performance of the product in the context of curing applications and ensuring the right intensity of curing is delivered.

6.3 Summary

The individual case analysis resulted in a tabulated representation of the 11 cases where the IoT usage instances for each case was further reduced to a set of 52 affordances and their actualisation. This was necessary to identify the different affordances perceived by manufacturers and the actions taken to actualise them on a case-by-case basis. This chapter has first described how the cases were analysed using a deductive thematic analysis technique. It presented the codebook created for the data analysis in this research. Based on this codebook, the cases analysed were later presented. All 11 cases were analysed, and this analysis was presented with a focus on the IoT usage instances observed through the data. These instances were analysed using the theoretical framework of the affordance theory and thus visualised in the form of tables that summarise the findings of each within-case analysis. This creates for the foundation for the cross-case analysis where the analysis of the case will be compared, and the research questions will be answered. Next, the tables representing the individual case analysis are compared to identify patterns that can answer the overarching research questions.

Chapter 7 Cross-case analysis

The chapter starts with a brief description of the importance of cross-case analysis and the objective of using such an analysis in this research (section 7.1). This chapter compares the within-case analysis presented in the previous chapter (section 6.2). More specifically, the tabulated findings in every case were compared based on the key constructs of the affordance framework. The comparison was focused on answering the three research sub-questions and the primary research question (section 2.4).

To answer the first question, the different affordances identified in the within-case analysis were categorised. This allowed the identification of four distinct affordances that directly correspond to the first research question (section 7.2). Similarly, to answer the second research question, the actions taken by the manufacturer to actualise the four types of affordances were categorised. This allowed the identification of three individual actions that are commonly taken by the manufacturers to actualise affordances, thus answering the second question (section 7.3).

To answer the third question, perception and actualisation of each of the four types of affordances were mapped against the individual cases to identify any emerging patterns between the types of affordances. As a result, a sequential relationship was identified between the affordances on the individual level of cases. This relationship is visualised as a progressively sequential process between the four types of affordances (section 7.4). Having answered all sub-questions, the chapter also presents an overarching answer to the primary research question, justifying the use of affordance theory to investigate IoT enabled servitization (section 7.5).

7.1 Principle of cross-case analysis

After conducting the within-case analysis, the next step is to compare the cases to each other and identify patterns that explain the research phenomenon (Meredith, 1998). The most common way of conducting cross-case analysis is visualising the data, which is done in the form of tables and figures in this study. A simple but effective analytical approach is to pick a group, category, or construct that is key to the research question and find common characteristics of that construct across the cases (Voss et al., 2002). The search for the patterns can also be influenced by the research questions set for the study, or it can be influenced by the theory as well.

This step is essential in the cross-case analysis as the patterns may not appear on an individual level as there is no benchmark relationship to compare against (Yin, 2012). However, once the researcher draws themselves out from an individual case and takes a holistic perspective, new patterns and causal mechanisms may emerge more freely (Miles and Huberman, 1994). If making generalized conclusions is an objective of a study, cross-case analysis ensures the internal validity of the findings (Eisenhardt, 1989). If theory development is an objective of the study, cross-case analysis can be used to identify new concepts, relationships, causal mechanisms that can change, contradict, or assertively develop the theory further.

For this study, the focus of the cross-case analysis was on addressing the research sub-questions.

- Which affordances to use IoT is perceived by servitizing manufacturers?
- How are the affordances to use IoT actualised by servitizing manufacturers?
- How does the perception and actualisation of affordances to use IoT enable servitization?

Based on these sub-questions, the key constructs to be compared across cases were found to be *affordances* perceived and *actions* taken by the manufacturer to actualise the affordances. Table 23 presents a summary of these two constructs across all the cases. The next sections explain the categorisation of affordances and actions in this table.

Table 23 Summary of key constructs

Cases	Affordances	Actions
Alpha	- Understanding the health of the product - Reducing repairs and visits - Avoiding breakdown - Providing visibility	- Monitor the product usage and identify faults - Analyse collected data and identify the source of the problem in product or environment - Comparatively analyse usage data of multiple products to develop predictive trends - Share access to product's usage data through an app
Beta	- Avoiding catastrophic failure - Providing predictive maintenance - Protecting the tooling and the press - Estimating productivity of the press - Ensuring quality in press output - Capturing service market from 3rd party	- Collect and analyse tool placement and machine usage data - Analyse live usage data with reference to a historic baseline and spot anomalies - Monitor the load pressure readings and flag anomalies - Analyse usage data and develop OEE reports - Monitor the placement and fitting of tools and components - Analyse motor vibrations for insights into machine health
Gamma	- Recording the product usage data - Developing a predictive model to identify breakdowns - Improving the accuracy of the predictive model - Accounting for environmental factors affecting product condition	- Embed a monitoring and control system - Analyse collected data to predict significant events in the operation - Collate and analyse data from other sources such as maintenance records - Add new sensors to measure environmental factors
Delta	- Understanding and recording product usage data - Simplifying data analysis and presentation - Developing central information access - Identifying the cause of the error - Understanding product condition - Prioritised resource allocation - Detecting errors occurring in live operations - Providing guaranteed uptime - Supporting the customers remotely - Demonstrating delivered uptime	- Monitor and collect usage data of the machine and present it through reports - Capture and analyse data in periodic snapshots and present data in a simplified form - Add all the information collected and reports created from usage data to a central portal and share access - Develop algorithms to diagnose the cause and the machine component at fault - Analyse the collected data to estimate the condition of the product and diagnose faults remotely - Develop a rule engine to categorise the identified errors - Identify problems and errors in operation and flag them - Analyse the usage data to diagnose, detect, and solve faults - Share live monitoring data to assist the on-site service teams - Monitor the input and outputs, and changes to the settings of the machine. Develop reports
Epsilon	- Identifying the exact component at fault for poor output - Identifying external factors that affect productivity - Estimating the health of consumables accurately - Comparing the performance of multiple machines - Providing information transparency to customers	- Collect and analyse usage data to identify trends that indicate the exact component at fault - Monitor humidity and temperature of the feed - Estimate condition of belt drives to avoid breakdown - Collate usage data from multiple machines and plot performance trends - Develop and share access to a live information portal

	- Generating a predictive performance model - Keeping track of changed settings and set of consumables	- Analyse historical data to predict the parameters that can affect the performance - Identify the set of consumables associated with different types of inputs
Zeta	- Understanding product condition and usage - Predict product condition and breakdown - Providing better access to and understanding of performance data - Customizing operations according to the customer's industry - Detecting and notifying accidental changes to operational settings - Providing transparent access to analysed data and information	- Monitor product usage and performance metrics - Analyse the performance and usage data to predict the condition - Develop a rule engine to interpret the data and send alert notifications to customers - Develop new rule engines and flag alerts and errors according to industry standards - Monitor and detect any abnormal settings in filter operation and send alerts - Develop and present a central access portal to customers with live and historic information and alerts
Theta	- Understanding the customer's usage of products - Evaluating the condition of the product - Integrating with the customer's IoT strategy - Informing the customer about the details of the package journey	- Monitor the stock usage and suggest restocking - Monitor the impact taken by the product and the journey travelled - Connect to customer's IoT system and monitor the data shared - Present the data back to the customer through a report of the journey and the points of handling
Kappa	- Understanding the usage and current status of the product - Identifying the maintenance spots and faults - Ensuring system availability - Identify the urgency in solving anomalies - Predicting part breakdown - Informing stakeholders about system status	- Monitor the usage and performance of the system - Monitor and analyse usage data to identify the exact need for maintenance - Monitor the power supply and power levels of the ventilation systems - Analyse usage and performance data along with historical records to develop priorities - Analyse performance and usage data and to predict maintenance requirements - Share the gathered system information in an understandable format
Lambda	- Gathering information about the product usage - Providing complete transparency to the customer - Identifying the faults correctly - Predicting maintenance requirements - Improving the predictive maintenance models - Reducing maintenance costs for the customer - Providing security to the products - Helping customer to improve product utility - Presenting the product usage data to demonstrate optimization opportunities	- Monitor product usage, performance, and location data - Share the usage and performance data with the customer through a portal - Analyse data collected with other sources and develop fault codes - Analyse multiple forms of data to accurately predict breakdowns, wear, and repair opportunities. - Analyse fault codes to identify patterns of occurring faults - Monitor the battery charging patterns of the customer and advise improvements - Monitor the location of the product and develop authorised geo-fences for the customer - Analyse usage patterns across the customer's fleet and advise on better product choices - Share the usage and performance data and schedule advisory meetings
Sigma	- Understanding the condition and location of the product - Providing security assurances to the customer	- Monitoring the location and connectivity of the product - Monitoring the customer's asset and providing controlled access for customs officers

	- Providing controlled access to the customer - Informing the customer about the location and accessing personnel	- Monitoring access to the customer's asset and provide secure access to employees - Share the location and access data for the customer's asset with the customer through a central portal
Omega	- Understanding the operating conditions of the product - Predicting the wear and tear of the product - Guaranteeing uptime of the product - Guaranteeing the performance of the product	- Monitor the temperature of the product in usage and take measures to reduce it - Monitor the power intensity passing through the product along with usage patterns - Monitor environmental parameters of the product to ensure reduced breakdown from factors outside the product - Monitor the performance of the product in the context of curing applications

7.2 Perceived affordances that enable servitization

This section describes the process of categorising the affordances identified in the within-case analysis and thus answering the first research sub-question. Four types of affordances: *Informative* (section 7.2.2), *Enhancive* (section 7.2.3), *Supportive* (section 7.2.4), and *Demonstrative* (section 7.2.5) are identified as a result of the categorisation process.

7.2.1 Categorising the affordances

The researcher examined the list of 52 affordances for common characteristics to associate with specific patterns. By definition, affordances are opportunities for action to create a desirable outcome (Table 5). Therefore, to broadly categorise the affordances, they were examined to identify what they allow the manufacturer to do by using the IoT features. This involved an inductive approach to analysis where the objective was to develop new categories without any theoretical influence (Braun and Clarke, 2006), as compared to the individual case analysis. The affordances were iteratively categorised, and finally, four categories were derived that suitably capture the diversity of actions they allow the manufacturer to take.

The first level of categories found that the affordances were opportunities for the manufacturer to *gather product peripheral data, estimate product status, understand product usage, reduce/avoid repairs, improve maintenance performance, prioritise/optimise resource allocation, detect problems, predict maintenance, improve product usage, protect the product, ensure product performance, support customer's business, provide customer notifications, share data access,* and *share insights.*

These affordances were further collated to form the second-level categories. These categories indicated that these affordances meant that the manufacturers could *gather and understand product-related information, maintain products better, ensure uptime, support product usage, provide performance advisory, demonstrate information,* and *demonstrate the value created.*

These second-level categories also had overlaps if observed from a broader level which enabled combining them into a final level of the category that identified four distinct types of affordances. The final categories were found as *Informative, Enhancive, Supportive,* and *Demonstrative.* These are explained in the following sections. This process of categorisation is illustrated in Table 24.

Table 24 Types of Affordances

Affordances	**First-level category**	**Second-level category**	**Final category**
-Understanding the operating conditions of the product -Measuring environmental factors	Gather product peripheral data	Gather and understand product-related information	Informative
-Estimating product condition -Understanding the condition and location of the product -Evaluating the condition of the product	Estimate product status		
-Understanding the customer's usage of products -Understanding the usage and current status of the product -Gathering information about the product usage -Recording usage data -Simplifying the usage of data analysis	Understand product usage		
-Reducing repairs -Avoiding breakdowns -Avoiding failure -Ensuring system availability -Guaranteeing uptime of the product	Reduce/Avoid repairs	Maintain products better	Enhancive
-Reducing maintenance visits -Improving the predictive maintenance models -Identifying the maintenance spots and faults	Improve maintenance performance		
-Prioritising resources -Identify the urgency in solving anomalies	Prioritise/Optimise resource allocation		
-Detect anomalies and problems in the system performance and usage -Identifying the faults correctly	Detect problems	Ensure uptime	

-Identifying the cause of the error			
-Predicting maintenance requirements -Predicting the wear and tear of the product -Predicting part breakdown -Providing predictive maintenance	Predict maintenance		
-Detecting errors in usage -Monitoring changes in usage	Improve product usage	Support product usage	Supportive
-Providing controlled access to the customer -Providing security assurances to the customer -Providing security to the products -Protecting customer's product	Protect the product		
-Guaranteeing the performance of the product -Helping customer to improve product utility -Predicting performance -Guaranteeing uptime -Ensuring productivity -Ensuring output quality	Ensure product performance	Provide performance advisory	
-Providing remote support -Integrating with the customer's IoT strategy -Reducing maintenance costs for the customer -Comparing customer's performance -Customizing operational parameters	Support customer's business		
-Informing the customer about the location and accessing personnel -Informing the customer about the details of the package journey -Informing stakeholders about system status	Provide customer notifications	Demonstrate information	Demonstrative
-Providing better visibility -Providing complete transparency to the customer -Creating a central access portal	Share data access		
-Presenting the product usage data to demonstrate optimization opportunities -Demonstrating delivered uptime	Share insights	Demonstrate value created	

7.2.2 Informative affordances

The first group of affordances represented by the final-level category of informative affordances allowed the manufacturer to establish remote connections to the product, collect product usage data and data indirectly related to the product, and develop analytical tools to process this data. Examples include affordances such as ‘recording usage data’, ‘measuring environmental factors’, ‘estimating product condition’ or ‘understanding the usage and current status of the product’.

By actualising these affordances, the manufacturers were able to collect product-related information, develop fault reports, alerts, develop predictive algorithms, and additional analytical tools. Effectively, the actualisation of these affordances allowed the manufacturer to develop a portfolio of information. Therefore, these affordances were termed as informative affordances. This provided the manufacturers with further opportunities to achieve higher-order outcomes.

7.2.3 Enhancive affordances

The next group of affordances represented by the final-level category of enhancive affordances was focused on enhancing the uptime and maintenance of the product. These include affordances such as ‘reducing repairs’, ‘reducing maintenance visits’ and ‘avoiding breakdowns’. By actualising these affordances, the manufacturers created outcomes such as ‘guaranteed availability of the system’, ‘accurate predictive maintenance models.’, ‘prediction of faults’. Through these outcomes, the manufacturers were able to improve their maintenance services, allowing the manufacturer to guarantee product uptime and availability, which represent the enhanced performance of the product. Therefore, they were names as enhancive affordances.

Additionally, there is a link between the informative affordances and the enhancive affordances. The collected information, as the outcome of the informative affordances, lays a foundation for the manufacturer to develop insights that facilitate enhanced product performance, which is the outcome of enhancive affordances. The manufacturers analysed the collected information to predict maintenance requirements, plan maintenance and repairs, detect faults, and reduce the overall requirement of these maintenance services so that the product uptime and availability can be improved.

7.2.4 Supportive affordances

The third group of affordances represented by the final-level category of supportive affordances focused on providing new services that support the customer's business performance. These include affordances such as 'Ensuring productivity', 'Providing remote support', 'Predicting performance', and 'Helping customer to improve product utility'. The actualization of these affordances leads to outcomes such as 'Improved customer satisfaction due to effective support to service teams', 'Reduction in battery replacement and repair costs for the customer'. New services such as performance advisory that educate the customer about improving the usage of the product result in improved performance of the customer's business. Therefore, this group of affordances is called supportive affordances.

The manufacturers were only able to provide these new supportive services after ensuring that the performance of their product can be guaranteed. After guaranteeing the uptime and availability of their product, the manufacturers were able to develop insights, using the collected information that support the customer's business performance. Overall, by supporting the customer's business, manufacturers were able to deepen the role of their product in the customer's business, reduce misuse of the product and accidents, lock-in new customers, and reduce customer proximity.

7.2.5 Demonstrative affordances

The fourth group of affordances represented by the final-level category demonstrative affordances allowed sharing of the collected information, demonstration of maintenance provided, performance delivered, and fulfilment of performance guarantees. These affordances are called demonstrative affordances. This included affordances such as 'Providing better visibility', 'Creating a central access portal', and 'Demonstrating delivered uptime'. By actualising these affordances, the manufacturers created outcomes such as 'Customer informed regarding the availability and efficiency of the machine' 'Customer provided with records of the employees accessing the asset and the location of the asset.' 'Reporting press productivity for the customer'. Effectively, the manufacturers were able to demonstrate the value being created for the customer through services provided. More specifically, communication and customer education about product status was important.

For instance, Theta also found it essential to demonstrate the loss of value that is experienced by the customer when not acquiring the manufacturer’s offerings. Theta provided detailed reports of the journey of the product and the physical impact sustained by the product in transit. They justify the value in their services by demonstrating the possible loss of value to the customer’s business if they do not take advantage of the manufacturer’s service offerings.

“The customer’s product can reach the destination in pieces and they would lose a product worth thousands of pounds without knowing it is broken till it reaches the destination. They don’t understand the value of this until I tell them that you will lose the business with your customers and have to ship your product again. They wait till this actually happens and then come to us and ask how did this happen?”

(Business Development Manager, Theta)

7.2.6 Answering research sub-question 1.1

Having categorised all the affordances perceived by manufacturers in the 11 cases to use IoT and enable servitization, the first research sub-question can be answered:

- Which affordances to use IoT is perceived by servitizing manufacturers?

Servitizing manufacturers in this study perceived 52 affordances. However, to understand the meaning of these affordances, they were categorised into four types of affordances that represent the different opportunities to use IoT for enabling servitization. Informative affordances provide the manufacturers with opportunities to use IoT and develop a portfolio of information regarding the product operating in the customer’s business. Enhancive affordances provide the manufacturers with opportunities to use IoT and enhance the performance of their product through improved maintenance and repair activities. Supportive affordances provide the manufacturer with opportunities to support the customer by offering advisory services to improve the customer’s business performance. Demonstrative affordances provide the manufacturer with opportunities to demonstrate the value created for the manufacturer and the customer by the other three affordances through sharing of insightful information.

The next step of analysis is investigating the actualisation of these affordances and thus answering the second sub-question.

7.3 Actualisation of perceived affordances

To actualize the perceived affordances, manufacturers took comparable actions, thus creating the outcomes that enable servitization. As compared to the categorisation of affordances, the actions were found to be simpler to categorise as they presented a lesser diversity between them. By definition, the actions are those taken by manufacturers to take advantage of affordances through its use of IoT. Therefore, they were examined to identify how the manufacturer used the IoT to actualise the affordances.

This section describes the process of categorising these actions using the identified actions from the within-case analysis. As a result of the categorisation, three individual actions were identified: *Monitoring* (section 7.3.2), *Analysing* (section 7.3.3), *Sharing* (section 7.3.4).

7.3.1 Categorising the actions

By comparing all the identified actions with a focus on understanding the reason behind the manufacturers' actions to use IoT, the first categories of actions were found. These categories are: *monitoring parameters, connecting to products, collecting data, developing analytical tools, analysing data, developing sharing platforms,* and *sharing data.* However, the first three categories (*monitoring parameters, connecting to products, collecting data*) indicated the manufacturer's actions to monitor information from the product. Therefore, they were regrouped under the term *monitoring* actions. Similarly, the next two categories (*developing analytical tools, analysing data*) indicate the manufacturer's actions to analyse information. Therefore, they were regrouped as *analytical* actions. The last two categories (developing *sharing platforms* and *sharing data*) indicates the manufacturer's actions to share information. Therefore, they were regrouped as *sharing* actions.

Overall, the manufacturers took three activities that revolved around product information; monitor information, analyse information and share information. Table 25 presents the two-step categorisation of the manufacturer's actions.

Table 25 Types of actions

Actions	Initial category	Final category
-Monitor usage data to identify faulty parts -Monitor load pressure -Monitor placement and fitting of tools -Monitor and collect data from supplementary sources -Monitor the input, output, and changes to settings -Monitor humidity & temperature -Monitor condition of belt drives -Monitor consumables -Monitor filter usage and performance metrics -Monitor the stock usage and suggest restocking -Monitor the impact taken by the product and the journey travelled -Monitor the usage and performance of the system -Monitor and analyse usage data to identify the exact need for maintenance -Monitor the power supply and power levels of the ventilation systems -Monitor product usage, performance, and location data -Monitor the battery charging patterns of the customer and advise improvements -Monitor the location of the product and develop authorised geo-fences for the customer -Monitoring the location and connectivity of the product -Monitoring the customer's asset and providing controlled access for customs officers -Monitoring access to the customer's asset and provide secure access to employees -Monitor the temperature of the product in usage and take measures to reduce it -Monitor the power intensity passing through the product along with usage patterns -Monitor environmental parameters of the product to ensure reduced breakdown from factors outside the product -Monitor the performance of the product in the context of curing applications	Monitoring parameters	Monitoring
-Collect usage data of machine -Collect and analyse the condition of a machine	Collecting data	
-Connect to customer's IoT system and monitor the data shared -Add new sensors to monitor environmental factors -Embed monitoring and control system	Connecting to products	
-Analyse usage data and identify the source of the problem -Analyse usage data -Analyse live usage data -Analyse motor vibrations -Analyse live monitoring data to detect significant events in the operation -Analyse usage data to estimate product condition -Analyse usage data to diagnose and detect faults -Analyse data in periodic screenshots -Identify errors in product operations -Collect and analyse usage data to identify trends -Analyse historical data to predict performance parameters -Analyse performance and usage data to predict the condition -Analyse usage and performance data along with historical records to develop priorities	Analysing data	Analysing

-Analyse performance and usage data and to predict maintenance requirements -Automate data analysis through rule engines to flag anomalies -Analyse data collected with other sources and develop fault codes -Analyse multiple forms of data to accurately predict breakdowns, wear, and repair opportunities. -Analyse fault codes to identify patterns of occurring faults -Analyse usage patterns across the customer's fleet and advise on better product choices -Compare usage data across multiple machines & plot trends		
-Develop a rule engine to categorise and prioritise faults -Develop algorithms to diagnose fault causes	Developing analytical tools	
-Provide the customer with access to product data -Share live monitoring data to assist on-site teams -Share the gathered system information in an understandable format -Share the usage and performance data with the customer through a portal -Share the usage and performance data and schedule advisory meetings -Share the location and access data for the customer's asset with the customer through a central portal -Present the data back to the customer through a report of the journey and the points of handling	Sharing data	Sharing
-Develop and share access to live information portal -Create a central portal for data access	Developing sharing platforms	

7.3.2 Monitoring

The first group of actions represented by the final-level category 'monitoring' represented the use of remote monitoring feature of the IoT to establish connections with their product, monitor, and collect data on parameters that indicate product usage, condition, location, performance, consumables, or the product's environment. For example, manufacturers took actions such as 'monitor condition of belt drives', and 'monitor consumables'. The monitoring actions were common in the actualising the informative affordances as monitoring various forms of product information is closely aligned with informative affordances. However, these actions are not exclusive to informative affordances as manufacturers also took these actions to actualise enhancive and supportive affordances.

7.3.3 Analysing

The second group of actions represented by the final-level category 'analysing' represented the use the data analytics feature of the IoT to develop analytical tools such as rule engines, algorithms, predictive models, and analyse the different forms of collected data. For example, manufacturers took actions such as ‘Develop algorithms to diagnose faults’, ‘Analyse usage data to estimate product condition’, ‘Analyse motor vibrations’. These actions were common in the actualisation of enhancive and supportive affordances as these affordances were based on the creation of insights from collecting information through its analysis. These actions were also not exclusive to the actualisation of any specific type of affordance.

7.3.4 Sharing

The third group of actions represented by the final-level category ‘sharing’ represented the use of the data sharing feature of the IoT to develop data-sharing platforms and share various forms of product information and insights with the customer through these platforms. For example, the actions taken by the manufacturer in this category include ‘Provide the customer with access to product data’ and ‘Develop and share access to live information portal’. These actions are taken when actualising demonstrative and supportive affordances because these affordances involve sharing information and educating the customer.

7.3.5 Connections between actions and IoT features

The three identified actions appear to be in direct relation with the IoT features. The actions categorised as ‘Monitoring’ are found to be directly related to the remote monitoring feature of the IoT artefact. The actions categorised as ‘Analysing’ are directly related to the data analytics feature of the IoT artefact. The actions categorised as ‘Sharing’ are directly related to the data sharing feature of the IoT artefact. This is also the reason why the categorisation of the actions was comparatively simpler to the categorisation of affordances because the actions are very closely related to the IoT features (which are of three types as well).

This implies that all three actions are equally crucial for the actualisation of affordances, and the manufacturer should be able to take all three of these actions. This also relates to the IoT features by indicating that the IoT artefact in use should have the three features of remote monitoring, data analytics, and data sharing as its key features. However, this finding also implies that the limited IoT features frame the range of actions that the manufacturers can take in order to actualise an affordance. Addition of new features may lead to the possibility of new actions for the manufacturer.

7.3.6 Answering research sub-question 1.2

Having categorised all the actions taken by the manufacturers in the 11 cases to actualise the affordances, the second research sub-question can be answered:

- How are the affordances to use IoT actualised by servitizing manufacturers?

The manufacturers actualised their perceived affordances by taking three types of actions. When the manufacturers' affordances were perceived based on the use of the remote monitoring feature of the IoT, the manufacturers used the monitoring action which involves establishing connections with their product, monitor, and collect data on parameters that indicate product usage, condition, location, performance, consumables, or the product's environment. When the affordances were perceived based on data analytics feature of IoT, the manufacturer took the analysing action. This includes developing analytical tools such as rule engines, algorithms, predictive models, and analyse the different forms of collected data. When the affordances were perceived based on the data sharing feature of the IoT, the manufacturers took the sharing action, which involves developing data-sharing platforms and sharing various forms of product information and insights.

The next section focuses on answering the third research sub-question by addressing the overall mechanism of affordance perception and actualisation to understand how it enables servitization.

7.4 Affordance dependency

Having answered the first and the second sub-question, the next and final step in the analysis was to investigate how the perception and actualisation of these affordances can enable servitization for a manufacturer. To investigate this, the research draws upon the principle of affordance dependency to understand how the actualisation of multiple affordances helps the actor achieve their goal (section 2.3.1).

The four types of affordances were mapped against the individual case analyses to identify any patterns within their perception and actualisation. The different affordances and their actualisation appeared to take a specific place in the manufacturer's servitization, indicating a sequential progression. This led to the identification of a new relationship between the four types of affordances, which was consistent across all 11 cases. This relationship indicated that manufacturers perceive and actualise affordances in a particular sequence that can explain how the actualisation of these affordances can enable servitization. As a result, a dependency mechanism was identified, which is explained in this section and visualised in Figure 6.

7.4.1 Connection between the affordances

As an example, to demonstrate the pattern, consider case Delta. First, the manufacturer perceived affordances 1 and 2, 'Understanding and recording product usage data' and 'Simplifying data analysis and presentation' that allow the collection of usage data and development of analysis. During the cross-case analysis, these affordances were categorised as **informative** affordances. By actualising these affordances, the manufacturer created the outcomes of 'collection of usage data', 'development of efficiency and availability reports', 'Better understanding and presentation of the information'. This means that the manufacturer was able to collect information about the use of their product.

Next, the manufacturer perceived the affordances 4, 5, 6 and 7; 'Identifying the cause of error', 'Understanding product condition', 'Prioritised resource allocation' and 'Detecting errors occurring in live operations'. During the cross-case analysis, these affordances were categorised as **enhancive** affordances. By actualising these affordances, the manufacturer created outcomes such as, 'Quick and accurate response to faults', 'Information on product condition and recurring faults that can be fed back to product design', 'Prioritised allocation of resources to solve errors based on urgency', and 'Development of a bank of error codes and quick identification of faults'. Effectively, Delta was able to improve its ability to detect and respond to faults, thus improving the product design to reduce the occurrence of common faults. Overall, these outcomes indicate enhancing the uptime and availability of the product.

Followed by these affordances, Delta perceived affordances 8 and 9; 'Supporting customers remotely', 'Providing guaranteed uptime' and 'Detecting errors occurring in live operations'. These affordances were categorised as **supportive** affordances as a result of the cross-case analysis. By actualising these affordances, the manufacturer created outcomes such as 'Improved customer satisfaction due to effective support to service teams' and 'Improved customer satisfaction through delivery of proactive remote assistance'. These outcomes allowed Delta to support the customer's business performance.

Simultaneous to the perception and actualisation of these three affordances, Delta perceived and actualised affordances 3 and 9, 'Developing central information access' and 'Demonstrating delivered uptime'. These were categorised as **demonstrative** affordances. By actualising these affordances, the manufacturer created outcomes such as 'Customer informed regarding the availability and efficiency of the machine' and 'Provision of reports demonstrating the delivery of uptime and factors that stop the fulfilment of guarantees'. These outcomes allowed Delta to demonstrate the outcomes of actualising informative, enhancive, and supportive affordances. Similar dependencies can be observed in other cases as well.

To summarise, Delta perceived and actualised the affordances starting with the informative affordances followed by enhancive affordances, and finally the supportive affordances. The demonstrative affordances were being perceived and actualised simultaneously. Such an order of affordance perception followed by actualisation demonstrates a chronological dependency that stems from the informative affordance, cascading into enhancive affordances and followed by the supportive affordances. The same pattern of affordance dependency was visible in all cases.

7.4.2 Illustrative example

Consider case Zeta. Affordance 1 allowed the manufacturer to understand the usage and performance of the product (**informative**). The affordance actualization led to the collection of usage and performance data and estimates of the product condition. Affordance 2 allowed the manufacturer to predict the condition and breakdown of the product (**enhancive**) by analysing the usage and performance data. This affordance was actualised by analysing the data collected as an outcome of affordance 1.

Affordance 3 allowed the manufacturer to provide the customer with better access and understanding of the product performance (**demonstrative**). Having improved the maintenance of the product by predicting product condition and demonstrating the product performance, affordance 4 and 5 allow the manufacturer to customise the product for customer's specific operations and detect accidental changes to the product's operational settings (**supportive**). Simultaneously, affordance 6 allowed the manufacturer to provide the customer with access to analysed data and product information (**demonstrative**) by developing a central access platform.

The affordance dependency indicates a series of steps that lead to the actualisation of affordances arising from the use of IoT, followed by the emergence of new affordances. The cumulative effect of this dependency enables the manufacturer's servitization. Therefore, the affordance dependency can be visualised as a mechanism through Figure 6.

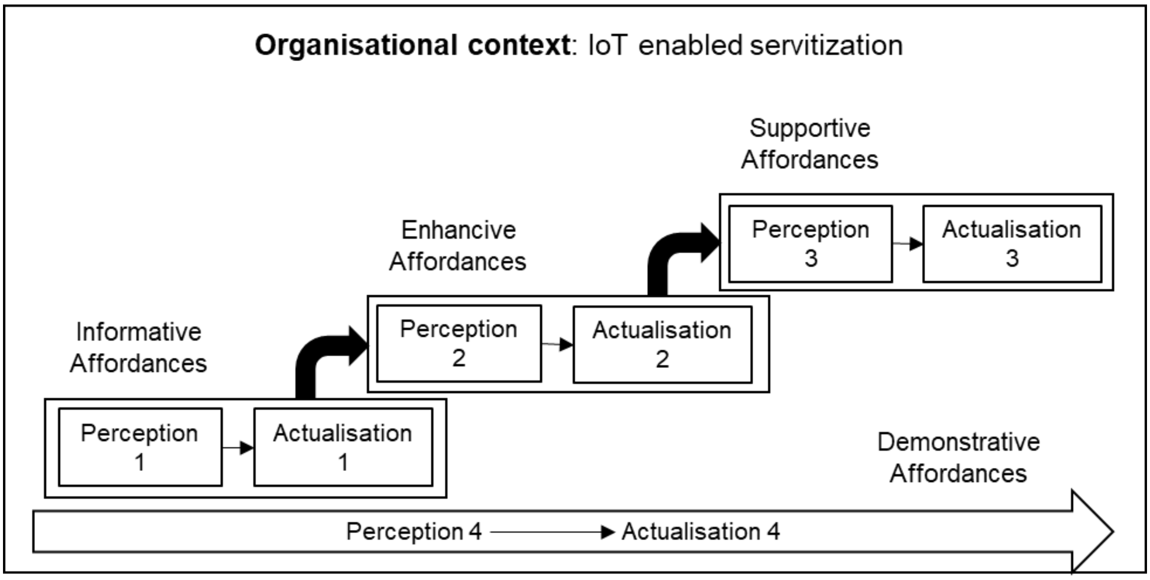

Figure 6 Affordance dependency mechanism

Figure 6 illustrates the dependency of affordances as explained previously starting from the perception (1) and actualisation (1) of informative affordances. The informative affordances are considered as the first affordances; therefore, its perception and actualisation are indicated as perception 1 and actualisation 1. This order further progresses with the affordances. The actualisation of the informative affordances allows the perception of enhancive affordances, the actualisation of which unlocks the perception of supportive affordances. This realisation occurs within the boundaries of the manufacturers' unique organisational context that is responsible for making the affordance dependency unique for each manufacturer, although every manufacturer will follow similar steps of progression. This organisational context includes elements such as the specific business of the manufacturer and the specific business of the customer.

The relationship shows that the perception of the supportive affordances is dependent on the actualization of enhancive affordances, while the perception of the enhancive affordances is dependent on the actualization of informative affordances. Demonstrative affordances play an important role in this process while being simultaneously perceived and actualised. This overall dependency can be attributed to the conditions created by the outcomes of these affordances.

The actualisation of informative affordances leads to the collection of crucial information about the products and development of analytical tools. This creates an opportunity for the manufacturer to use analytical tools and create further value. With a specific goal for servitization, the manufacturer decides how it wants to use the tools to improve their product's performance. They must improve their product performance because this helps them ensure the primary role of their product in the customer's business. Therefore, the manufacturers perceive enhancive affordances which allow them to ensure and enhance their product's uptime and availability in the manufacturer's business.

With an assurance that the product is performing at its maximum potential, the manufacturers take steps to extend their product's role in the customer's business while specifically focusing on the initially set goal. For the manufacturers who wanted to achieve a competitive advantage (for example; Beta, Kappa) it was necessary to create value for the customer that differentiates it from the competition. Similarly, for manufacturers who had a customer-focused goal (for example; Gamma, Epsilon, Zeta), it was necessary to make their product more critical for the customers' business. Therefore, they perceived the supportive affordances where they used the insights generated and the assurance of product performance to support the customer's business process.

All of these affordances created different forms of value for the customer and the manufacturer either in the form of information, enhanced performance, or business support. However, the perception of value is not always clear unless demonstrated transparently. The value from the outcomes of these affordances had to be shared transparently between manufacturers' organisations and their customers. Therefore, the manufacturers perceived demonstrative affordances as and when a demonstration of value was crucial.

7.4.3 Answering research sub-question 1.3

By identifying a dependency between the perception and actualisation of the four types of affordances, the third sub-question can be answered:

- How does the perception and actualisation of affordances to use IoT enable servitization?

The foundational role of IoT is to allow manufacturers to understand their product's status in customers' business processes. The product status relates to the condition, usage, location, and performance. The manufacturer must connect to the products and gather this information remotely. By using IoT, the manufacturer perceives opportunities to establish these connections, collect information, and generate historical accounts of the product usage. This information becomes a vital resource in unlocking opportunities to create higher-level outcomes.

Use of IoT allows manufacturers to analyse the collected information on product status to enhance product performance. The product performance relates to the availability and uptime of the product to deliver its capabilities. The manufacturers can improve this performance by improving maintenance and repair services through proactive identification of operational faults, predicting breakdowns, improved scheduling of maintenance, prioritisation of resources, and predictive maintenance. The manufacturers can analyse the information on the product status to develop tools that allow them to develop insights to improve maintenance. With the enhanced product performance, the manufacturer can mitigate risks involved in offering contractual guarantees of availability and uptime, thus unlocking opportunities to create more value for the customer beyond the sale of products.

IoT also allows the manufacturer to develop services that directly support the customer's business based on product usage because the manufacturer can now manage the risk of guaranteeing their product's performance. Using the analysis of the product information, manufacturers can develop insights about how the customers can obtain more value from the product by adopting best practices, educating operators, and offering performance advisory services. Manufacturers can reduce customer proximity through these service offerings that revolve around supporting the customer's business process using the product.

IoT also plays a consistent role in enabling transparency through communication. Manufacturers can share the information they collect about the product, demonstrate the enhanced product performance, and share insights that support the customer's business through effective communication channels. Overall, transparent communication helps the manufacturers to demonstrate the value delivered through the services they offer.

7.5 Explaining IoT enabled servitization through affordance theory

Through section 7.2.6, 7.3.6, and 7.4.3, this chapter has successfully answered the three sub-questions that were developed to address the primary research question:

- Can the affordance theory explain how IoT enables servitization?

Based on the answers of these sub-questions, the chapter has demonstrated that the affordance theory helps explain the use of IoT to enable servitization by taking two new perspectives. Specifically, this study focused on adopting a process and actor-focused perspective to investigate the use of IoT, as compared to focusing on the impact of using IoT which is commonly observed in extant literature (section 2.4.1). By using the affordance theory, this study advanced the existing knowledge on IoT enabled servitization by identifying the opportunities that manufacturers perceive to use IoT for achieving their goals and the actions they take to realise these opportunities. The study was also able to identify the relationship between these opportunities, which indicates a mechanism that explains how IoT can enable servitization. The use of affordance theory provided a structure for the data analysis by using the affordance actualisation framework as an analytical tool for this study (section 2.3.1, Table 5), while also structuring the findings based on the key principles of the theory. The answer to this question is further substantiated through chapters 8 and 9, as they provide a detailed evaluation of the study, thus further reinforcing and critically analysing the claim that affordance theory can successfully investigate and explain the use of IoT to enable servitization.

7.6 Summary

This chapter presented the cross-case analysis of the 11 cases, which were analysed and tabulated in chapter 6. The cases presented 52 instances of IoT usage, therefore implying 52 affordances that were perceived and actualised across the 11 cases. By comparing the 52 affordances, they were categorised into four types; *informative, enhancive, supportive,* and *demonstrative.* Similarly, three types of actions were also categorised, namely; *monitor, share* and *analyse*. Finally, the affordance categorisation was mapped against the individual cases to explore further the relationship between the four types of affordances on the individual case level. This led to the identification of a specific pattern between the affordances that suggests a dependency between them. This dependency indicated a precise mechanism that explains how perception and actualisation of affordances to use IoT can enable servitization. The mechanism was visualised and explained through Figure 6.

Through sections 7.2.6, 7.3.6, and 7.4.3, the chapter explicitly answered the three research sub-questions that were developed to address the primary research question of the study. As a result of these answers, section 7.5 answered the primary research question asserting the suitability and use of affordance theory to explain the phenomenon of IoT enabled servitization from a process and actor-focussed perspective. This chapter marks the end of Phase 2 of the research programme; Analysis and findings. The next chapter initiates, Phase 3: Evaluation and conclusion. This involves discussing the findings and stating the research implications and contributions.

Chapter 8 Discussion

The previous chapter presented the findings of this study, answers to the research questions, and marked the end of Phase 2 of the research programme. As part of phase 3: Evaluation and conclusions, this chapter reflects upon how the study has addressed the research aim and gaps in relation to the existing literature by focusing on the use of new perspectives and a new theoretical framework. The research aim for this study was set as:

"To use the affordance theory as an actor and process-focused lens to investigate the role of the manufacturer in the process of using IoT to enable servitization."

The chapter starts by reflecting upon the actor and process-focused perspectives that were introduced through the use of affordance theory. The chapter discusses how these perspectives allowed the study to advance the literature as compared to existing research (section 8.1). Similarly, to evaluate the answers to the research questions, the chapter discusses the use of the affordance framework to address the research question in comparison to the extant literature (section 8.2). The chapter ends with an explanation of limitations to applying this study's findings in the broader context of IoT enabled servitization, specifically the use of the affordance dependency mechanism (section 8.3).

8.1 New research perspectives

By examining the academic literature on servitization and its practical adoption in general, the literature review (section 2.4) revealed gaps that indicate the lack of focus on the manufacturer's role in using IoT to enable servitization. It also identified that the extant literature focused on the value created by using IoT for servitization while ignoring the process of using that leads to the creation of this value (section 2.4). This section explains explicitly how the adoption of an actor and process-focused perspective helped address these gaps.

8.1.1 Actor-focused perspective

The actor focused perspective differentiates explicitly this study from the extant literature that has focused on exploring the value of IoT for servitization (Lightfoot et al., 2011; Kryvinska et al., 2014; Adrodegari et al., 2017; Lightfoot et al., 2013; Allmendinger and Lombreglia, 2005; Opresnik and Taisch, 2015; Neff et al., 2014; Porter and Heppelmann, 2014, Evans and Annunziata, 2012; Rijsdijk, 2007). The study argues that IoT enabled servitization is not a phenomenon that results purely from IoT integration in a manufacturer's product. Instead, it is a result of a manufacturer's goal-oriented use of IoT that create desired outcomes for the manufacturer's business. IoT plays the role of a technological artefact that enables opportunities to create these outcomes, but only with the manufacturers' unique goals. The use of affordance theory has allowed the study to make this argument by using an established theoretical lens to focus on the manufacturer's role as a key actor responsible for using IoT. It also addresses the calls for more theoretically grounded research (Baines et al., 2017; Frank et al., 2019).

By using the affordance theory, the study adopted the concept of affordance perception (Strong et al., 2014), which helps understand the opportunities to use IoT that manufacturers perceive. More specifically, affordance perception implies that the uses of IoT cannot be recognised outside the context of its use, which is decided by the actor. This means that IoT only has value when a manufacturer finds its features useful to address their challenges in servitization. Affordance theory has been recognised for highlighting the importance of such contextual uses of artefacts which means that an artefact's use is not an inbuilt feature of the artefact (Davis and Chouinard 2017, Volkoff and Strong 2018). This study further substantiates this argument of affordance theory by contributing empirical evidence to validate the concept of contextual use of IoT in servitization (Dmitrijeva et al., 2019; Schroeder et al., 2018).

The focus on the manufacturer's role revealed the reason behind the diverse outcomes from the use of IoT. As the IoT's features are limited, such as *remote monitoring, data analytics,* and *data sharing,* the diversity of the perceived affordances is a result of the unique manufacturers' goals. The affordance theory helped develop this argument based on its notion that an artefact can be used in different ways based on the different goals set by different actors using the artefact (Strong et al., 2014; Hutchby, 2001; Zammuto et al., 2007). By actualising these affordances, the manufacturer is responsible for creating diverse outcomes from using IoT. This further reinforces the concept of contextual use as it implies that the value of IoT depends on what the actor aims to use it for (Gartner, 2014; Bradley et al., 2013). This differentiates the study from extant literature that adopts an increasingly technology-centric perspective where it assumes that IoT creates these outcomes for the actor by itself (Grubic and Jennions, 2018; Gubbi et al., 2013; Barrett, Davidson et al., 2015; Cenamor et al., 2017; Lee and Lee, 2015; Rymaszewska et al., 2017).

Overall, the actor focused investigation argues that IoT does not have an intrinsic purpose or goal but instead it as a platform for creating opportunities to achieve the actor's goal. It also argues that IoT does not create value on its own, but it is valuable when used in a specific context, by a goal-oriented actor (Schroeder et al., 2018). Therefore, the creation of opportunities to enable servitization requires active and goal-oriented participation from the manufacturer who is responsible for extracting value from the use of IoT.

8.1.2 Process-focused perspective

The process-focused perspective of affordance theory contributed to the study in two-ways: methodologically, and empirically. Methodologically, the principles of affordance theory, affordance perception, actualisation, and dependency (section 2.3.1) indicate a three-step process of studying a transformation. Empirically, the use of affordance theory helped uncover a mechanism that illustrates the dependency between the informative, enhancive, supportive, and demonstrative affordances (Figure 6).

In terms of methodology that is based on the key principles of perception and actualisation (Strong et al., 2014), the investigation of IoT usage in servitization was viewed as a process of identifying the various opportunities perceived by the manufacturers, followed by the actions taken to realise these opportunities. The use of this perspective differentiates this study from the existing literature by highlighting a new methodological, and analytical tool for IoT enabled servitization literature (Lehrig et al., 2017; Mallampalli et al., 2018; Dremel et al., 2019; Du et al., 2019). Affordance perception and actualisation were driven by the theoretical framework (Figure 3), and thus also guided the use of thematic analysis to structure the case analysis. The framework proved crucial in designing the codebook that was used to conduct deductive analysis, aligned with the overarching deductive research strategy (section 3.3.1).

Empirically, the study identified the affordance dependency mechanism (Figure 6) that indicates a step-by-step process of perceiving and actualising the four types of affordances identified in this study (section 7.2). This step-by-step process enables outcomes such as remote monitoring and intervention, predictive maintenance, location monitoring, health tracking, performance monitoring, and providing maintenance insights which are already argued to be critical uses for servitization (Suppatvech et al., 2019; Rymaszewska et al., 2017; Coreynen et al., 2017; Kohtamaki et al., 2019; Ardolino et al., 2018). The study argues that these uses of IoT occur in a fixed pattern, starting with collecting product usage information, using the information to enhance the product's performance, and based on the guarantee of product performance, developing actionable insights to support the customer's business. As a consequence of this, IoT is found to enable a manufacturer's servitization. The affordance dependency mechanism played a crucial role in answering the research questions in this study which are further elaborated in the following section.

8.2 New theoretical framework

The phenomenon of IoT enabled servitization was found to lack suitable theoretical frameworks in its investigation (section 2.2.6). In the domain of information systems, digitally-enabled organisational transformation is studied using the affordance theory (section 2.2.5). The key principles of affordance theory make it crucial for explaining organisational transformation (section 2.3.4). Therefore, the primary research question for this study was set to investigate if the affordance theory can explain IoT enabled servitization, a type of digitally-enabled organisational transformation (section 2.4). This section precisely reflects upon how the answers found in this study advance the literature on IoT enabled servitization.

8.2.1 Adopting the concept of affordances

The first research sub-question was answered by identifying 52 affordances that were categorised as informative, enhancive, supportive, and demonstrative. The categorisation was based on the kind of opportunities represented by the affordances to enable servitization using IoT. These affordances support the claims made in the literature that IoT has the potential to enable servitization in different ways (Coreynen et al., 2017; Lenka et al., 2017; Opazo-Basáez et al., 2018). More specifically, through the identification of informative affordances the study echoes the claims made in the literature that IoT provides visibility of the product in terms of the information about the product's usage, condition, and overall status (Vendrell-Herrero et al., 2017; Ardolino et al., 2018).

IoT is also claimed to enable manufacturers to assess operational risks and make interventions while also developing fault awareness, improve maintenance, enhance equipment design to reduce existing faults, simplify maintenance activities, and inform operator behaviour (Coreynen et al., 2017, Parida et al., 2017). Enhancive affordances confirm these claims by helping manufacturers to improve maintenance of their product through improved fault detection, enhanced maintenance scheduling and prioritisation, thus ensuring that the performance of the product can be guaranteed.

IoT is known to enable manufacturers in offering services that create additional value by supporting the customer's business (Baines et al., 2014; Lenka and Parida, 2016). Supportive affordances provide evidence to these claims by showing that IoT can enable services that support the customer's business performance by helping the customer make correct choices about the product, educating the customer about the product's operations, encouraging the customer to adopt best operational practices to extract the most value out of the product.

Additionally, IoT is understood to enable servitizing manufacturers to maintain closer customer relationships by sharing consolidated usage information with the customers (Ardolino et al., 2018; Frank et al., 2019). Demonstrative affordances exemplify this understanding while also highlighting that IoT allows the manufacturer to prove the value customers may lose if they do not adopt the manufacturer's services.

While these findings resonate with the extant literature, the study uses affordance theory to emphasise the opportunities of using IoT more than the value it creates for servitizing manufacturers. The study draws upon the actor's role in using IoT and focuses on the importance of these opportunities for the manufacturer's business. Therefore, the categorisation makes the utility of IoT more relevant on a business level, rather than a technical or monetary level as found in extant literature (Frank et al., 2019).

8.2.2 Acknowledging the goal-oriented actions

The study highlights the role of the manufacturer in taking goal-oriented actions to realise the perceived opportunities to use IoT (Hutchby, 2001; Volkoff and Strong, 2018). The findings show that the affordances perceived by the manufacturer do not indicate that they been actualised but require the manufacturer to take specific actions that create outcomes (Hutchby, 2001). This was achieved by adopting the principle of affordance actualisation, which actively argues that perception of affordances to use an artefact does not indicate creation of outcomes (Strong et al., 2014). By acknowledging the actions of the manufacturer to actualise the affordances, this study argues that the value of IoT is only created if the manufacturer decides to act upon opportunities to use IoT for to achieve its goals. This use of the principle of affordance actualisation highlights the importance of the actor-focused perspective for research and challenges the assumption made in extant literature that the IoT enables servitization by allowing digitalisation of the manufacturers' products (Ardolino et al., 2016; Rymaszewska et al., 2017; Ardolino et al., 2016).

The study identified three types of actions taken by the manufacturers, namely *monitoring, analysing* and *sharing* (section 7.3). These actions advance the understanding of the manufacturer's role in enabling servitization by using IoT to create diverse outcomes. However, these actions are closely related and limited by the number of features an IoT artefact possesses. Therefore, the manufacturer must choose an IoT artefact that possesses the essential features but also explores the integration of new features that can enable new types of actions. Additionally, the study addresses the literature's call for more insights into how manufacturers can use IoT to achieve their goals (Rymaszewkša et al., 2017; Zancul et al., 2016; Bigdeli et al., 2019;

Frank et al., 2019). This perspective will be further useful in research to explain the outcomes of IoT usage in different contexts.

8.2.3 Identifying the mechanism behind IoT enabled servitization

Following the categorisation of the affordances, the study found that the affordances have a cascading relationship between them. This draws upon the principle of affordance dependency (Strong et al., 2014) and shows that the use of IoT in servitization is based on a progressively dependent sequence that creates desirable outcomes (Gubbi et al., 2013; Barrett et al., 2015; Cenamor et al., 2017). Informative affordances lay the foundation for the perception and actualisation of the other three affordances. They provide information that is used to perceive and actualise enhancive affordances. The analysed data and mitigation of operational risks from the actualisation of enhancive affordances leads to the perception of supportive affordances. The demonstrative affordances are perceived and actualised simultaneous to these three affordances and demonstrate the value created by those affordances.

The identification of this dependency, as illustrated in Figure 6, advances the understanding of IoT's role in servitization and the literature on IoT enabled servitization, in general. Although IoT is acknowledged to enable servitization (Rymaszewska et al., 2017, Vendrell-herrero et al., 2017; Coreynen et al., 2017), affordance dependency argues that servitization enabling outcomes from IoT usage is created sequentially and do not exist independent of each other. Managing the risk of guaranteeing a product's performance (enhancive affordances) is not possible without clear visibility of the product's usage (informative affordances). Similarly, creating additional value by supporting the customer's business (supportive affordances) is not possible without managing the risks involved in guaranteeing the product's performance (enhancive affordances). It also contributes to the development of affordance theory by providing empirical evidence to substantiate the concept of affordance dependency (Wang et al., 2018).

Based on affordance dependency, the study argues that IoT enables servitization through orderly bundling of outcomes aligned with the manufacturer's goal. Extant literature suggests servitization to be a bundle of services (Baines et al., 2014; Baines et al., 2009b). This study extends the notion of bundling service in IoT enabled servitization as the bundles of outcomes are aligned with the types of services suggested in the literature (Baines et al., 2014). The enhancive affordances allow the manufacturer to achieve outcomes that are related to intermediate services. Similarly, the outcomes from actualising supportive affordances are closely related to the services described as advanced services. Therefore, the findings of this research further reinforce the types of services in servitization by introducing the contribution of IoT in creating these services.

8.3 Conditional application of the findings

The findings of this study, specifically the affordance dependency mechanism (Figure 6), can be used to study other cases of IoT enabled servitization. However, two essential conditions need to be considered when applying the mechanism to a broader context. This section explains these conditions along with discussion in extant literature that makes similar arguments, specifically about the capital value of the products and the partial progression in servitization.

8.3.1 Capital value of the product

As the mechanism (Figure 6) illustrates, the affordance dependency exists within the manufacturer’s business context. An element of the business context is the manufacturer’s product. The capital value of the product was found to play an essential role in deciding the affordances perceived and actualised by the manufacturers.

Consider the example of manufacturers Beta, Theta, and Sigma. These manufacturers perceived and actualised informative affordances to collect information on product status and then analysed this information to develop insights and support their customer’s business performance (supportive affordances). As it appears contradictory to the affordance dependency framework, enhancive affordances were not perceived and actualised before the perception of supportive affordances in these cases. Although this pattern indicates limits to the application of the dependency mechanism, it is important to note that the products of Beta, Theta, and Sigma have low capital value.

Literature has previously indicated lower adoption of servitization in manufacturers with low capital value products (Adrodegari et al., 2015; Davies, 2004; Brax, 2005). It claims that manufacturers may struggle to make the necessary investments in IoT integration and operationalisation of a servitization strategy. However, through this study, it is clear that manufacturers selling low capital value products do not necessarily struggle with these investments but adopt a different pathway to mitigate the challenge of investment in resources and capabilities required for maintenance and repair activities. Assigning a monetary value to be considered of low-capital value of a product is somewhat unclear, but if the manufacturers find certain products cheaper to replace than maintain, then those products can be considered as low capital value products.

The manufacturers with lower capital value products found it easier to replace their products in cases of faults and breakdowns than investing resources for the maintenance and repair of these products. The absence of enhanced product performance, as a result of the improved maintenance activities, did not hinder their ability to support the customer’s business. The manufacturers guaranteed the availability and uptime of their products by timely replacement of products that were diagnosed as faulty. In terms of extant research on servitization, this condition highlights the need to distinguish between servitization of low and high capital value products.

8.3.2 Partial Progression

Another condition that is important when applying the affordance dependency framework is the partial progression of a manufacturer. For example, manufacturers such as Alpha, Gamma, and Omega perceived and actualised informative, enhancive and demonstrative affordances. They did not perceive and actualise supportive affordances, although the conditions for their perception (actualisation of enhancive affordances) were met. This can be attributed to two factors. First, when the study was conducted, the manufacturers had not yet perceived the supportive affordances but perceived and actualised them shortly after. This relates to the maturity of the manufacturer in their servitization journey (Rapaccini et al., 2013). Bigdeli et al. (2019) point out that manufacturers are going through the servitization journey progress through four distinct stages of exploration, engagement, expansion, and exploitation that represent their progress or maturity along the journey. The affordance dependency framework indicates a similar notion of progression and some manufacturers may not have progressed through it entirely at the time of the investigation, as in the case of Alpha, Gamma, and Omega in this study.

The second factor contributing to partial progression could be a decision by the manufacturer to stop at a specific step in the dependency mechanism. This can occur when the manufacturer has achieved its goal without progressing through all steps of the dependency mechanism. However, the framework does not measure the achievement of the goal. Additionally, the complete progression of a manufacturer through the mechanism’s steps does not necessarily indicate that the manufacturer has achieved the set goal. Literature has recently started to explore measures to assess a manufacturer’s overall servitization success or progress (Bigdeli et al., 2018a) and integration of these measures could potentially further explain the reasons for partial progression of a manufacturer on the affordance dependency framework.

8.4 Summary

To summarise, this chapter reflected upon the achievement of the research aim and answers to the research questions. It evaluated the key findings of the study from the perspective of advancing knowledge in the domain of IoT enabled servitization. The chapter discussed the new actor and process-focused perspectives introduced by the use of affordance theory. This perspective has highlighted the manufacturer’s role as key in perceiving opportunities to use IoT and in taking goal-oriented actions to create desirable outcomes. By giving due importance to the manufacturer’s role, the study was also able to identify the actions taken by the manufacturer to make goal-oriented use of IoT.

Next, the chapter also reflected upon the answers to the research questions. It explained how the concept of affordances allows focusing on the value of IoT for the manufacturers’ businesses. Similarly, acknowledging the principle of affordance actualisation highlighted the relationship between the limited IoT features and the actions that the manufacturers can take. The chapter also reflected on the dependency between the types of affordances which represents a sequence of using IoT to create servitization enabling outcomes.

While the dependency framework presents a justified form of relationship between the opportunities perceived by manufacturers, the specific business context in which the manufacturers operate present conditions for a broader application of the mechanism. This chapter discussed these conditions and explained their relevance in the application of the affordance dependency framework. Overall, this chapter initiated Phase 3: Evaluation and conclusions by presenting an evaluation of how the research achieves its aim and addresses the research question. The next chapter presents the conclusions of this thesis through a research summary, discussing the contributions to theory and practice, highlighting the research limitations, and identifying the avenues for future research.

Chapter 9 Conclusions

This chapter concludes Phase 3 of the research programme (i.e. Evaluation and conclusions) by presenting contributions to theory and practice (section 9.1), a summary based on the key arguments and findings (section 9.1), key limitations (section 9.3), and avenues for future research (section 9.4).

The chapter describes how this study contributes to the advancement of the servitization literature (section 9.1.1) and affordance theory (section 9.1.2). It presents the overall argument of the research regarding the roles of IoT and manufacturers in servitization (section 9.2.1). It also discusses the importance of methodological choices made in this study to reach these arguments (section 9.2.2). The chapter identifies a lack of access to interviews when investigating servitization and the lack of tools to measure servitization success as important limitations of the research. The chapter further describes avenues for future research focused on the manufacturer's capabilities to actualise affordances, and an IS (information systems) artefact approach taking a socio-technical perspective.

9.1 Contributions

The research makes substantial contributions to theory in the field of servitization, IoT, and affordances. The research will also provide practical contributions to the knowledge of practitioners using IoT to enable servitization in their manufacturing organisations. This section provides detailed descriptions of these theoretical (section 9.1.1) and practical contributions (section 9.1.2) of the research.

9.1.1 Theoretical contributions

The research makes five crucial contributions to theory. It contributes to the domain of servitization by introducing a socio-technical perspective to the investigation of IoT's role in servitization (Strong et al., 2014; Majchrzak and Markus, 2012). The research highlighted the importance of manufacturers in making goal-oriented use of IoT and the role of IoT in providing a platform of key technical features that enable the creation of opportunities to enable servitization. It provides evidence suggesting the the opportunities to enable servitization do not exist individually but rather exist as bundles of dependent opportunities. Additionally, the application of affordance theory to the context of servitization provides further evidence to substantiate the principles of affordance perception, affordance actualisation, and affordance dependency.

First, from a socio-technical perspective, the study highlights the value of studying the use of IoT within the context of its use. It suggests that IoT should be considered as a platform of opportunities which help the manufacturer achieve its servitization goal (Gil et al., 2016). It focused on the crucial role of the manufacturer's goal in influencing the different opportunities to use IoT. The adoption of socio-technical perspective through the affordance theory differentiates the study from the extant literature that has considered IoT enabled servitization as a primarily technological phenomenon (Frank et al., 2019).

Secondly, the study argues that the value of IoT should be assessed based on its features and consequentially, the actions it affords. The research established three key features of IoT that are commonly found to be useful by servitizing manufacturers (*remote monitoring, data analytics,* and *data sharing)*. Although this study agrees with extant literature regarding the most valuable features of IoT, it argues that the three features afford a limited range of actions for the manufacturers to realise different opportunities. Research has often considered IoT as an individual technology capable of achieving a variety of outcomes (Lee and Lee, 2015). However, this research argues that IoT should be considered a combination of distinct features that represent how IoT can be used by the manufacturer.

Third, by identifying the different affordances and the dependency between them, this study argues that the affordances do not exist independently but rather as a bundle of opportunities (Anderson and Robey, 2017; Dremel et al., 2020). The bundling of affordances contributes to furthering the notion that different services exist as bundles, for example, base, intermediate, and advanced services (Baines et al., 2014; Kindstrom and Kowalkowski, 2014). This concept of bundles is extended to the context of IoT enabled servitization, and the study argues that IoT enables services that bundle together are that are built over a foundation of product-usage data and actionable insights.

Fourth, by adopting the affordance theory, the study has further extended the application of affordance theory to a new context of IoT enabled servitization. The theory has been widely used in the domain of Information Systems to address digitally-enabled organisational change (Pozzi et al., 2014; Wang e al., 2018), but this research has established its suitability in the domain of Operations Management while also arguing for its use as an analytical and methodological tool (Strong et al., 2014; Volkoff and Strong, 2018). Additionally, the application in the new context has allowed for substantiating the principle of affordance dependency with empirical evidence which called for in extant literature (Strong et al., 2014; Herterich et al., 2016; Volkoff and Strong et al., 2017; Nambisan et al., 2019)

Fifth, through this study the affordance theory has now been extended to an organisational level, a level of analysis that was inadequately explored (Pozzi et al., 2014; Wang et al., 2018). The theory has been increasingly used to identify the individual level of affordances while conceptualising organisational level as a combination of individual-level affordances. Evidence has suggested that the individual and organisational objectives can be very different and therefore, cannot be viewed in alignment (Wang et al., 2018). The organisational level of analysis in this study allows the identification of affordances and their actualisation with a focus on the organisational goal, as compared to the focus on individual goals found in extant literature (Strong et al., 2014, Zammuto et al., 2007; Goh et al., 2011; Markus and Silver, 2008).

9.1.2 Practical implications

Firstly, in terms of the practical contributions from the technological perspective, the research indicates that IoT should be considered as an artefact built from a combination of features to create opportunities for value creation. An IoT artefact used by a manufacturer will include key features of remote monitoring, data analytics, and data sharing (section 7.3) that will afford the manufacturer with specific actions. The manufacturer can manage the outcomes they want to achieve based on these features that afford opportunities to create desirable outcomes. Manufacturers can choose to embed necessary features in their IoT artefacts and unlock opportunities. Additionally, with case examples such as Gamma, Delta, Zeta, and Lambda, the study shows how manufacturers have extended the existing features of their IoT artefacts by developing the feature of data analytics in-house. A manufacturer can, therefore, choose to develop specific features themselves, if they have the necessary resources and capabilities, or explore the options of sharing or acquire new IoT features.

Secondly, the study presents a four-step process to use IoT for enabling servitization, as visualised in Figure 6. These steps indicate the different services that can be created through the use of IoT. Although the higher-order affordances cannot be actualised without the lower order affordances, it does not imply that all affordances should be actualised. The manufacturers can decide the type of affordances they intend to actualise depending on the level of services they believe are suitable for their organisational goals. The study clarifies the type of outcomes created with each type of affordances and the conditions they need to create in order to actualise these affordances successfully.

As a third practical contribution, the study emphasises the manufacturers' goals in driving the use of IoT in servitization. Only when the IoT features are viewed in the context of the manufacturers' goals, that the value becomes apparent. Therefore, the manufacturers need to ensure that they have a clear goal to servitize as it will play a crucial role in their IoT enabled servitization. The research also informs the manufacturers about the vital role they play in taking actions to realise the perceived opportunities. Therefore the manufacturer can use the research findings to identify the type of actions they will have to take in order to actualise the different affordances, and thus prepare resources and capabilities to ensure necessary actions are taken.

9.2 Research summary

The research aimed to study the use of IoT in servitization using the affordance theory to adopt actor and process-focused perspectives. By achieving this aim, the study presented the affordance dependency mechanism that explains how manufacturers use IoT to enable servitization (Figure 6). It states that manufacturers can use IoT to connect to their products and gather information, use the information to improve its overall performance, and based on the performance guarantees manufacturers can further support the customer's business. They can also use the IoT to demonstrate the additional value created through these actions to the customer by sharing information and performance metrics. As a result of these findings, the research can make key arguments about the roles of IoT and the manufacturer in servitization.

9.2.1 Role of manufacturer and IoT in servitization

Extant research has predominantly considered IoT as a critical enabler of servitization (Ryamszewska et al., 2017; Coreynen et al., 2017; Suppatvech et al., 2019). A separate stream of literature came into inception that focused on the investigation of the role of digital technologies in enabling servitization, known as digital servitization (Vendrell-Herrero et al., 2017; Kohtamaki et al., 2019). Such a focus of the literature led to the understanding that the use of IoT in digitalising the manufacturers' products can lead to immense value. However, this research challenges this focus by arguing the value of IoT in servitization can only be assessed when a goal-oriented manufacturer takes specific actions to use IoT and achieve its servitization goals.

The research found that the manufacturer’s goal to servitize plays a crucial role in defining how they use IoT. IoT as a technology possess a limited number of features, but the diversity in the manufacturers’ goals enables the creation of a range of outcomes that contribute to servitization. The importance of the manufacturer’s role extends beyond their goal, as their ability to take goal-oriented actions ensures that the opportunities to use IoT are successfully realised. Without their actions, the opportunities only indicate the potential value that IoT can create for servitization which is a widely explored topic in servitization literature (Bustinza et al., 2018; Baines et al., 2013a; Opazo-Basaez et al., 2018; Romero et al., 2019). This implies that researchers should give due importance to the manufacturer’s role, as it leads to the identification of the critical factors creating value from IoT.

The research found that different IoT features decide the range of actions that the manufacturers can take, making it essential for the manufacturer to choose the IoT artefact with features suitable for their context. However, solely focusing on technology does not create outcomes, but the goal-oriented use of technology in specific contexts does. Therefore, IoT must be considered as a platform to create opportunities when used in different business contexts (Akaka and Parry, 2019). Similarly, IoT does not have any intrinsic value or purpose, but it is instead used to create value in a range of contexts, as studied in the literature (Zhong et al., 2017; Weber et al., 2017; Perera et al., 2013).

9.2.2 Importance of methodology in this research

The methodology used in this research was novel based on the critical choices made in designing case studies such as the expert interviewing technique for data collection and a deductive thematic analysis for data analysis. First, expert interviewing enables the researcher to gather expert insights that relate to the intersection of technical knowledge of IoT and its application on a business level (Bogner and Menz, 2009; Meuser and Nagel; 2009). Additionally, expert interviewing also ensured that the interviewees were able to provide insights about the manufacturer’s goal for servitization, which was a crucial part of the affordance perception process. Such strategic information would not have been accessible from non-experts as they may not be involved in strategic decision-making.

Second, the deductive thematic analysis allowed structuring the research based on a pre-developed theoretical framework, which was the affordance actualisation framework in this study (Figure 3). This framework helped design the interview themes (section 4.1.5) and the codebook for the within-case analysis (section 6.1.1). Based on the framework, the affordance dependency was identified visualised as a step-by-step process of perceiving and actualising the four types of affordances. These affordances enable servitization by sequentially providing manufacturers with opportunities to create valuable services that help them achieve their goals.

Third, the case selection criteria and the unit of analysis also played an essential role in ensuring the research was able to achieve the set aim. The case selection criteria helped ensure that the cases contributing to the study were specifically focused on using IoT to drive their servitization journeys and not using IoT only to improve their production efficiencies. That would have created substantial overlap with studies that focus on Industry 4.0 as compared to IoT enabled servitization (Frank et al., 2019; Kamp and Parry, 2017). The unit of analysis also ensured that the study focused on how manufacturers use IoT. This ensured that the study focused on investigating IoT usage by the manufacturer in the context of servitization instead of focusing on the potential value of IoT for servitization, as that is a topic increasingly addressed in the literature (Frank et al., 2019; Paschou et al., 2020)

9.3 Research limitations

While the study makes substantial contributions to advance theoretical and practical knowledge, it has to be seen in the light of certain limitations. First of all, the findings are based on a limited number of cases (11) that belong to a range of industries and sizes (MNCs and SMEs). This restricts the generalisability of the findings in the context of servitization as the findings cannot be claimed to be typical for any specific industry size or sector. Although the number of cases can be justified based on the most commonly used guideline for case samples by Eisenhardt (1989) (Kindstrom et al., 2014; Eloranta and Turunen, 2015; Yang et al., 2018), other studies suggest more numbers of cases as a justifiable case study sample (Marshall et al., 2013). Having more number of cases would have contributed to a more diverse range of cases as well as improved arguments for generalisability (Meredith, 1998; Voss, 2010). However, a more extensive range of cases would not be able to provide the depth in the study in terms of analysis and nuance (Marshall et al., 2013). Studies with 1-15 cases are found to have more depth in explaining a particular phenomenon, while studies with 15-30 cases have a broader type of cases and generalisability but shallower findings.

Secondly, the interview themes developed (section 4.1.5) were not consistently implemented in the same sequence as stated in the design, as the respondents answered the questions in the form of retrospective accounts of IoT usage. The researcher ensured that the questions from the interview design (section 4.1.5) were asked. However, they were asked as the topic of conversation evolved based on the interviewees' responses. Such a deviation from the design and inconsistency across cases raises concerns regarding the comparability across cases (Whiting, 2008). However, considering the lack of experience of the researcher, challenges in controlling the interview responses are not uncommon and expected (Rowley, 2012). Such challenges can be addressed by conducting a structured interview while limiting the exploratory nature of case study research, but providing a rigid structure for the respondent to follow and thus makes the responses consistently comparable. However, the choice between semi-structured and structured interviews has to be made based on the depth to which the study wants to capture detail and nuance, as compared to directly comparable and consistent responses.

Finally, bias can affect the study's case selection and data collection methods. Qualitative research often faces the unavoidable challenge of bias in terms of researcher's opinion and knowledge on the phenomenon (Collier, 1995). The researcher's understanding of servitization and IoT may not be the same as the manufacturers' understanding, therefore leading to misinterpretation of results that lean towards the researcher's understanding. Although presenting the researcher's interpretation of the data is the overarching aim of any research, such a bias can overshadow a part of the manufacturers' accounts. To avoid this bias, the researcher ensured that the interviewees are provided with an information sheet (Appendix 1) that states the definitions adopted by this study. Additionally, the researcher ensured that the interpretation of results is not purely based on interview data but also triangulated with secondary sources of data (section 4.1.6). However, considering the researcher's lack of experience in conducting research, the bias in this study was not completely avoidable.

9.4 Future research

The study was designed for a specific focus and to achieve a specific aim of the study. This research design restricted the topics that can be addressed through this research. These topics are also important in completing the picture of servitization and therefore, they are expressed as seven avenues for future research in this section.

First, the research is limited to the explanation of manufacturers' IoT usage aligned with their servitization goal but does not indicate the achievement of the goal. This is a current issue in the literature in terms of measuring servitization progress (Baines et al., 2017). Scholars have recently started addressing this topic as more manufacturers are adopting and transforming through servitization (Bigdeli et al., 2018b; Calabrese et al., 2019). Without a measure of success or progress, the findings of this research cannot conclude where IoT enabled servitization ends, whether it ends or not, or does IoT enable only a specific phase in servitization. Addressing this gap would help practitioners manage their journey and assess their progress in servitization.

Secondly, monetizing the service offerings created by actualising the affordances is crucial for capturing value. This research does not explore how the manufacturers captured this value because the scope of the research is restricted to understanding the role of IoT in the creation of value (section 2.2.5). Addressing the value capture process would provide valuable insights into the design of revenue models. However, this would also overlap substantially with studies focused on business models for servitization (Martin-Pena et al., 2018; Kohtamaki et al., 2019; Adrodegari et al., 2018). The affordance theory does not provide enough insight into how IoT enabled services can be monetized. Therefore it falls outside the scope of the study.

As a third avenue for future research, the framework can be enhanced by providing actionable guidance to manufacturers requirements for actualising perceived affordances. The present study identified three types of actions that manufacturers take to actualise affordances to use IoT (section 7.3). Future research can focus on identifying the resources and capabilities required to perceive and actualise these affordances. This could lead to insights into the role of financial, human, and technical resources that are necessary to perceive the affordances in the first place (Herterich et al., 2016). Additionally, the capabilities can also be identified that is required from the manufacturer to be able to actualise perceived affordances (Naik et al., 2017). The concept of digitalisation capabilities is also being addressed by scholars (Lenka et al., 2017; Martin-Pena et al., 2019). However, the exploration of these capabilities within the affordance actualisation theory is absent. This would lead to the guidance of manufacturers about the importance of developing capabilities that ensure that perceived affordance can be actualised, while such capabilities can also be externally acquired, shared, or outsourced (Teece and Linden, 2017). The capabilities perspective can be further extended on an individual level to understand the specific capabilities required from the individual employees of the manufacturer to ensure perception and actualisation of affordances, which is being investigated only recently (Raddats et al., 2019).

The fourth avenue refers to the adoption of a new perspective because similar to the issue with extant research (Baines et al., 2017), this study does not explore the customer's perspective on IoT enabled servitization. The research has adopted an actor-focused perspective where the manufacturer is the actor in focus. A focus on the customer has been called for in extant literature (Baines et al., 2017), while only recently studies have started exploring the customer's focus in servitization (Green et al., 2017; Jang et al., 2017; Rabetino et al., 2017). A customer perspective would allow understanding how customers perceive the value of IoT enabled servitization, and thus create insights for manufacturers to drive their servitization initiatives to align with the customers' needs (Raddats et al., 2017; Garcia Martin et al., 2017). However, adopting a customer perspective was considered beyond the scope of this study as the integration of IoT in servitization is a manufacturer driven process (Rymaszewska et al., 2017; Coreynen et al., 2017). Additionally, the affordance theory has never been used for a multi-actor investigation (Volkoff and Strong, 2017).

As a sixth avenue, the research did not identify affordances that were perceived but not actualised by the manufacturers for unknown reasons. This has been observed as a possible occurrence during the development of the theory by Strong et al. (2014). The occurrence of failed actualisations has been observed in other studies previously (Strong et al., 2014) which leads to another question; how does affordance actualisation fail? In this study, affordance actualisation could have failed in some instances due to denied or lack of access to usage data. However, neither of the 11 cases demonstrated a lack of access or denial to access product usage data. All the affordances were successfully actualised. However, the interview design could have been adapted to incorporate a theme that investigates failed actualisations. By acknowledging any failed actualisations, the study could also highlight any external factors that are responsible for perception and actualisation or the failure of the same. Identification of these factors that contribute to failed actualisations can help practitioners manage such factors and ensure successful affordance actualisation.

Finally, the seventh avenue for future research refers to adopting the socio-technical theory as a critical lens. The study has been able to explain the role of IoT in servitization and its importance as a platform for creating opportunities for contextual use based on its features. Further extension of the concept of contextual use demands a socio-technical focus on IoT. This can be achieved by conceptualising IoT as a socio-technical artefact (Schroeder et al., 2018; Spring and Araujo, 2017). By conceptualising IoT as an IS artefact (Lee et al., 2014), IoT can be investigated as a subsystem that operates with information and social subsystems. In this way, the value of IoT is measured in a combination of its effects on the information and social subsystems when it is used in any context (Schroeder et al., 2018). Extending this concept in servitization, IoT can be viewed as a technological subsystem that impacts how information is shared and how social interactions are affected. This would help understand how IoT is used in different systems (that represent IS artefacts), as a combination of technology, social, and information subsystems. Such research could develop a study around using such IS artefacts as a unit of analysis which will be able to explain how manufacturers can design effective IS artefacts to create more value.

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Appendices

Appendix 1: Information Sheet

The purpose of this document was to inform the participants about the objective of the project and the process of collecting data. It states how the interviews will be conducted, for how long, and what the expected outcome of this project is. Additionally, the sheet also explains the data protection policy under which the data collected and the participant's identity (organisation and individual) is protected.

Information Sheet

Investigating the goal-oriented use of IoT in servitization: an affordance theory perspective

Project information

The Advanced Services Group is currently investigating the use of the internet of things (IoT) for manufacturer's servitization. We define servitization as a transformative process through which manufacturers shift from selling products to offering bundles of products and services. The objective of this study is to;

Identify the organisational mechanisms that help manufacturers extract most value from their IoT investments.

Based on this research, guidelines and recommendations will be created that help manufacturers to further exploit the industrial potential of IoT and drive their servitization journey.

Data collection

As part of the research we will conduct interviews with manufacturing representatives to identify the range of scenarios in which IoT is used in the Advanced Services and analyse the experiences in these scenarios. The interviews will focus on the following themes:

• The specific objectives for integrating the IoT technologies

• The skills and resources that played a role in extracting value from these IoT technologies

• The contribution these IoT technologies are providing to the business

The interviews will take between 30-40 minutes and can be conducted face-to-face or by phone. All participating companies and individuals will obtain an industry-focused report of the research findings.

Data protection policy

The research is being conducted with approval of the Research Ethics Committee of Aston University. All raw data will be kept confidential and after concluding the project, the raw data will be destroyed within a year. Collected, collated and analysed data may be published in case studies, academic journals and presented at conferences. Any information and opinions that you provide will not be attributed to you or your organisation, and you will not be identifiable in any way. Even after having carried out the interview, you have the right to withdraw from the study at any point of time.

We look forward to your participation and valuable contribution to this project. For further details on participation and the project please contact me, Parikshit Naik, at naikpv@aston.ac.uk .

(Parikshit Naik is a Doctoral Student working with the Advanced Services Group, Aston Business School, Birmingham. The project in discussion contributes to his doctoral degree in management at Aston University).

Appendix 2: Consent form

The purpose of this document is to confirm the participation of the interviewee in a written form. It describes what the interviewee agrees to when confirming participation in the project.

Consent Form

Investigating the goal-oriented use of IoT in servitization: an affordance theory perspective

Name, position and contact address of Researcher:
Mr. Parikshit Naik
PhD Student
naikpv@aston.ac.uk

Please put initials in box

I confirm that I have read and understood the information sheet for the above study and have had the opportunity to ask questions.	☐
I understand that my participation is voluntary and that I am free to withdraw at any time, without giving reason.	☐
I agree to take part in the above study.	☐
I agree that my data gathered in this study may be stored (after it has been anonymized) in a specialist data center and may be used for future research.	☐

Please tick the box

	Y	**N**
I agree to the interview being audio recorded	☐	☐
I agree to the use of anonymized quotes in publications	☐	☐

________________________ _______________ ______________________

Name of Participant Date Signature

Aston University takes its obligations under data and privacy law seriously. For further information as to how the University processes personal data, please visit www.aston.ac.uk/dataprotection.