The roles of internet of things technology in enabling servitized business models: A systematic literature review

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Abstract

The internet of things (IoT) is gaining attention from both scholars and practitioners regarding its potential as a key enabler of servitized business models; academic research on this emerging concept is increasing but overall underexplored, however. This paper comprehensively analyses and consolidates the relevant literature on the emerging concept of IoT and servitized business models through conducting a systematic literature review. Based on an analysis of 74 articles, four archetypes of business models are identified that are enabled by the IoT: add-on, sharing, usage-based and solution-oriented and supplemented with information on what role IoT adoption takes, benefits from the provider perspective, and the inhibiting factors per archetype. A framework draws the findings together and forms five propositions about these elements and their corresponding business models that may guide future empirical research and serve as a common typology. Therefore, this study contributes to the body of knowledge on innovative servitized business models by classifying emergent business models utilising IoT and what is currently known about them. For practice, this paper provides an overview for initial consideration by practitioners before adopting IoT in enabling servitized business models and the range of applications IoT may have in enabling servitized business models with examples.

1. Introduction

The term internet of things (IoT) was first coined by Kevin Ashton in 1999 to describe the interconnection of physical objects through adding radio frequency identification and other sensors for various purposes, including identification, sensing, communication and data collection (Ashton, 2009). In being considered a key element of the fourth industrial revolution currently underway, the popularity of IoT has since grown rapidly as evident in the expectation that the number of devices connected to the internet will reach 34 billion by 2020, up from 10 billion in 2015 (Greenough & Camhi, 2016).

This development potentially offers a variety of benefits for firms able to utilise the underlying technology and seamlessly embed them in business models and products to improve market competitiveness. Since IoT allows firms to capture in-depth information on how products are being used by customers, it has particularly gained attention from practitioners and scholars regarding its potential in enabling firms to offer innovative product and service offerings, and in redesigning their current business models based on this information (Rymaszewska, Helo & Gunasekaran, 2017).

This function of IoT fits naturally with the closely related concepts of servitization and product-service systems (PSS), which have been discussed in the previous literature and have profoundly impacted on manufacturing paradigms (cf. Lightfoot, Baines & Smart, 2013). Here servitization is defined as "the innovation of an organisation's capabilities and processes to better create mutual value through a shift from selling product to selling PSS" (Baines, Lightfoot, Benedettini, Whitney & Kay, 2009, p.555) and PSS as "a system of products and services which are jointly capable of fulfilling specific client demands" (Manzini & Vezzoli, 2003, p.851).

This is based on the assumption that offering integrated product-service bundles will help firms avoid price-based competition and customer relationships to secure market share, and create new and stable revenue streams (Baines et al., 2007). Challenges associated with servitization, for example organizational transformation and the design of servitized offerings, have been extensively addressed and discussed in the current servitization research (Baines et al., 2009; Baines & Lightfoot, 2013; Brax, 2005; Slack, 2005). An example of a manufacturing firm that is frequently named here is Rolls-Royce, who switched their business model from selling aircraft engines to "Power-by-the-Hour" service contracts – a result of a servitization drive to offer an integrated result-oriented PSS. This means customers purchase the hours of flying capabilities instead of engines, while Rolls-Royce provides all support (including maintenance and spare parts provision) to make engines continuously provide power (Baines et al., 2009).

It has thus been established that in order to provide servitized offerings, firms are required to modify their current business model and its value proposition to align specifically with individual customer interests (Zhang & Banerji, 2017). It is expected that by adopting IoT, firms can fundamentally transform their business models and enable various types of service-oriented business models which facilitate the provision of servitized offerings beyond the traditional ones emerging from the PSS body of knowledge (Leminen et al., 2012; Gerpott & May, 2016; Noventum, 2016).

The research on the IoT-enabled business model framework has been previously discussed by Leminen, Westerlund, Rajahonka, and Siuruainen (2012), Dijkman, Peeters, and Janssen (2015) and Kralewski (2016), who based their work on the elements of Osterwalder and Pigneur's (2010) business model canvas. Leminen et al. (2012) classified different types of IoT business models, using two dimensions, i.e. the type of ecosystem (open network and closed private) and customer types (business or consumers), and used case examples of servitized business models from the automotive industry to support this argument. Dijkman et al. (2015) focused on creating a business model framework for IoT applications by identifying the relatively important building blocks and types of options that can be focused within these blocks through conducting empirical research. Kralewski (2016) evaluated existing business model patterns and identified 33 business models that suggest their application in the field of IoT. Additionally, Gerpott and May (2016) identified three different roles of IoT components in promoting a firm's servitized offerings and illustrate these roles with real-life case examples. Leminen et al. (2018) extended their previous work via a case study approach and found four types of IoT business models based on the type of ecosystem (heterarchical open and hierachical closed) and nature of IoT service application (standard and context-sensitive). However, these papers only provided a generic overview of how business models of IoT applications could be constructed, supported by the evidence of existing case studies. In this study, an attempt is made to move a step further by mapping different types of servitized offerings to the IoT-enabled business models.

However, despite recognising IoT as the key enabler of servitized business models in practice, academic research on the interchange of the emerging IoT and servitized business models is in its infancy – it is not clear what range of functions IoT may have in enabling servitized business models and what motivates or impedes their utilisation in practice. This is because while case-based research on individual servitized business models or conceptual contributions has advanced understanding in individual or theoretical servitized business models, knowledge has not been consolidated, making it opportune to review what progress has been made and how future research might be fruitful on the journey to more innovative and competitive servitized business models.

Through a systematic literature review (SLR), this paper advances the field by identifying different types of IoT-enabled servitized business models and reporting the corresponding roles of IoT used in these different business models to survey what progress has been made in practice, as well as in conception. This will be supplemented with the variety of benefits and inhibiting factors that firms might be confronted with when deciding to adopt different types of IoT-enabled servitized business models, with assumptions being made about the relationships between these factors. Lastly, a framework of IoT-enabled servitized business model archetypes will provide an overview of where the field currently stands and may guide future research by investigating these business model archetypes further, which are expanded upon via a number of propositions. To conclude, this study aims to answer the following research question:

How do IoT technologies enable different types of servitized business models?

This paper begins with a description of the research methodology used in the study, which is followed by a descriptive analysis of the selected papers and a thematic analysis, which discusses the emerging themes from the literature. Here the different types of IoT-enabled servitized business model, the roles of IoT, the firm's benefits and the inhibiting factors are extracted from the literature. Thereafter, the framework synthesised from the thematic findings is established and the proposition on how the variables in the framework interact are discussed. Finally, the contribution to knowledge, practical implications and limitations of this paper are summarised in the conclusions.

2. Research Methodology

In order to increase the rigour in reviewing the literature, given the criticism of narrative reviews, the methodology adopted in this paper is a systematic review or evidence-based approach based on the five-step approach proposed by Denyer and Tranfield (2009), which is illustrated in Figure 1 and then discussed in turn.

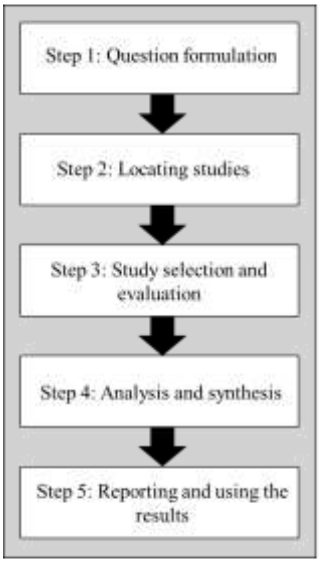

Figure 1: Five-step systematic literature review process (Adapted from Denyer and Tranfield, 2009)

2.1 Question formulation

In the planning phase, the review protocol, including the review question and search strategy, was developed and presented to an expert panel for review. The panel consisted of six researchers from business schools with considerable experience in the areas of servitization, PSS, and operations management research. Two of the authors formed a sub-set of the panel with the main author being the main research resource. The review question and sub-questions were then formulated from setting the scope, identifying emerging research fields and through discussion with the panel members.

Based on the over-arching research question given above, a number of review questions were suggested to focus the enquiry further:

a) *What are the different types of IoT used and which business models do they support?*

b) *What are the benefits of the different IoT-enabled servitized business models?*

c) *What are the factors which inhibit firms from adopting IoT-enabled servitized business models?*

The development of search keywords was then guided by these questions.

2.2 Locating studies

Two classes of keywords relating to the concept of servitization and IoT were selected as relevant to the review and its sub-questions, drawing on the expert panel for guidance on which search strings would enable the location of relevant studies. Therefore, the article search was based on the combinations of two types of keywords relating to "Servitization" and "Internet of Things" as shown in Table 1.

Table 1: Specification of search terms used in the systematic review

Servitization		Internet of Things
Serviti* OR		
Servici* OR		"Internet of Thing*" OR
"Service-dominant logic" OR		IoT* OR
"Product-Service System" OR	AND	"Cyber-Physical" OR
"Product Service System" OR		"Connected Device"
"Product-Service" OR		
"Integrated solutions" OR		
Service-orien* OR		
Service-cent* OR		
"Service-based business model" OR		
"Value Co-creation"		

The search keywords were used to construct search strings with Boolean operators. These search strings were then applied to search five databases (Emerald, ABI/INFORM Global, ScienceDirect, Scopus, Web of Science) for the title and abstract of scholarly articles, conferences papers, chapters of edited books, and reports published between January 1999 and December 2018, as per the study selection criteria given in the following section. These databases were selected because they cover the key topics addressed in this paper and are generally used in the area of recent servitization research (cf. Grubic, 2014).

2.3 Study selection and evaluation

For the initial search, only English language articles were included and 7,680 papers from the five databases were identified; the duplicates were then removed, reducing the total number to 6,949 papers. In order to reduce the number of papers from the initial search, the titles and abstract of the remaining papers were screened against inclusion and exclusion criteria, as shown in Table 2. As part of this process, each author screened a random sample of 100 abstracts after which inclusions and exclusions were discussed between the three authors. This was done to ensure that criteria were understood and applied similarly to remove reviewer bias and improve the reliability of the study. Based on the revised criteria, the lead author drove the abstract screening process whilst seeking guidance from co-authors on ambiguous abstracts as needed. 6,659 papers were rejected at this stage, primarily because they focused on developing platforms and architecture for IoT applications rather than describing IoT-enabled servitized business models or the roles of IoT in offering integrated product-services.

Table 2: Criteria for including and excluding papers

Criteria	Rationale
Inclusion	
Publications since 1999	The term “Internet of things” was first coined in 1999 by Kevin Ashton
Publications included academic journals, conferences papers, reports and chapters of edited books	To ensure that all relevant published work was included
Peer and non-peer reviewed publications (e.g. conferences proceedings, chapters of edited books, and business reports)	The research in this area is in its infancy, so there is a trade-off between publication quality and the available publications on this research topic – it has been decided to relax common quality guidelines to allow for more publications to be included, as is common with other reviews of nascent bodies of literature (cf. Masi et al., 2017)
All business contexts (e.g. business-to-business (B2B), business-to-consumer (B2C), business-to-government (B2G))	To make a comparison between roles of IoT in different business contexts and widen the scope beyond B2B
Papers in the field of information systems, engineering, manufacturing technology and marketing	To ensure that all possible fields relating to the research were covered
Exclusion	
Non-English language papers	Due to limited language capability of the authors
Papers focused on IoT platform or architecture development	The main objective of this research is to identify and explore IoT-enabled business models rather than develop an IoT platform or architecture

The remaining 320 papers were read in full and each paper was evaluated against quality assessment criteria to distinguish between less and more robust studies, assess contributions, and scrutinise theory, research methodology, and data analysis (cf. Wong, Skipworth, Godsell, & Achimugu, 2012). A process was applied by which the three authors independently reviewed a random sample of 30 articles against the inclusion and exclusion criteria, with the lead author subsequently screening the rest of the articles once common criteria had been established. Only the publications able to contribute to answering the review and its sub-questions and aligning with quality criteria were selected to be taken forward. After this final screening, only 58 papers were identified as relevant to this research. An additional 16 papers from cross-referencing were added because they were revealed as relevant to the research but were not found in the initial literature search. Accordingly, a total number of 74 papers were selected for further analysis and synthesis (see Appendix A). The systematic selection process is illustrated in Figure 2.

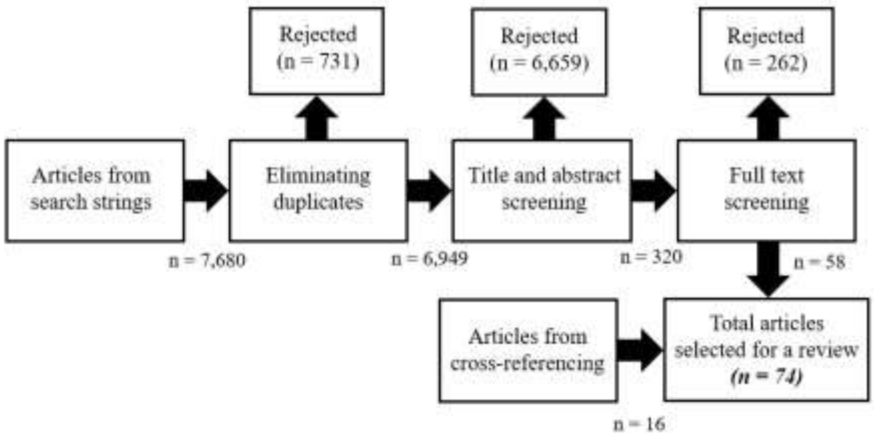

Figure 2: Summary diagram of the systematic selection process

2.4 Analysis and synthesis

The content of the selected publications was analysed descriptively and thematically. In the descriptive analysis, a deductive approach was adopted, which focuses on the classification of papers according to year of publication, type of publication, geographical location of where the fieldwork was conducted, methodology, and industry.

The thematic analysis identifies and categorises different types of IoT-enabled servitized business models, as well as other factors that may be relevant. An inductive approach was chosen here – each author read a sample of ten articles and synthesised salient constructs of interest related to the review questions to form the basis of a data extraction sheet (Denyer & Tranfield, 2009). These constructs were then clustered according to themes and presented to the expert panel for discussion. The revised data extraction sheet, which included the constructs clustered by themes (different roles of IoT, benefits, and inhibiting factors corresponding to each type of IoT-enabled servitized business model), was then applied by the main author to all 74 papers, working collaboratively with the two other authors as necessary in cases of ambiguity. The tables and cross-tabulations forming the basis for the descriptive and thematic results were similarly discussed between the three authors and working together with the expert panel. These results later fed into the conceptual framework as one of the main findings of the SLR, which required synthesising the connections between the themes – a mind mapping technique was utilised here which included the expert panel. Results from the thematic analysis and particularly the business model archetypes were subsequently reviewed with the authors' entire research group to ensure clarity of presentation.

2.5 Reporting and using the results

This paper reports the results of descriptive and thematic analysis prior to the discussion of how these results are associated. The framework of IoT-enabled servitized business model archetypes and its associated findings is established lastly to guide future research and aid practice in identifying viable IoT-enabled servitized business models given a set of constraints or circumstances.

3. Descriptive Analysis

The 74 papers selected through a systematic review are descriptively analysed in this section in respect of the year of publication, research methodology, types of publication, journal, and field of study, with the aim of identifying trends among this young body of literature and establishing a future trajectory.

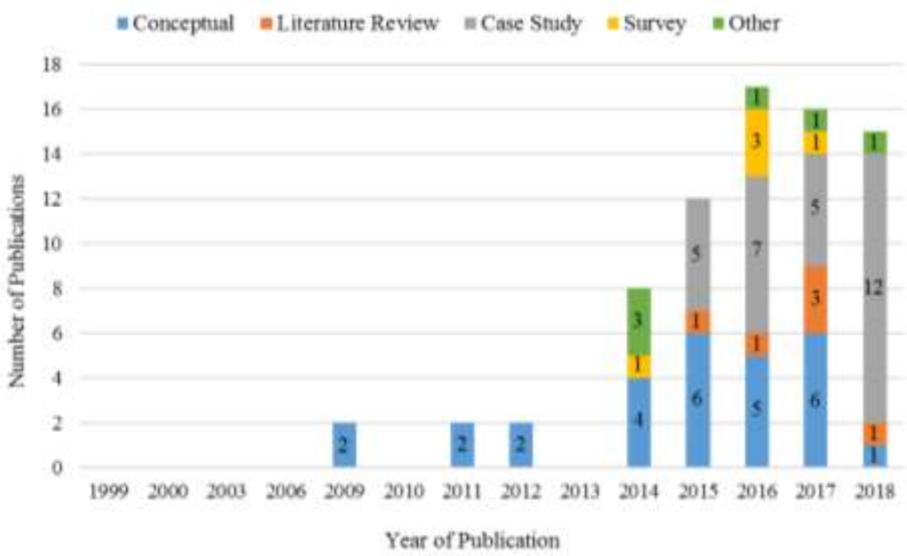

Figure 3: Analysis of papers according to publications across the years and research methodology

As illustrated in Figure 3, the results show that while six studies on the concept of IoT in the context of servitized business models are published up to 2012, the topic only achieved exposure post 2013, even though the term of IoT itself stems from 1999. From 2014 onwards, the research gradually increased as 68 papers were published in this timeframe, which constitutes approximately 90% of the papers in this study. While the number of publications peaked in 2016 and have since then seen a minor decline of one publication per year, it can be expected that as more success cases from industry are reported the previous growth trend will resume in the coming years. This is also reflected in the sharp decline of conceptual studies in 2018 combined with a large increase in number and proportion of case studies in the same year.

In these conceptual studies, which make up 38% of the total, authors have discussed the concept of IoT based on the available literature and reported brief, often anecdotal, case examples to support their arguments. While such papers led the field in terms of numbers until the end of 2017, in 2018 this has changed in favour of case studies at 39% of the total over the whole period. In sum this indicates indicates that tentative theory development based on empirical approaches is becoming more common, which bodes well for the field. Quantitative studies are largely lacking however, which has impeded theory validation and generalisation.

The papers selected for a systematic review were mainly published in academic journals (69%) and conference proceedings (20%), whilst the rest are chapters of edited books (8%) and business reports (3%). Although business reports provide information about current developments of IoT business applications, they were generally not considered in this study due to concerns about their reliability and lack of academic rigour. Instead, conference proceedings as a more scientifically rigorous source of contemporary information were included since they met the quality criteria set for the SLR process (see Table 2). This confirms that the research is currently still at a nascent stage. Furthermore, the majority of the papers, focusing on IoT in the context of servitized business models were published in the operation management field, indicating that the topic of IoT and its servitized business model has gained attention with academics in the field. In addition, the selected papers were published in 35 different journals and 13 different Proceedings, indicating large fragmentation. The selected publications are sorted broadly following the Association of Business Schools (ABS) categories (See Appendices B and C). Thus 39% of the journal publications are from journals of the operations and technology management, followed by the marketing (12%) and the information management (11%) categories.

In terms of the first author's geographical location, the interest in IoT-enabled servitized business models was distributed over five continents, i.e. Europe, the Americas, Asia and Australia. Most of the contributions came from European countries, and account for 74% of the total number of papers, suggesting a strong interest in the topic in Europe, especially Germany (18%), Switzerland (12%) and, Finland and Italy (9%). The US accounts for the fourth largest contribution of papers at 8%. This could be because IoT has been largely recognised by firms in developed countries in terms of its substantial benefits in extending the service business to increase profitability and business growth in the current industrial revolution. Consequently, this encourages local scholars to initiate research on this topic. The contribution of other countries including China, Australia and Canada only accounts for 8% of the total number of papers.

Finally, it is essential to investigate which industry sectors have contributed to the body of knowledge on IoT-enabled servitized business models. The findings show that the applications of IoT in the concept of servitization are predominantly discussed in the context of manufacturing/machinery (34%) and consumer goods (28%). This illustrates that the application of IoT in enabling servitized business models is within the context of both B2B and B2C.

4. Thematic Analysis

Through the analysis of the content of the selected publications, four main findings can be established. These include four available archetypes of (1) IoT-enabled servitized business models; (2) the variety of operational and strategic roles IoT may take in enabling servitized business models; (3) the various benefits of different types of IoT-enabled servitized business models from a firm’s perspective; (4) the inhibiting factors, which prevent firms from adopting different types of IoT-enabled servitized business models. In the following, these findings will be displayed in turn.

4.1 Types of IoT-enabled Servitized Business Models

The SLR suggests that IoT-enabled servitized business models can be categorised into four archetypes based on their main value propositions. These include add-on, sharing, usage-based, and solution-oriented business models, with a total of nine sub-categories. Each type of business model will be described and discussed using a supporting case study, its proposed business context, a corresponding traditional PSS, and its pricing mechanism. The summary of the discussion with supporting references is illustrated in Table 3.

Table 3: Types of IoT-enabled business model and corresponding business context, PSS and pricing mechanism

IoT-enabled Servitized business model		Business Context	PSS	Pricing Mechanism	References
Add-on	Innovative digital service	B2C	Product-oriented	Transactional	Mejtoft (2011), Fleisch et al. (2014), Atzori et al. (2015), Lee and Lee (2015), Wünderlich et al. (2015), Gerpott and May (2016), Kralewski (2016), Klein et al. (2017)
	Facilitate service provision	B2C/B2B		Transactional	Haller et al. (2009), Mejtoft (2011), Leminen et al. (2012), Harvard Business Review Analytic Services (2014), Turber and Smiela (2014), Atzori et al. (2015), Balaji and Roy (2016), Gerpott and May (2016), Hagberg et al. (2016), Sassanelli et al. (2016), Shih et al. (2016), Vendrell-Herrero et al. (2016), Ikävalko et al. (2018), Leminen et al. (2018)
	Leverage customer data	B2C		Transactional	Bohli et al. (2009), Haller et al. (2009), Mejtoft (2011), Leminen et al. (2012), Fleisch et al. (2014), Harvard Business Review Analytic Services (2014), Dijkman et al. (2015), Keskin and Kennedy (2015), Lee and Lee (2015), Hagberg et al. (2016), Hartmann and Halecker (2016), Kralewski (2016), Parry et al. (2016), Scholze et al. (2016), Takenaka et al. (2016), Green et al. (2017), Mikurz et al. (2017), Ng and Wakenshaw (2017), Saarikko et al. (2017), Woodside and Sood (2017), Ibarra et al. (2018), Leminen et al. (2018), Mittag et al. (2018), Pei Breivold and Rizvanovic (2018), Zheng et al. (2018)
	On-demand	B2C		Transactional	Haller et al. (2009), Leminen et al. (2012), Andersson and Mattsson (2015), Atzori et al. (2015), Dijkman et al. (2015), Lee and Lee (2015), Mikusz (2015), Rong et al. (2015), Dominici et al. (2016), Gerpott and May (2016), Zheng et al. (2016), Mikurz et al. (2017), Risteska Stojkoska and Trivodaliev (2017), Woodside and Sood (2017), Leminen et al. (2018)
Sharing		B2C	Use-oriented	Pay-per-use	Bucherer and Uckelmann (2011), Harvard Business Review Analytic Service (2014), Schenkl et al. (2014), Rong et al. (2015), Wünderlich et al. (2015), Ardolino et al. (2016), Carpanen et al. (2016), Dominici et al. (2016), Gerpott and May (2016), Nishino et al. (2017), Ardolino et al. (2018)
Usage-based	Pay-per-use	B2C/B2B	Result-oriented	Pay-per-use	Bucherer and Uckelmann (2011), Fleisch et al. (2014), Gerpott and May (2016), Kralewski (2016), Gebauer et al. (2017), Ardolino et al. (2018), Bressanelli et al. (2018), Heinis et al. (2018), Mittag et al. (2018)
	Subscription			Subscription	Bucherer and Uckelmann (2011), Kralewski (2016), Zancul et al. (2016), Bressanelli et al. (2018)
Solution-oriented	Availability	B2B	Result-oriented	Performance-based contract	Fleisch et al. (2014), Paluch (2014), Herterich et al. (2015a), Wünderlich et al. (2015), Ardolino et al. (2016), Kralewski (2016), Takenaka et al. (2016), Zancul et al. (2016), Zheng et al. (2016), Helo et al. (2017), March and Scudder (2017), Wiesner et al. (2017), Ardolino et al. (2018)
	Optimisation/Consulting			Long-term contract	Bucherer and Uckelmann (2011), Fleisch et al. (2014), Lee et al. (2014), Herterich et al. (2015b), Porter and Heppelmann (2015), Tuunanen et al. (2015), Wünderlich et al. (2015), Ardolino et al. (2016), Kralewski (2016), Scholze et al. (2016), Gierej (2017), Helo et al. (2017), Kiel et al. (2017), Rymaszewska et al. (2017), Ardolino et al. (2018), Cedeño et al. (2018), Hasselblatt et al. (2018), Kanovska and Tomaskova (2018), Metallo et al. (2018), Mittag et al. (2018), Rachinger et al. (2018), Sayar and Er (2018)

4.1.1 The Add-on Business Model

The add-on business model refers to a business model that uses IoT in enabling additional functions or adding personalised services to the existing physical products or service. This corresponds to product-oriented business models in the traditional PSS categorisation, where the provider offers services that are added to a physical product to support its function (Tukker, 2004). The findings of the SLR suggest that with the adoption of IoT, firms will be able to offer four types of services that latch onto the core physical good and service, which are innovative digital services, facilitate service provision, leverage customer data, and on-demand provision, within the context of both B2B and B2C.

In the *innovative digital service* business model, IoT is applied in order to link digital services to physical goods to create a single hybrid offering (Fleisch et al., 2014). Thus, classical products are charged with integrated sensor-based digital services, which offer new value propositions for customers. Gerpott and May (2016) provide a B2C example of the case study of FuelBand, a wristband that monitors the health and fitness activity of the user which has been launched by the sport equipment manufacturer Nike. This FuelBand will transmit the data wirelessly to the smartphone, allowing the wearer to keep track of their training in a way that was unavailable before the introduction of this device. The adoption of IoT technology allows Nike to be able to offer this innovative product as a core service offering.

In the *facilitate service provision* business model, IoT technology is adopted in order to facilitate existing product-related or service provisions to increase the efficiency and/or decrease the complexity of the delivered service (Gerpott & May, 2016). An example of a B2B case study in this category is Geis Group, a logistics service provider to the automotive industry (Leminen et al., 2012). IoT has been leveraged by the company to help process customer orders more efficiently, while customers can share the information required to facilitate just-in-time procurement.

In the *leverage customer data* business model, information obtained from customers during the use of a product is utilised by the product or service provider to offer customised services or enable integrated offerings to the customer (Fleisch et al., 2014; Kralewski, 2016). For example, the business model of Bundles, reported by Dijkman et al. (2015), offers a connected washing machine. By embedding IoT technology into the washing machines, customers will receive monthly feedback on their washing behaviour, allowing them to improve their usage activity from the information obtained. Thus, customers need to purchase their washing machine from Bundles in order to access this service.

In the *on-demand* business model, the additional service or information during the use of the product is available when required by customers. The example of this type of business model is Philips Hue, the residential lighting system discussed in the study of Gerpott and May (2016). Philips Hue is a personal wireless lighting system in which IoT technology facilitates the connection between LED light bulbs to smartphones or personal devices. This allows the lighting system to be controlled remotely by the user. The LED light bulb and IoT technology, such as control units and connected bridges, are sold as premium-priced packages, whereas the light bulbs themselves are sold more cheaply on their own.

Summarising, add-on business models are defined by the provider offering digital services in addition to the utility of existing physical goods or services, which are augmented by IoT technology to enable a service offering that provides additional utility. To access the additional IoT-enabled service, customers need to purchase the main physical good or service first however, and, in some cases, pay a premium to access the IoT-enabled service.

4.1.2 The Sharing Business Model

In this business model, the customers pay for using or accessing a product for a limited amount of time, which allows different users to continue using the product when it is available – this corresponds to a type of use-oriented PSS according to Tukker's (2004) classification. From the perspective of the provider, this increases asset utilisation, but the provider is responsible for making sufficient products available for the customers to access. As ownership of the physical good providing utility to the customer remains with the provider and users change, this business model is conceptually close to renting. However, Firnkorn and Müller (2011) and Alfian, Rhee, and Yoon (2014) argue that sharing business models generate more frequent changes of ownership and shorter use periods than their traditional renting counterparts. When comparing traditional car renting and free-floating car-sharing schemes for example, this is achieved by allowing the vehicles to be cycled among customers without being returned to the provider after each use, precluding the need for booking requirements, and by enabling more accurate use and payment by utilising mobile applications and technology to track product use.

A representative case study of a sharing business model is Car2Go, an innovative car-sharing scheme that, in comparison to traditional car renting, features shorter and previously unspecified use times. Instead of collecting the car from the store, the customer will be able to access the car at the nearest available public parking point (Leminen et al., 2012; Rong et al., 2015). Car2Go uses IoT technology in their vehicles to allow customers to locate the nearest available cars, unlock it, and drive it from that point via mobile applications. After use customers can then return the car to the nearest car park, allowing different customers to continue using the available car. According to the present literature, sharing business models featuring IoT technology are currently only reported in B2C, although this business model is likely to be transferred to B2B contexts.

4.1.3 The Usage-based Business Model

Usage-based business models use IoT to measure the amount of product usage and allow customers to pay for or subscribe to the plan, based on their actual usage and needs. The provider is then responsible for delivering the expected utility in use. This can be considered as a result-oriented model in a traditional PSS business model as the service that firms offer to the customer has a certain result or outcome (Tukker, 2004). In this case providers can adopt two types of business models, namely pay-per-use and subscription, which can be applied in the context of both B2B and B2C.

In the *pay-per-use* business model, the customer is only charged for the actual usage or consumption of the product or service. In order to promote this business model, the provider will require IoT technology to monitor and measure the product during its usage. The case example of this business model is provided by Fleisch et al. (2014) in a B2C context. Brothers, a computer accessories manufacturer, offers managed print services where customers can choose to pay per page for their printing regardless of the amount of ink they use. Customers can lease or purchase the printers and then pay per page for the printing. Brothers will monitor the ink level remotely through IoT and automatically provide new ink cartridges to customers, which also enables the return and recycling of used ink cartridges afterwards.

In the *subscription* business model, the customer is charged for unlimited access to the product or service, restricted to the time span of a subscription. Customers will need to pay a fee for being able to access the product or service. For example, Bucherer and Uckelmann (2011) report a case study of an information service provider in a B2B context, who offers information services on verification and detection of counterfeit spare parts in the machinery and equipment industry. After purchasing this service through a monthly subscription, customers may access a database containing aggregated information from a variety of sources. This database allows the customer to verify the authenticity of a product via serial numbers.

4.1.4 The Solution-oriented Business Model

The solution-oriented business model refers to business models that utilise IoT in enabling the provision of solutions to customers. With the aid of IoT technology, providers are able to offer integrated solutions to customers' needs, which in B2B practice relate to supporting customers' core operations and increases in efficiency, and expanding business capabilities (Kralewski, 2016; Noventum, 2016). Hence, this business model corresponds to the result-oriented PSS, where firms make agreements with customers in order to deliver a specified outcome or result (Tukker, 2004). Solution-oriented business models in the context of IoT can be divided into two types, i.e. availability and optimisation/consulting, which are available in the B2B context.

In the *availability* business model, providers offer customers a guaranteed continuous utilisation and uninterrupted usage of products that provide a specified utility. The provider is responsible for product maintenance and operational support to ensure that the products are able to provide such utility without interruption during the contract. By adopting IoT technology, providers are able to access real-time information about the product status, allowing them to offer more effectively undertaken maintenance and other supporting services (Noventum, 2016). Noventum (2016) provides a case study of Agfa HealthCare, a healthcare provider, that uses IoT to remotely monitor imaging hardware and software to respond to faults faster.

In *optimisation/consulting* business models, the service providers utilise IoT in monitoring the current usage of the product and analysing the pattern of operations in order to provide solutions and/or advice to the customer's core business operations, e.g. optimisation of the operations. This means the providers not only ensure the availability of the product but also support the customer's processes and operations. An example of an optimisation/consulting business model is reported in a study by Rymaszewska et al. (2017). A provider of sheet metal machinery in Finland that originally focused on designing and selling complex machines has since transitioned to provide product-service offerings with the adoption of IoT technology. With the aid of IoT, the provider remotely monitors the actual daily performance of connected machines at customers' sites. This allows firms to offer long-term contracts through the provision of remote support and optimisation of their customer's production schedule. This means that the provider is responsible for the installation and scheduled maintenance, and can help customers optimise their production and increase asset utilisation to reduce operating costs. Thus, instead of buying ownership of the machine, customers pay for the integrated solution to a business function through long-term contracts.

4.2 Roles of IoT in IoT-enabled servitized business models

Based on the analysis of the SLR, the roles of IoT in enabling servitized business models can be categorised into two levels: firstly an operational level, which involves the functionalities of IoT used in offering services, and secondly a strategic level where the roles of IoT are classified according to how they are strategically used by firms in enabling a service. These will be discussed in the following sections.

4.2.1 Operational roles

Seven roles of IoT used in enabling services at the operational level were extracted during the literature review. Each operational role of IoT has been used to support different types of IoT-enabled servitized business models as illustrated in Table 4 with supporting references. These will be discussed in this section.

Table 4: Operational roles of IoT, corresponding to each type of IoT-enabled servitized business model

IoT-enabled Servitized Business Model		**Operational roles of IoT**						
		1.Responsive Maintenance	2. Proactive Maintenance	3. Optimisation of operations	4. Remote control	5. Autonomous management	6. Track and report real-time information remotely	7. Monitor customer's usage behaviour
Add-on	Innovative digital service				(50)	(4)(31)	(16)(21)(26)(31)(34)	(21)
	Facilitate service provision				(8)		(4)(5)(7)(16)(12)(28)(31)(32)(37)(39)(41)(68)	(39)
	Leverage customer data				(38)		(1)(2)(7)(38)(40)(57)(65)(68)(70)(74)	(2)(4)(7)(8)(13)(17)(20)(21)(32)(33)(35)(38)(40)(42)(47)(52)(53)(59)
	On-demand		(45)		(2)(6)(21)(31)	(26)(31)	(2)(5)(7)(15)(21)(24)(30)(31)(34)(44)(52)(55)(59)(68)	(16)(26)(34)
Sharing							(3)(5)(8)(11)(22)(24)(27)(29)(30)(31)(54)(60)	(5)(24)(31)
Usage-based	Pay-per-use					(31)	(3)(61)(70)	(3)(7)(8)(31)(34)(60)(61)(64)
	Subscription						(3)(43)(61)	(3)(34)(61)
Solution-oriented	Availability	(10)(27)(43)(58)(60)	(8)(18)(27)(34)(36)(40)(43)(47)(48)(51)(60)		(10)(18)(27)	(44)	(7)(34)(58)	
	Optimisation/Consulting		(3)(9)(25)(27)(36)(49)(56)(63)(67)(70)(73)	(3)(23)(27)(34)(36)(38)(46)(48)(49)(56)(60)(62)(63)(70)(72)(73)	(27)(38)(47)(60)(62)(67)(70)	(27)(47)(60)	(3)(7)(23)(38)(48)(56)(58)(62)	(27)(36)(62)

The number presented in the table corresponds to the paper number listed in Appendix A.

The colour represents the total number of papers allocated in the cells (i.e. White – 0-2 papers, Light grey – 3-5 papers and Dark grey – 6+ papers).

Responsive maintenance refers to maintenance and repairs after a machine has already broken down. The literature suggests that IoT allows firms to monitor the condition of machine or product at the customer's site where firms can respond to the breakdown promptly to ensure that it returns to its normal operating condition to minimise interruption (Noventum, 2016; Zancul et al., 2016). Proactive maintenance includes the use of IoT technology to monitor and gain detailed product insights, which helps firms deal with the problems of machines or products before they occur (Noventum, 2016). Optimisation of operations is where IoT-embedded devices and products capture the insight and operational data of the products, the use of algorithms and data analytics tools for the product operations, and the capacity utilisation and performance to be optimised (Ardolino et al., 2016; Lee & Lee, 2015; Noventum, 2016; Porter & Heppelmann, 2015). Remote control means that the product embedded with IoT allows firms to monitor the product to diagnose and rectify or repair non-complex problems remotely (Cedeño et al., 2018; Paluch, 2014). Here not only do service providers utilise IoT to remotely control the product, but the customer may be able to remotely control various components of the connected product, which may be regarded as an additional service provided by the provider (Lee & Lee, 2015).

Autonomous management can be considered as a high-level capability of the IoT-embedded product. In this role, IoT will be utilised to enable autonomous operations, automated decision-making, and self-diagnosis (Porter & Heppelmann, 2015; Wünderlich et al., 2015). This means that the IoT-embedded products have their own capabilities to decide whether or not to perform particular functions such as self-maintenance without human intervention (Ardolino et al., 2016; Lee et al., 2014). Another role of IoT is to track and report real-time information remotely, where IoT is used to monitor aspects of the product such as the current location or usage measurement, and then report the relevant information to customers as required during product usage (Ardolino et al., 2016; Leminen et al., 2012). Finally, monitoring customer's usage behaviour means that IoT is used to observe product usage patterns (Ardolino et al., 2018; Parry et al., 2016). These data are usually utilised by firms in order to offer personalised services.

According to the thematic result shown in Table 4, add-on business models currently primarily use the tracking and reporting real-time information remotely in order to offer appropriate services by fitting the product in question as part of an additional innovative service offering to the customer. However, in the leverage customer data business model, IoT is predominantly used to monitor the customer's product usage behaviour. This is because, in order to enable the service, firms need to understand how the product is being used by the end customer. Similarly, in the sharing business model, IoT is used to track and report the real-time information, especially the information about the location of the product and the amount of product usage. This helps to support the customer in using and purchasing the service. In the usage-based business model, IoT is mostly used to monitor customer's usage behaviour in order to allow firms to offer the service, based on the amount of usage. However, in the solution-oriented business model, IoT is used to help firms with the product's maintenance and support the customer's operation. For the availability business model, the main role of IoT used is proactive maintenance, where it will notify a firm to undertake the maintenance before the machine is actually broken. For the optimisation and consulting business model, IoT is used to help firms in supporting customers' operations and providing solutions through the optimisation function.

4.2.2 Strategic Roles

According to Gerpott and May (2016), there are three strategic roles of IoT used in enabling servitized business models: smoothing, adaptation, and innovation. In a smoothing role IoT is used to help initiate and facilitate the service and transaction, which reduces overall transaction costs; however, IoT is not used for a substantive part of the product-service offer itself. In an adaptation role IoT is used to enable additional functionalities to the standalone product or service, which significantly increases the value of the product or service, but is not the main value driver. In an innovation role IoT is used to enable the functionalities of product or service that have not been previously offered, as they depend on IoT – it is the main value of product-service offerings here. Table 5 illustrates the strategic roles used in the different types of IoT-enabled servitized business models, based on the case studies presented in section 4.1.

Table 5: Strategic roles of IoT, corresponding to each type of IoT-enabled servitized business model, based on the case study examples

IoT-enabled Servitized Business Model		**Strategic Roles of IoT**		
		Smoothing	Adaptation	Innovation
Add-on	Innovative digital service			Nike FuelBand – Wearable fitness monitoring
	Facilitate service provision	Geis Group – Intelligent logistics		
	Leverage customer data		Bundles – Connected washer	
	On-demand		Philips Hue – Personal wireless lighting system	
Sharing		Car2Go – Car sharing service	Car2Gether – Car sharing system integrated in the public mobility chain	
Usage-based	Pay-per-use		Brothers – Managed print services	
	Subscription	Information service provider		
Solution-oriented	Availability		Agfa HealthCare – Guaranteed availability service	
	Optimisation/Consulting			Machinery provider – Solution provider

4.3 Benefits of IoT-enabled servitized business models

Based on the SLR, nine benefits of IoT-enabled servitized business models from a firm's perspective have been identified. These benefits correspond to different types of IoT-enabled servitized business models and are illustrated in Table 6 with supporting references.

The literature suggests that adopting IoT technology allows firms to offer additional services or features to the existing product or service. Hence, firms can generate additional revenue from these services (Dijkman et al., 2015; Harvard Business Review Analytic Services, 2014; Kralewski, 2016; Rachinger et al., 2018) and generate income more steadily as long-term contracts replace sales (Helo et al., 2017; Kralewski, 2016; Zancul et al., 2016). It is presented in the literature that the use of IoT in enabling services helps firms to reduce the resources used in providing services, e.g. labour costs, as fault diagnosis can be conducted remotely. Thus, firms may benefit from reduced operating costs (Harvard Business Review Analytic Services, 2014; Hasselblatt et al., 2018; Herterich et al., 2015a; Noventum, 2016). Furthermore, the adoption of IoT-enabled services can lead to, or maintain, a closer relationship with customers as IoT enables customers to co-create value with the provider, allowing the provider to offer a customer-oriented service (Hagberg et al., 2016; Paluch, 2014). Furthermore, the adoption of IoT technology allows firms to offer long-term solutions which create significant value to customers and hence, lead to a deep relationship between customers and firms (Noventum, 2016; Porter & Heppelmann, 2015). In addition, the incorporation of IoT components allows firms to extend their portfolio of products and services (Gerpott & May, 2016). As a result, firms will be able to extend their current business (Ardolino et al., 2016; Kralewski, 2016; Rymaszewska et al., 2017). Furthermore, IoT can be leveraged to improve the current service offerings, since by adopting IoT technology, firms can provide the offering in a way that is perceived to be more convenient by the customer. Moreover, since IoT enables firms to gain an insight into product usage behaviour and resource usage rates, firms can improve their resource utilisation with this information (Bressanelli et al., 2018; Parry et al., 2016). Firms will also gain competitive advantage from providing an IoT-enabled service. This is because the fusion of technology and integrated product-service offering is difficult for competitors to imitate (Kaňovská & Tomášková, 2018; Noventum, 2016; Porter & Heppelmann, 2015). Finally, firms will be able to assess the risks of their current product or service provision. Apart from extending service offerings, firms can leverage IoT opportunities to continuously estimate their current service provision in order to identify optimal support for customers, which in turn leads to a profitable service portfolio (Noventum, 2016).

Table 6: Firm's benefits corresponding to each type of IoT-enabled servitized business model

IoT-enabled Servitized Business Model		**Firm's benefits**								
		1.Generate additional revenue	2.Generate steady income	3. Reduce operating cost	4. Maintain long-term relationship with customers	5. Extend firm's current business	6. Improve product-service offerings	7. Increase resource utilisation	8. Gain competitive advantage	9. Assess the risks of current product or service provision
Add-on	Innovative digital service	(21)		(50)		(4)(21)(34)(50)	(21)(26)		(21)	
	Facilitate service provision	(32)		(2)(8)(21)(39)(41)(68)	(32)	(4)(32)(37)	(2)(5)(28)(31)(39)		(68)	
	Leverage customer data	(13)(17)(21)(32)(65)(71)	(20)	(2)(8)(21)(65)(66)(74)	(32)(57)(70)	(4)(20)(32)(35)(52)(53)(55)(57)(65)(74)	(1)(2)(7)(8)(13)(17)(20)(38)(40)(42)(47)(53)(57)(59)	(35)	(1)(13)(21)(33)	(8)(35)
	On-demand	(17)(24)		(5)(52)(68)	(15)	(5)(15)(31)(34)(52)(60)	(2)(24)(30)(31)(52)(59)(60)		(6)(21)	
Sharing				(3)			(5)(24)(29)(31)	(11)(54)		
Usage-based	Pay-per-use			(7)(8)(60)(64)	(70)	(3)(31)(61)	(61)	(45)(61)	(45)	
	Subscription		(34)(43)			(3)(61)	(61)	(61)		
Solution-oriented	Availability	(34)(36)	(43)(48)	(7)(10)(18)(34)(36)(43)(44)(51)(58)(60)	(10)(51)	(19)(43)(48)	(19)(48)		(3)(19)(36)	(19)(27)(36)
	Optimisation/ Consulting	(51)(67)(72)(73)		(7)(9)(48)(60)(62)(63)(67)	(25)(36)(49)(70)(73)	(19)(34)(36)(48)(56)	(19)(46)(48)(63)(67)	(56)(62)	(19)(23)(36)(56)(67)(73)	(27)(34)

The number presented in the table corresponds to the paper number listed in Appendix A.

The colour represents the total number of papers allocated in the cells (i.e. White – 0-2 papers, Light grey – 3-5 papers and Dark grey – 6+ papers).

4.4 Inhibiting factors of IoT-enabled servitized business models

Eight inhibiting factors were extracted from the literature, which require to be addressed by providers considering adopting IoT-enabled servitized business models. The inhibiting factors corresponding to different types of IoT-enabled servitized business model are illustrated in Table 7 with supporting references.

Table 7: The inhibiting factors corresponding to each type of business model

IoT-enabled Servitized Business Model		Inhibiting Factors							
		1. Privacy concerns	2. Data security	3. Require close collaboration with different stakeholders	4. Require new ways of customer interaction	5. Require skills and expertise in data management	6. Technical issues	7. High upfront capital investment	8. Develop innovative offerings that align with customers' needs
Add-on	Innovative digital service	(7)(16)(21)(26)(50)	(7)(16)(21)(26)	(7)(50)	(50)	(7)(21)	(4)(50)(68)	(4)(31)	(4)(50)
	Facilitate service provision	(8)(16)	(8)(16)	(66)	(28)(32)(41)	(8)	(2)(4)	(4)(41)	(4)(37)(39)
	Leverage customer data	(8)(20)(21)(35)(53)(71)	(8)(20)(21)(33)(35)(53)(57)(71)	(1)(13)(17)(42)(57)(65)(68)(71)(74)	(13)(47)(70)	(8)(21)(35)(57)	(2)(4)(57)	(1)(4)	(1)(4)(33)
	On-demand	(16)(21)(26)(30)(55)	(16)(21)(26)(30)(55)	(5)(6)(15)(22)(31)(59)(68)	(59)	(21)	(2)(5)(55)	(55)	(6)
Sharing		(5)	(5)	(3)(5)(24)(29)(54)	(3)(29)	(11)	(5)		
Usage-based	Pay-per-use	(7)(8)(60)	(7)(8)(60)	(3)(45)	(5)(8)(45)(70)	(3)(5)(7)(8)	(60)(64)	(45)	(45)
	Subscription					(3)			(44)
Solution-oriented	Availability	(7)(10)(34)(40)(51)	(7)(10)(34)(40)(51)	(7)(18)(19)(27)(36)(58)(60)	(26)(40)(44)	(7)	(10)(18)(48)(58)(60)	(34)	(26)(40)(43)
	Optimisation/Consulting	(7)	(7)(23)	(7)(19)(23)(25)(27)(36)(44)(46)(49)(60)(63)(69)(72)(73)	(23)(26)(46)(62)(63)(69)(70)(72)(73)	(3)(7)(48)(63)(72)(73)	(9)(25)(62)	(23)(49)(62)	(26)(46)(56)(63)(67)

The number presented in the table corresponds to the paper number listed in Appendix A.

The colour represents the total number of papers allocated in the cells (i.e. White – 0-2 papers, Light grey – 3-5 papers and Dark grey – 6+ papers).

One challenge for providers is privacy concerns, as IoT allows firms to access and collect information that may be sensitive for customers (Klein et al., 2017; Wünderlich et al., 2015). Hence, firms need to ensure that sensitive information is protected – this, however, may be difficult if services are offered in partnership with third parties, for example, if repair functions are outsourced (Fleisch et al., 2014). This is related to the problem of data security, and providers will be required to invest in resources that restrict access to data to legitimate parties only (Paluch, 2014).

This relates to the next inhibitor – close relationships and collaboration between different stakeholders in the service network may be required to enable IoT-enabled business models (Leminen et al., 2012; Tuunanen et al., 2015), examples of which include partners who are experts in IoT technology being required to implement servitized business models (Ardolino et al., 2018; Noventum, 2016). The ensuing networks can be expected to be complex, and feature coordination costs and risk from the perspective of the customer-facing provider, especially in the case of solution-oriented business models, where utility is guaranteed through contracts (Leminen et al., 2012).

Furthermore, new provider-customer interaction skills need to be developed as it is required for providers to communicate to understand and verify the value being expected by customers (Hasselblatt et al., 2018). This is because in order to successfully leverage IoT benefits, providers need to be able to feed gathered data from connected products into propositions that help to solve customer needs (Carpanen et al., 2016; Harvard Business Review Analytic Services, 2014). Therefore, skills and expertise in data management are required. As IoT products generate a large amount of data, it is important for firms to develop capabilities to analyse those data and make them usable by customers when providing data-driven services (Bucherer & Uckelmann, 2011; Fleisch et al., 2014; Lee & Lee, 2015).

Another inhibiting factor that firms need to consider is technical issues. These issues refer to the lack of interoperability and compatibility of the systems among all stakeholders in the service network, and problems stemming from the relative immaturity of the technology itself (Herterich et al., 2015a; Paluch, 2014; Risteska Stojkoska & Trivodaliev, 2017; Wiesner et al., 2017).

The high upfront capital investment required is another factor that needs to be considered. As there is a high cost associated with embedding sensors in products, which requires new product designs, and then implementing the data into an IoT infrastructure, this could inhibit firms from adopting IoT-enabled servitized business models (March & Scudder, 2017; Porter & Heppelmann, 2015).

Finally, firms need to be able to develop an innovative offering that aligns with customers' needs to unlock the majority of the previously stated benefits. In order to provide the service offering according to IoT opportunities, firms based on the arms-length selling of physical goods will face the challenge of changing their existing business models comprehensively. Thus, firms need to be able to identify the right strategy in order to offer an attractive service provision that leads to a financially viable business model (Takenaka et al., 2016; Wünderlich et al., 2015).

5. Discussion

The descriptive analysis shows that research activity on the topic of IoT-enabled servitized business models has increased markedly over the recent years, a trend that can be expected to continue. However, while the term IoT is defined, knowledge is highly fragmented and the topic has been approached from a variety of angles and in a number of journals. In the thematic analysis the lens of servitization and PSS has been shown to be effective in structuring the knowledge according to the archetypes of business models that have emerged, and it is likely that the field will consolidate in publications covering the three primary components: (industrial) marketing, operations management, and technology utilisation, as the viability and configuration of the emerging business models are decided within this nexus. Looking at the number of studies allocated to either of the identified business models, the majority of scholars have focused on add-on business models, as these are most frequently encountered in practice, with solution-oriented a close second. However, with regard to publications looking at sharing and usage-based business models, only nine and six contributions can be reported respectively.

Based on cross-tabulating the thematic results, in terms of the operational and strategic roles of IoT, inhibiting factors and benefits, with their respective business models, the summary of relationships between the IoT-enabled servitized business model, as synthesised from the literature, is illustrated in Figure 4.

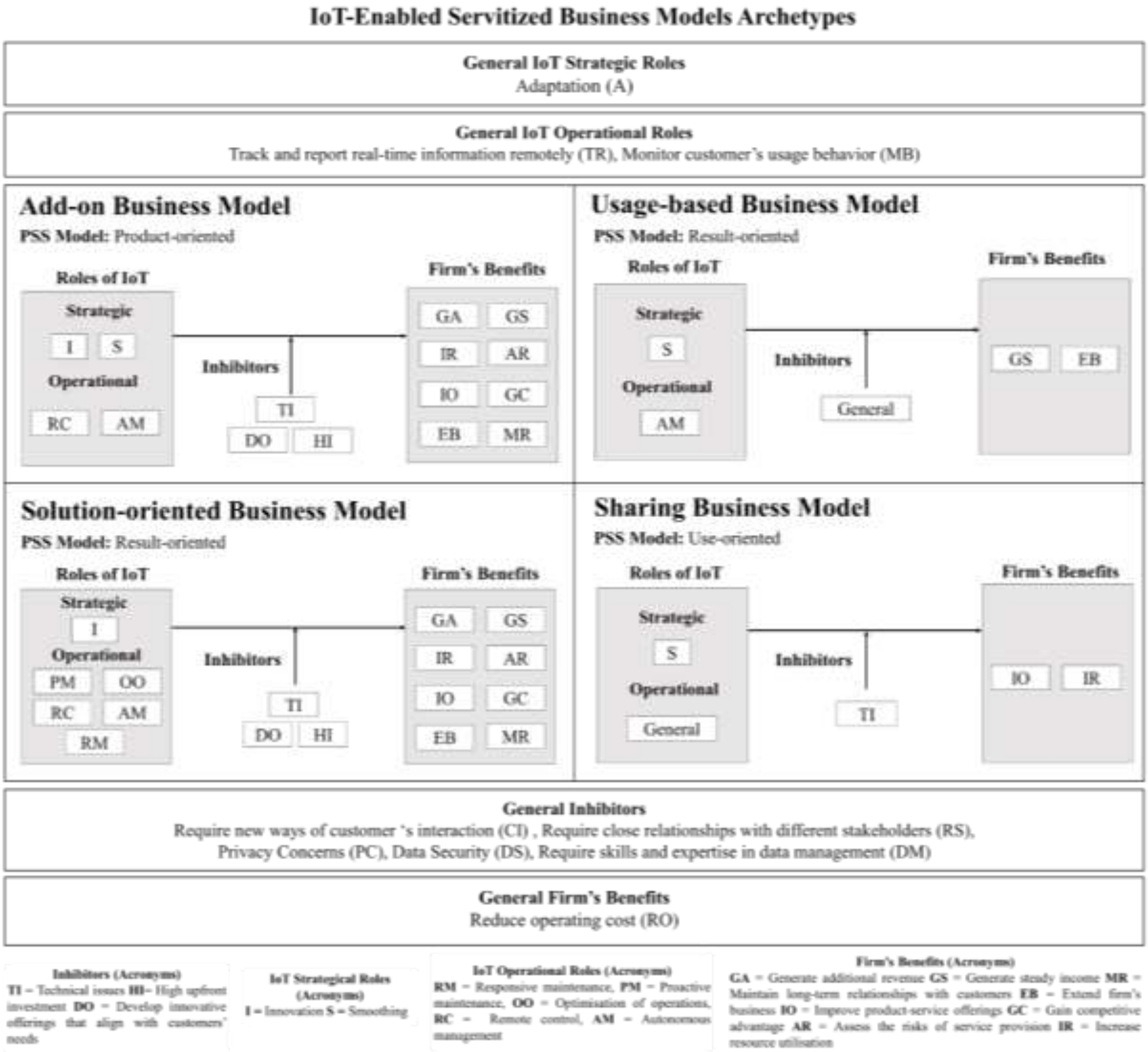

Figure 4: Archetypes of IoT-enabled servitized business model

Regarding the interpretation and implication of the established framework in B2B contexts, five propositions were formulated based on the interaction between the variables in the framework.

Firstly, the framework suggests that certain types of PSS are better aligned with particular types of IoT-enabled business models. Add-on business models provide product-oriented PSS and offer additional services to their core products. For example, manufacturers provide more efficient repair or maintenance services as an add-on to their equipment in order to support their operational function. Sharing business models are associated with use-oriented PSS since the customers pay for using the product. However, the case example of this business model is only reported in the B2C transportation context of car-sharing. This could be because it is not feasible to share the high-value manufacturing equipment for very short-term use because of high transportation and transaction costs that are significantly lower with personal vehicles. Manufacturing firms could explore more opportunities, for example, instead of sharing the product, firms might share the information obtained from the product. However, usage-based business models and solution-oriented business models are aligned with result-oriented PSS as firms offer the functional result to customers through pay-per-use, subscription or long-term contract. These can be expected to suit manufacturers who are already offering traditional result-oriented PSS and adopting IoT may help them further improve their value propositions. For these firms, it is important to design an IoT-enabled business model that supports their current stage of PSS offering.

Proposition 1: The type of IoT-enabled business models must be aligned with the type of PSS offering.

Secondly, according to Figure 4, the general strategic role of IoT in all identified business models is adaptation, which means firms leverage IoT to enable additional functionalities to an existing product or service. This illustrates that all types of business models use IoT to extend the scope of their current offerings. Furthermore the four business models' archetypes, except for the solution-oriented business model, use IoT in the smoothing role, which refers to the lowering of transaction costs through easier interaction between provider and customer. Cases featuring the innovative role of IoT that not only affects the value offering itself but also the underpinning business model are reported less and are only adopted in add-on and solution-oriented business model cases. The reason for this is likely to be that in the other business model archetypes there is no scope to use IoT in a truly innovate role and it appears that the introduction of IoT will not result in comprehensive changes to these business models or PSS offerings. This shows that using IoT in a strategic role to enable a business model does not necessarily result in an innovative PSS.

Proposition 2a: The strategic roles of IoT in innovation and smoothing need to be aligned with the type of IoT-enabled business model.

Proposition 2b: The strategic role of IoT in adaptation is integral to all types of IoT-enabled business models.

Thirdly, in terms of IoT's operational roles, all business models adopt IoT for tracking and reporting real-time information of the product or service remotely. Solution-oriented business models use the full suite of operational roles here, which may be explained by their offers being designed and provided in a more integrated way, and thus featuring more sensor capability and being more crucial to the business model overall. Diebold, an ATM solutions manufacturer, for example, utilises IoT to monitor and assess its ATM's status in real-time for providing availability service. In addition, Diebold can retrieve a detailed diagnosis of the problem for predictive maintenance, which gives the possibility to remotely repair when its ATM starts malfunctioning. Hence, various operational roles are required in this case. The case of sharing business models seems to utilise the least operational opportunities provided by IoT technology. This is because current service offerings provided in the sharing business model are limited and this may be seen as scope to enable other services through more integration of IoT.

Proposition 3a: The operational role of IoT needs to be aligned with the type of IoT-enabled business model.

Proposition 3b: The more complex solution-oriented business model requires IoT to support a broader range of operational roles.

Fourthly, by considering the spread of a firm's benefits, only a reduction in operating cost is a benefit that applies to all types of IoT-enabled business models. As illustrated in Figure 4, IoT enables usage and sharing business models to maintain and manage assets more efficiently. In the case of sharing this allows for smoothing revenue flows and reaching additional customers. Opportunities for add-on and solution-oriented business models are higher, as IoT technology is integrated further with the value offering. The variety of potential benefits reported in the literature are diverse; under which circumstances these are achieved in practice is uncertain but the inhibitors proposed here are a starting point for future research. The creation of more diverse and unique services, and subsequent capture of generated value for add-on business model cases, as well moving down the supply chain for solution-oriented business models, are the ultimate goals. It has been shown that IoT technology can aid in this journey. GE aviation, for example, utilise IoT to monitor and analyse engine data at the point of operation, helping the airline companies to optimise their flight operations and increase the efficiency of their aircraft utilisation. As a result, GE is now able to offer services directly to its end customers, which deepens the relationship with its customers and reduces the power of its immediate customer, the airframe manufacturer (Porter and Heppelmann, 2015).

Proposition 4: The type of IoT-enabled business model determines the types of benefits potentially realised by the firm.

Fifthly, when the strategic IoT role of innovation is adopted, there are additional inhibiting factors. These factors include the task of developing innovative offerings that align with customer needs, as well as a high upfront investment, which may dissuade firms from implementing solution-oriented business models and add-on business models. This is because applying IoT in an innovative role requires firms to enter new markets or offer advanced service offerings, which substitute non-IoT enabled products (Gerpott & May, 2016). For example, when Xerox invested in IoT technology to enable the shift from selling printers to offer "Managed Print and Content Services", it required Xerox to change its value proposition by providing a service offering that transformed the customers' needs for existing product or service (Noventum, 2016). In addition, this new service business model needs to be supported by the customers' digital environments as IoT is integrated to help optimise their document management and reduce printing needs. Such changes in the value proposition of the core business of a firm include risk. Developing products and business models that incorporate IoT technology seamlessly to target specific customer needs remains a challenge and further research is needed to determine what customers may value. It has been shown that at this point insights from both the B2C and B2B context are valuable as the underpinning technology based on sensors and subsequent information gathering, distribution, and utilisation, remains comparable. The usage and sharing business models actually encounter the least number of inhibitors as IoT technology is used purely in an information gathering and distribution function to manage the physical good, while the other business models attempt to use the technology to augment the utility of the product-service bundle. However, this finding may be challenged as more studies on usage-based and sharing business models featuring IoT technology are reported.

Proposition 5: The strategic role of IoT in innovation supports a wider range of benefits to the firm, but is more disruptive and has to overcome more inhibiting factors.

6. Conclusion

This study has investigated the literature on the interchange of IoT and how this technology fits into servitized business models. It has been shown that four archetypes and nine subcategories describe the current range of IoT-enabled servitized business models, with IoT technology contributing to either the operational side of how value is delivered, or what kind of value is delivered at a strategic level. A variety of inhibiting factors preventing the widespread adoption of IoT-enabled business models, as well as benefits that might drive such an adoption, have been outlined and attributed to their respective subcategories. Lastly, this study provides an overview of examples of such business models where they have achieved success in practice.

6.1 Implications for theory

The synthesised framework and five propositions presented in this paper are further steps in developing the theory base relating to the role of IoT in supporting servitized business models. It looks beyond individual papers, to present a more holistic view achieved through the SLR methodology. There are three main theoretical contributions.

Firstly, the current adoption of IoT-enabled business models is associated with different stages of servitization along Tukker’s (2004) product-service continuum. Previous studies have identified the main elements of business models and business model frameworks that support IoT technology application (Dijkman et al., 2015; Kralewski, 2016; Leminen et al., 2012). This study reflects these through the lens of servitization. Manufacturers are recommended to design their IoT-enabled business model to align with an appropriate PSS offering. Add-on business models fit with product-oriented PSS where manufacturers can provide product-related services such as maintenance, warranties or product training more efficiently with the aid of IoT. Sharing business models which are associated with use-oriented PSS seem more suitable for adoption in a B2C context. There are currently no reported applications in the B2B context and it is not clear whether applications here are commercially feasible. Usage-based and solution-oriented business models suit result-oriented PSS and manufacturers tend to exploit their existing capability in designing services to align with their customer needs. IoT is commonly leveraged to capture information on customer operations.

Secondly, it is also suggested that an integration of IoT in business models will accelerate manufacturers' adoption of servitization. This means that when opportunities of IoT technology are seized, manufacturers move towards service-based business models. Moreover, since a successful adoption of IoT-enabled business models is easier for manufacturers that already successfully provide servitized offerings, IoT will increase the performance gap between pure product and more servitized manufacturers. This challenges pure product manufacturers to decide on their strategy for the utilisation of IoT application to support the innovation of their product manufacture or the integration of service with the product.

Thirdly, the business models that provide temporary usage rights to customers, including usage-based and sharing business models, will be less influenced by IoT technology compared with add-on and solution-oriented business models, which are at the extreme ends of a product-service continuum. Therefore, this study suggests that manufacturers have higher potential to leverage IoT integrated with their servitized offerings that fit either the add-on business model or solution-oriented business model.

6.2 Implications for practice

This paper suggests a number of managerial implications for manufacturing firms who consider adopting IoT integrated with servitized business models. Regarding the application of IoT, there are two ways that IoT can be used in promoting servitized business models. Initially manufacturers can augment IoT into their existing servitized offerings and make these more efficient for customers to retrieve and also help firms to drive down their operating cost. For example, the manufacturers who currently provide a maintenance service for their customers can aim to use IoT to monitor and obtain an insight into information on their products remotely at the customer's site to help them manage their maintenance schedule more efficiently, which reduces their overall service costs. Manufacturers can also aim to integrate IoT in the design of an innovative servitized offering which is fundamentally based on IoT technology. Manufacturers should consider utilising IoT as a core element in offering advanced product-service bundles that support their customers' core business process. However, this option is more appropriate for manufacturers who are already on the service side in the product-service continuum. This is because this option relies heavily on close collaboration between multiple actors involved in advanced service provision and hence, the difficulties in organisational change would be less for manufacturers who currently offer a service-based provision as their main value proposition.

Given the complexity of adopting a solution-oriented business model in practice, the add-on business model is likely to be the largest beneficiary of IoT technology in the near future. Pure manufacturers are encouraged to start integrating IoT technology with the adoption of an add-on business model as this is less complicated while similar benefits (e.g. additional revenues, develop competitive advantage and maintain good relationships with customers) can be obtained. However, in order to realise these benefits, manufacturers need to overcome two main types of inhibiting factors: the technical side of IoT and the change in value chain network design. In this case manufacturers will need to develop capabilities in building an IoT infrastructure that not only supports a useful product usage data capture but also ensures the privacy and security of this data, which contributes to high upfront investment costs. Furthermore, manufacturers will have to design their service offerings to maximise customer value, which may require an involvement of different strategic partners (e.g. technology and service partners) and a change in their position in the value chain.

Overall, the main practical contribution of this study is to highlight that pure product manufacturers need to seize the opportunities presented by IoT and start transitioning towards add-on business models in order not fall behind already more servitized manufacturers.

6.3 Limitations and future research

As is the case in all research, this study has some limitations. Firstly, the SLR is conducted at a point in time when the IoT concept and IoT-enabled servitized business models are in their infancy. The authors of this paper have made full use of the existing studies to arrive at a conceptual framework and formulate propositions which are appropriate to guide future research. However, it is acknowledged that as the body of knowledge expands, parts of this literature review are likely to be contested. This can be expected especially in the area of usage-based and sharing business models, where currently fewer publications are available for review.

Secondly, it is likely that state of the art IoT technology and its role in business models in practice has advanced beyond what is reflected in the academic literature reviewed in this paper. While conferences proceedings, chapters of edited books, and business reports were included in the review to narrow this gap, it should be assumed that industry has found additional applications for IoT technology which have not been captured in this paper due to a lack of reliable published information about them.

Thirdly, this paper only focuses on the benefits of IoT-enabled servitized business models from a provider's perspective and thus future research should address the benefits of each business model from a customer's perspective, as acceptance of such business models is also likely to depend on customer perception.

Lastly, as emerged from the proposed propositions, in order to adopt IoT-enabled servitized business models, manufacturers are required to decide on the role of IoT for value creation and the choice of IoT-enabled servitized business model that suits them, since they have different inhibiting factors to overcome. The decision and strategy from manufacturers at different points of the product-service continuum are likely to be different, as their resources (e.g. human resources, physical resources and knowledge) and capabilities (e.g. managerial capabilities and technical capabilities) to manage these resource differ. Hence, future research could extend the work here by taking the perspective of the resource-based view or dynamic capabilities to investigate how pure manufacturers and servitized manufacturers can exploit their existing resources and capabilities to successfully implement an IoT-enabled servitized business model.

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Appendix

Appendix A: The coverage of four types of business model, corresponding to the paper

	Author (s)	IoT-enabled servitized business model			
		Add-on	Sharing	Usage-based	Solution-oriented
1	Bohli, Sorge, and Westhoff (2009)	*			
2	Haller, Karnouskos, and Schroth (2009)	*			
3	Bucherer and Uckelmann (2011)		*	*	*
4	Mejtoft (2011)	*			
5	Leminen, Westerlund, Rajahonka, and Siuruainen (2012)	*	*		
6	Li, Hou, Liu, and Liu (2012)	*			
7	Fleisch, Weinberger, and Wortmann (2014)	*		*	*
8	Harvard Business Review Analytic Services (2014)	*		*	
9	Lee, Kao, and Yang (2014)				*
10	Paluch (2014)				*
11	Schenkl, Sauer, and Mörtl (2014)		*		
12	Turber and Smiela (2014)	*			
13	Turber, Vom Brocke, Gassmann, and Fleisch (2014)	*			
14	Westerlund, Leminen, and Rajahonka (2014)	*	*	*	*
15	Andersson and Mattson (2015)	*			
16	Atzori, Iera, and Giacomo (2015)	*			
17	Dijkman, Sprenkels, Peeters, and Janssen (2015)	*			
18	Herterich, Uebernickel, and Brenner (2015a)				*
19	Herterich, Uebernickel, and Brenner (2015b)				*
20	Keskin and Kennedy (2015)	*			
21	Lee and Lee (2015)	*			
22	Mikusz (2015)	*			
23	Porter and Heppelmann (2015)				*
24	Rong, Hu, Lin, Shi, and Guo (2015)	*	*		
25	Tuunanen, Hänninen, and Vartiainen (2015)				*
26	Wünderlich et al. (2015)	*			*
27	Ardolino, Saccani, Gaiardelli, and Rapaccini (2016)		*		*
28	Balaji and Roy (2016)	*			
29	Carpanen, Patricío, and Ribeiro (2016)		*		
30	Dominici, Roblek, Abbate, and Tani (2016)	*	*		
31	Gerpott and May (2016)	*	*	*	
32	Hagberg, Sundstrom, and Egels-Zandén (2016)	*			
33	Hartmann and Halecker (2016)	*			
34	Kralewski (2016)	*		*	*
35	Parry, Brax, Maull, and Ng (2016)	*			
36	Noventum (2016)				*
37	Sassanelli, Seregni, Hankammer, Cerri, and Terzi (2016)	*			
38	Scholze, Correia, and Stokic (2016)	*			*
39	Shih, Lee, and Huarng (2016)	*			
40	Takenaka, Yamamoto, Fukuda, Kimura and Ueda (2016)	*			*
41	Vendrell-Herrero, Bustinza, Parry, and Georgantzis (2016)	*			
42	Wiesner, Hauge, Haase, and Thoben (2016)	*			
43	Zancul et al. (2016)			*	*
44	Zheng, Song, and Ming (2016)	*			*
45	Gebauer, Haldimann, and Saul (2017)			*	
46	Gierej (2017)				*
47	Green, Davies, and Ng (2017)	*			
48	Helo, Gunasekaran, and Rymaszewska (2017)				*
49	Kiel, Arnold, and Voigt (2017)				*
50	Klein, Pacheco, and Righi (2017)	*			
51	March and Scudder (2017)				*
52	Mikurz, Schafer, Taraba, and Jud (2017)	*			
53	Ng and Wakenshaw (2017)	*			
54	Nishino, Takenaka, and Takahashi (2017)		*		
55	Risteska Stojkoska and Trivodaliev (2017)	*			

	Author (s)	IoT-enabled servitized business model			
		Add-on	Sharing	Usage-based	Solution-oriented
56	Rymaszewska, Helo, and Gunasekaran (2017)				*
57	Saarikko, Westergren, and Blomquist (2017)	*			
58	Wiesner, Marilungo, and Thoben (2017)	*			*
59	Woodside and Sood (2017)	*			
60	Ardolino et al. (2018)		*	*	*
61	Bressanelli, Adrodegari, Perona, and Saccani (2018)			*	
62	Cedeño, Papinniemi, Hannola, and Donoghue (2018)				*
63	Hasselblatt, Huikkola, Kohtamäki, and Nickell (2018)				*
64	Heinis, Loy, and Meboldt (2018)			*	
65	Ibarra, Ganzarain, and Igartua (2018)	*			
66	Ikävalko, Turkama, and Smedlund (2018)	*			
67	Kaňovská and Tomášková				*
68	Leminen, Rajahonka, Westerlund, and Wendelin (2018)	*			
69	Metallo, Agrifoglio, Schiavone, and Mueller (2018)				*
70	Mittag, Rabe, Gradert, Kühn, and Dumitrescu (2018)	*		*	*
71	Pei Breivold and Rizvanovic	*			
72	Rachinger, Rauter, Müller, Vorraber, and Schirgi (2018)				*
73	Sayar and Er (2018)				*
74	Zheng, Lin, Chen, and Xu (2018)	*			

Appendix B: Analysis of papers according to journal and ABS category

ABS Fields	Journal	Number of publications	References
Operations and Technology management	Procedia CIRP	4	Herterich et al. (2015b); Ardolino et al. (2016); Scholze et al. (2016); Mittag et al. (2018)
	International Journal of Production Economics	3	Rong et al. (2015); Green et al. (2017); Rymaszewska et al. (2017)
	Business Process Management Journal	2	Dominici et al. (2016); Zancul et al. (2016)
	Technology Innovation Management Review	1	Westerlund et al. (2014); Ikävalko et al. (2018)
	Supply Chain Management: An International Journal	1	Parry et al. (2016)
	Journal of Cleaner Production	1	Risteska Stojkoska and Trivodaliev (2017); Zheng et al. (2018)
	International Journal of Automation Technology	1	Wiesner et al. (2017)
	Procedia Engineering	1	Gierej (2017)
	Procedia Manufacturing	1	Ibarra et al. (2018)
	CIRP Annals – Manufacturing Technology	1	Takenaka et al. (2016); Nishino et al. (2017)
	International Journal of Production Research	1	Ardolino et al. (2018)
	Journal of Manufacturing Technology Management	1	Rachinger et al. (2018)
	LogForum	1	Cedeño et al. (2018)
	Research Technology Management	1	Heinis et al. (2018)
Marketing	Journal of Business and Industrial Marketing	2	Hasselblatt et al. (2018); Leminen et al. (2018)
	Journal of Marketing Management	2	Balaji and Roy (2016); Woodside and Sood (2017)
	Industrial Marketing Management	1	Vendrell-Herrero et al. (2016)
	International Journal of Research in Marketing	1	Ng and Wakenshaw (2017)
	Journal of Service Marketing	1	Wünderlich et al. (2015)
	International Journal of Retail and Distribution Management	1	Hagberg et al. (2016)
	IMP Journal	1	Andersson and Mattsson (2015)
General management	Harvard Business Review	2	Harvard Business Review Analytic Services (2014); Porter and Heppelmann (2015)
	Business Horizon	2	Lee and Lee (2015), Saarikko et al. (2017)
Information management	Information Systems Frontiers	2	Atzori et al. (2015)
	International Journal of Information Management Journal	1	Dijkman et al. (2015)
	Information Technology and Management	1	Li et al. (2012)
	Digital Policy, Regulation and Governance	1	Gerpott and May (2016)
	Computer Communication Review	1	Bohli et al. (2009)
	Journal of Information Systems and Technology Management	1	Klein et al. (2017)
	Agris On-line Papers in Economics and Informatics	1	Kanovska and Tomaskova (2018)
Innovation	Technovation	1	Kiel et al. (2017)
Section studies	Journal of Service Management	2	Paluch (2014); Gebauer et al. (2017)
	Journal of Sustainability	2	Shih et al. (2016); Bressanelli et al. (2018)
Social Sciences	Technological Forecasting and Social Change	1	Metallo et al. (2018)
	International Journal of Design	1	Sayar and Er (2018)

Appendix C: Analysis of papers according to other types of publications (proceedings, reports and chapters of edited books)

Type of Publication	Conferences, reports, the title of books	Number of publications	References
Proceedings	Proceedings of the 6th CIRP Conference on Industrial Product-Service Systems	2	Lee et al. (2014); Schenkl et al. (2014)
	Twenty-first Americas Conference on Information Systems, Puerto Rico, 2015	2	Mikusz (2015); Tuunanen et al. (2015)
	CCD: International Conference on Cross-Cultural Design	1	Zheng et al. (2016)
	IFIP International Conference on Advances in Production Management Systems	1	Wiesner et al. (2016)
	IEEE International Conferences on Internet of Things, and Cyber, Physical and Social Computing	1	Mejtoft (2011)
	International Conference on Design Science Research in Information Systems	1	Turber et al. (2014)
	22nd European Conference on Information Systems	1	Turber and Smiela (2014)
	XI Summer School "Francesco Turco" - Industrial Systems Engineering	1	Sassanelli et al. (2016)
	48th Hawaii International Conference on System Sciences Strategies	1	Keskin and Kennedy (2015)
	Pacific Asia Conference on Information Systems	1	Herterich et al. (2015a)
	XXVI ISPIM Conference – Shaping the Frontiers of Innovation Management in Budapest, Hungary	1	Hartmann and Halecker (2016)
	IEEE 19th Conference on Business Informatics	1	Mikurz et al. (2017)
	IEEE 11th International Conference on Cloud Computing (CLOUD)	1	Breivold and Rizvanovic (2018)
Report	Noventum Service Management	1	Noventum (2016)
	Bosch IoT Lab White Paper	1	Fleisch et al. (2014)
Chapter of edited books	Lecture notes in Computer Science	2	Haller et al. (2009); Leminen et al. (2012)
	Lecture Notes in Business Information Processing	2	Carpanen et al. (2016); Kralewski (2016)
	SpringerBriefs in Operations Management	1	Helo et al. (2017)
	Architecting the Internet of Things	1	Bucherer and Uckelmann (2011)