Tampere University

KRISTA SORRI

# Bridging the Gap at Ecosystem Level

## Enhancing Business Model Innovation in Internet of Things-Enabled Platform Ecosystems

Tampere University Dissertations 870

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## Enhancing Business Model Innovation in Internet of Things-Enabled Platform Ecosystems

ACADEMIC DISSERTATION
To be presented, with the permission of
the Faculty of Management and Business
of Tampere University,
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To my son, who may have had his doubts but relentlessly encouraged me to continue.

# PREFACE

I always thought one has to be really smart – if not even brilliant – to be a doctor. For me to become a D.Sc. (Tech.) seemed impossible, but as people say, one should pursue one's dreams.

Nine years ago, I did not even have a master's degree let alone be able to dream about becoming a D.Sc. (Tech.). Yet here we are. During these nine years I have learnt one utmost important thing: You don't have to survive by yourself and you probably wouldn't if you tried.

Not to say this journey has been a long one, but I conducted this research in two decades and two different universities. I would say this journey started in spring 2016, when I started my master's thesis and joined BENI team at the Tampere University of Technology in Pori. A year later, I started the actual doctoral research.

This whole project has been enabled by one person, whom I respect and will be grateful to until the end of times. Professor Marko Seppänen was kind (or brave) enough to take a nearly 50-year-old somewhat over exited woman into his team. Every now and then he has believed in me much more than I have believed in myself. He has "turned over all stones" to find financing for my employment. He has challenged me, when I have tried to find an easy way out, but also supported and guided me when I have struggled through the more challenging ways. Not to forget his ability to understand my bad jokes. Marko, you are the best boss I have ever had and the best thesis supervisor I could have had. Thank you for believing in me and all the support you have given.

I was honored to have two distinguished scientists, Professor Marshall Van Alstyne (Boston University, USA) and Professor Seppo Leminen (University of South-Eastern Norway, Norway) to act as the pre-examiners of my thesis. Their insightful feedback helped me to improve this dissertation significantly. I am grateful for the time and effort they invested in reviewing this thesis. I would also like to thank Professor Hannu Kärkkäinen for his feedback, while conducting the internal review of this thesis.

Professor Navonil Mustafee (University of Exeter, UK) has been a guide and a friend during this journey. Thank you Nav, for helping me to become a better researcher and having me as a visiting researcher in your team in 2018.

I would also like to thank all the organizations that participated in my research as well as Linnea Harala, Harri Länsipuro and Matti Majuri D.Sc. (Tech.) for helping me in data collection.

This being an article-based dissertation, I am also thankful for all the anonymous peer-reviewers of my articles, and their comments, which helped me to improve the articles. I am also grateful to the editors of the journals and conference proceedings for publishing my research.

The importance of peer-support is indescribably important. Hence, two ladies have had a significant role during this project. Katariina Yrjönkoski, D.Sc. (Tech.) and Anu Suominen, D.Sc. (Tech.) have sparred my ideas and guided in methodological questions whenever I have needed help. They have been on call 24/7. Thank you for you both for digging me out from the dark pits of "I'm never going to be able to finalize this" and pulling me down from the skies of "this seems simple". I highly value the countless hours you spent in guiding me.

I have had the pleasure to have amazing colleagues. The BENI-team has offered fun and games to balance work. Thank you Antero, Jukka, Rainer and Tapio for helping me professionally but also sharing fun moments. Harri (Keto), thank you for your endless positivity and support.

I would also like to thank my friends, who around two years ago stopped asking when the dissertation will be ready and change their mode to compassionate listening. I have been fortunate to have them being interested in my research but also making me think other things than just work. They have celebrated my success and held me up during challenging times. Thank you Katariina, Meri, Suvi, Jussi, Mikko, Hannu, Kirsi, Sari, Seija and Maarit for always being there for me. A special thank you for Meri, the timing of that chocolate slab was impeccable.

Finally, my beloved family. I would like to thank my parents for helping me in managing the household and caring the dogs during busy times. Thank you, dad, for trying to understand my research. I would also like to thank my son, Niilo, for remembering to ask regularly, whether this Christmas is the one, when my thesis is ready – for three consecutive years. This year it is. I love you from the bottom of my heart.

In Säkylä, August 30th, 2023
Krista

# ABSTRACT

Digital transformation is challenging businesses and societies to offer innovative services to customers and to increase profitability through the development of new business models. The Internet of Things (IoT) has been identified as a potent enabler for novel services and businesses. However, despite the potential benefits, successful implementation of IoT-enabled platform ecosystems remains scarce. Research on IoT has mainly focused on technological advancements, while the importance of business model innovation has been largely overlooked. The research in the field of IoT has predominantly focused on technological advancements, disregarding the critical aspect of business model innovation. However, successful implementation of technology largely relies on a well-defined business model that delivers outstanding value propositions.

Social Exchange Theory (SET) is a theoretical framework that is pertinent in the context of IoT-enabled platform ecosystems. According to SET, actors in value exchange should find the distribution of value equitable vis-à-vis the effort invested in value creation. Therefore, in the present research, SET is adopted as a conceptual framework to explore how ecosystem-level business model innovation (BMI) in IoT-enabled platform ecosystems could be enhanced to increase actor retention, and to internalize network externalities to increase the positive network effects during times of digital transformation.

The contribution of this research extends beyond the theoretical development of value exchange in the context of IoT-enabled platform ecosystems. This research identifies two different views of social value and recognizes that in the ecosystem context, conditional value is often overlooked in theoretical discussion and neglected by practitioners.

This research also contributes to BMI theories in the IoT-enabled platform ecosystem context by identifying, in an interdisciplinary manner, the required building blocks, i.e., characteristics of a platform ecosystem BMI, and IoT. Further, a model for BMI is created, which combines two novel frameworks, namely, the Ecosystem Value Balance and the Platform Canvas. This provides ecosystem

actors with valuable insights to co-create a joint value proposition and enable positive network effects by utilizing the model iteratively as a strategic tool.

In addition, this research advances research methodologies by presenting a novel approach to clarifying concepts through literature reviews. The method involves a combination of snowballing, Porter stemming, and thematic analysis, which enables a comprehensive and structured synthesis of relevant literature and promotes a more nuanced and deeper understanding of the research topic. This approach can be applied in other research fields, too, to achieve more rigorous and accurate literature reviews.

Although this research opens up avenues for researching value proposition evaluation in IoT-enabled ecosystems, more attention to the business opportunities that can be realized is necessary. The proposed model needs validation with more and longer-term cases, and a cross-industry study could explore potential similarities and differences in the challenges and opportunities of IoT platform ecosystems. Moreover, further research is required to validate the proposed model, explore potential similarities and differences in IoT platform ecosystems, and investigate the role of emerging technologies in shaping the value proposition and value creation processes. Further, the research emphasizes the need for cultural change in companies operating in ecosystems, as traditionally companies have focused on maximizing their profits instead of maximizing the overall value for the whole ecosystem.

In conclusion, this research contributes to the theory and practice of business model innovation in IoT-enabled platform ecosystems by offering a BMI model which relies on value balance in ecosystem contexts and proposes a model for IoT platform ecosystem actors to co-create joint value propositions. It also clarifies related concepts and offers a novel approach to literature reviews. This research can help businesses and societies to understand the importance of business model innovation and to create a more sustainable and profitable ecosystem.

# TIIVISTELMÄ

Digitaalinen murros haastaa yrityksiä ja yhteisöjä tarjoamaan innovatiivisia palveluita asiakkailleen ja lisäämään omaa kannattavuuttaan uusia liiketoimintamalleja luomalla. Esineiden internet (IoT) on tunnistettu potentiaaliseksi uudenlaisen arvon mahdollistajaksi. Odotetuista hyödyistä huolimatta onnistuneesti toteutettuja IoT:llä varustettuja alustaekosysteemejä on toistaiseksi vähän. IoT-tutkimus on pääosin keskittynyt teknologisten edistysaskeleiden ottamiseen, kun taas liiketoimintamallien innovaatioiden merkitys on suurelta osin sivuutettu. On kuitenkin muistettava, että teknologian onnistunut käyttöönotto on suurelta osin kiinni hyvin määritellystä liiketoimintamallista ja sen arvolupauksen onnistuneisuudesta

Sosiaalisen vaihdannan teoria (SET) on olennainen IoT:llä varustettujen alustaekosysteemien kontekstissa. Sen mukaan toimijoiden tulee kokea arvon vaihtaminen oikeudenmukaiseksi eli kokea saamansa arvo riittäväksi tekemiinsä panostuksiin nähden. Tätä teoreettista viitekehystä hyödynnettiin tässä tutkimuksessa selvitettäessä, miten digitaalisen murroksen aikoina liiketoimintamallien innovointia (BMI) voitaisiin parantaa IoT:llä varustetuissa alustaekosysteemeissä. Siten toimijoiden pysyvyyttä voitaisiin parantaa ja verkostojen ulkoisvaikutuksia lisätä.

Tämän tutkimuksen tulokset lisäävät teoreettista ymmärrystä arvon vaihtamisesta IoT:tä hyödyntävien alustaekosysteemien kontekstissa. Tutkimuksessa tunnistettiin sosiaalisen arvon dimensiolle kaksi erilaista tulkintaa. Tutkimuksen perusteella voidaan myös todeta, etteivät teoriat – saati käytännön tekijät – huomioi ehdollista arvoa alustakontekstissa.

Tutkimus tunnisti monitieteellisesti IoT:n ja alustaekosysteemien liiketoimintamalli-innovaatioiden luomiseen tarvittavat osat. Lisäksi tutkimuksessa luotiin uusi malli BMI:lle, joka yhdistää kaksi uutta työkalua eli ekosysteemin arvotaseen ja alustakanvaasin. Käyttämällä mallia iteratiivisesti strategisena työkaluna luodaan arvokasta näkemystä ekosysteemin toimijoille, minkä avulla he voivat luoda yhdessä yhteisen arvolupauksen ja mahdollistaa positiiviset verkostovaikutukset.

Lisäksi tämä tutkimus edistää tutkimusmenetelmiä esittämällä uuden tavan tarkentaa konseptien ominaisuuksia kirjallisuuskatsauksen avulla. Parannettu menetelmä on yhdistelmä lumipallomenetelmää, Porter sanarunkohaku-algoritmia ja temaattista analyysiä. Näitä hyödyntämällä voidaan luoda kattava ja strukturoitu synteesi oleellisesta kirjallisuudesta ja edistää monivivahteisempaa ja syvempää ymmärrystä tutkimusaiheesta. Menetelmää voidaan hyödyntää myös muilla tutkimusalueilla täsmällisten kirjallisuuskatsausten tekemiseen.

Tämä tutkimus avaa väylän arvolupausten arvioinnin tutkimiseen IoT:llä varustetuissa alustaekosysteemeissä. Lisää tutkimusta kuitenkin tarvitaan ennen kuin liiketoimintamahdollisuudet realisoituvat odotetusti. Ehdotettua mallia tulee tutkia vielä useammilla ja pidempikestoisilla tapaustutkimuksilla. Lisäksi monialainen tutkimus voisi tunnistaa yhtäläisyyksiä ja eroavaisuuksia IoT:llä varustettujen alustaekosysteemien haasteissa ja mahdollisuuksissa. Lisäksi tulisi tutkia, miten uudet ja tulevat teknologiat vaikuttavat arvolupauksen muodostamiseen ja arvon tuottamiseen. Tämän tutkimuksen tuloksissa korostetaan ekosysteemissä toimimisen vaatimaa kulttuurimuutosta. Perinteisesti yritykset ovat keskittyneet oman voittonsa maksimoimiseen, mutta ekosysteemeissä tulisi keskittyä koko ekosysteemin kokonaisarvon maksimoimiseen. Tämän kulttuurimuutoksen tarvetta ja sitä, miten muutos voitaisiin saada aikaan, tulisi tutkia lisää.

Yhteenvetona voidaankin todeta, että tämä tutkimus edistää niin liiketoimintamallien innovoinnin teoriaa kuin käytäntöjäkin IoT:llä varustetuissa alustaekosysteemeissä. Se tarjoaa BMI-mallin, joka rakentuu ekosysteemin arvotaseen ympärille. Se mahdollistaa ketterän mallin, jolla IoT:llä varustetun alustaekosysteemin toimijat voivat iteratiivisesti luoda ja kehittää arvolupaustaan. Tämä tutkimus myös kirkastaa käsittelemiään konsepteja ja tarjoaa tuoreen lähestymistavan kirjallisuuskatsauksen tekemiseen. Tämä tutkimus voi auttaa yrityksiä ja yhteisöjä ymmärtämään liiketoimintamallien innovoinnin merkityksen ja näin johtaa ne luomaan kestävämpiä ja kannattavampia ekosysteemejä.

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# ORIGINAL PUBLICATIONS

The publications are numbered in the order of publication date.

| | |
|---|---|
| Publication I | Sorri, K., Seppänen, M., Still, K., & Valkokari, K. (2019). Business Model Innovation with Platform Canvas. *Journal of Business Models*, *7*(2), 1–13. https://journals.aau.dk/index.php/JOBM/article/view/1966/2972 |
| Publication II | Sorri, K., & Seppänen, M. (2020). Business model frameworks in IoT context – a literature review. In *Proceedings of the 24th UK Academy for Information Systems (UKAIS) International Conference: 9th-10th April 2019, St. Catherine's College Oxford* (pp. 210-232). Association for Information Systems AIS. |
| Publication III | Sorri, K., & Seppänen, M. (2021). Co-creation of ecosystem-level value propositions. In I. Bitran, S. Conn, C. Gernreich, E. Huizingh, M. Torkkeli, & J. Yang (Eds.), *Proceedings of the XXXII ISPIM Innovation Conference, Berlin, Germany, "Innovating our Common Future."* https://www.conferencesubmissions.com/ispim/berlin21/proceedings/index.html |
| Publication IV | Sorri K., Yrjönkoski K., Harala L. (2021) Conceptual Model of the Ecosystem Value Balance. In: Shishkov B. (Eds) *Business Modeling and Software Design. BMSD 2021. Lecture Notes in Business Information Processing, vol. 422. Springer, Cham.* https://doi.org/10.1007/978-3-030-79976-2_17 |
| Publication V | Sorri K., Mustafee N., Seppänen M. (2022). Revisiting IoT Definitions: A Framework towards Comprehensive Use. *Technological Forecasting & Social Change,* 179 (June 2022): 121623. https://doi.org/ 10.1016/j.techfore.2022.121623 |
| Publication VI | Sorri K., Yrjönkoski K., Seppänen M, (in review). Tale of two smart cities: Building value from an IoT ecosystem. |

## *Author's contribution to the co-authored publications*

| | |
|---|---|
| Publication I | The development of the idea, framing, and positioning of the paper was created by the author of this thesis together with the second author. The author of this thesis conducted the literature review, analysis, and framework creation. The author of this thesis designed and executed the empirical research and conducted the analysis of the data. The second author led the review response process. All of the authors contributed to the writing and revision of the article. |
| Publication II | The idea for this article was created by the author of this thesis. Also, the author of this thesis conducted the literature review and analysis alone. The co-author reviewed the findings and participated in the writing and revision of the article. The author of this thesis led the review response process and presented the paper at the 24th UK Academy for Information Systems (UKAIS) International Conference. |
| Publication III | The idea, framing, and positioning of this article was done by the author of this thesis. The co-author reviewed the findings and participated in the writing and revision of the article. The author of this thesis led the review response process and presented the paper at the XXXII ISPIM Innovation Conference. |
| Publication IV | The idea of the concept presented in this article was created by the author of this thesis. The concept was developed together with the second author. The third author collected the data. The whole research team analyzed the data. All of the authors contributed to the writing and revision of the article. The author of this thesis led the review process and presented the paper at the conference of Business Modeling and Software Design. BMSD 2021. |
| Publication V | The author of this thesis developed the original idea and positioning of the article. All authors contributed to the literature review. The first and second authors conducted the analysis. All of the authors contributed to the writing and revision of the article. The author of this thesis led the review response and revision process. |
| Publication VI | The author of this thesis designed the empirical study and organized the data collection. The second writer, together with the author of this thesis collected the data. The author of this thesis conducted the data analysis. All of the authors contributed to the |

writing of the article. The author of this thesis led the review response and revision process.

# 1 INTRODUCTION

This dissertation aims to investigate how the Internet of Things (IoT) can be utilized to create prosperous business. The topic is prominent as during the past two decades IoT has been expected to revolutionize people's lives (Carayannis et al., 2018; Gubbi et al., 2013), but its adoption has still been slower than anticipated (Hasan, 2022; Sinha, 2021). This has led to fewer applications offering potential and plausible financial, functional, and social value than expected (Akaka et al., 2023; Chui et al., 2021). At least three reasons for this tardiness have been identified. First, the research has been focused on technology development instead of understanding the value offered through IoT (Markfort et al., 2022). Second, according to Mielli and Bulanda (2019), over 50% of executives believe the lack of clear business cases and understanding the return on investment are the biggest challenges in capitalizing on IoT. Further, the ambiguity of the meaning of IoT has hindered both the research and application of IoT (Motta et al., 2019). Therefore, this research study seeks to create a model that enhances our understanding of how to innovate business models to capitalize on the opportunities presented by IoT. By exploring the potential of IoT in business, this study aims to provide insights and recommendations for businesses to create successful models that harness the power of IoT.

## 1.1 Motivation and Background

Digital transformation (DT), although its precise meaning remains ambiguous (Gong and Ribiere, 2021; Hanelt et al., 2021), has and will affect our lives as it disrupts an increasing number of markets and businesses, causing changes in the behavior and expectations of customers, which force companies to innovate new, largely service based, business models to survive (Kohtamäki et al., 2019; Verhoef et al., 2021). There are three phases in increasing the use of digital assets –

digitization, digitalization, and DT. While digitization focuses on converting analog data into digital format to increase the cost-effectiveness of resource utilization, and digitalization focuses on utilizing digital technologies to improve business processes, DT has an even broader focus as it aims to transform how the whole company (and even its surrounding markets and ecosystems) does business (Gong and Ribiere, 2021; Verhoef et al., 2021). The digital ecosystems required by DT compel organizations to become more malleable to be able to adapt to external changes (Hanelt et al., 2021). Therefore, DT is largely a process of strategic change, which requires new values, aligning the organization accordingly, and even a new organizational identity (Favoretto et al., 2022; Sebastian et al., 2020).

Venkatraman (1994) has identified five levels of IT-enabled business transformation, illustrated in Figure 1. While digitization and digitalization enable the first three levels, DT affects the last two levels: (1) redesigning the business network and (2) redefining the business offering and scope (Hess, 2022, p. 17). DT is a comprehensive, systemic change process, where in addition to digital technologies, also key resources and capabilities need to be utilized innovatively and effectively to achieve radical improvements within the company and its surroundings so as to offer a redefined value proposition to its customers (Gong and Ribiere, 2021). This is a major challenge, especially for traditional incumbent and SME companies (Hanelt et al., 2021; Paiola et al., 2022; Sebastian et al., 2020).

The technologies related to DT (e.g., cloud computing, Internet of Things (IoT), and social media) require companies to involve a wider ecosystem as the technologies cannot necessarily be restricted to use by a single firm to achieve the best results (Hanelt et al., 2021). These technologies also create a massive amount of data, called big data, offering new innovative ways to capture value from information, creating a data-driven economy (later referred to as data economy) (Cavanillas et al., 2016). The big data collected through IoT devices offers new information about how consumers use their products and hence offers new possibilities for revenue (Cheah and Wang, 2017). In the data economy, novel business models are created based on large volumes of data, where the value of the data relies on its quality (Otto and Aier, 2013). Namely, data becomes an intangible product and can be considered as an asset to the owner (Spiekermann et al., 2018).

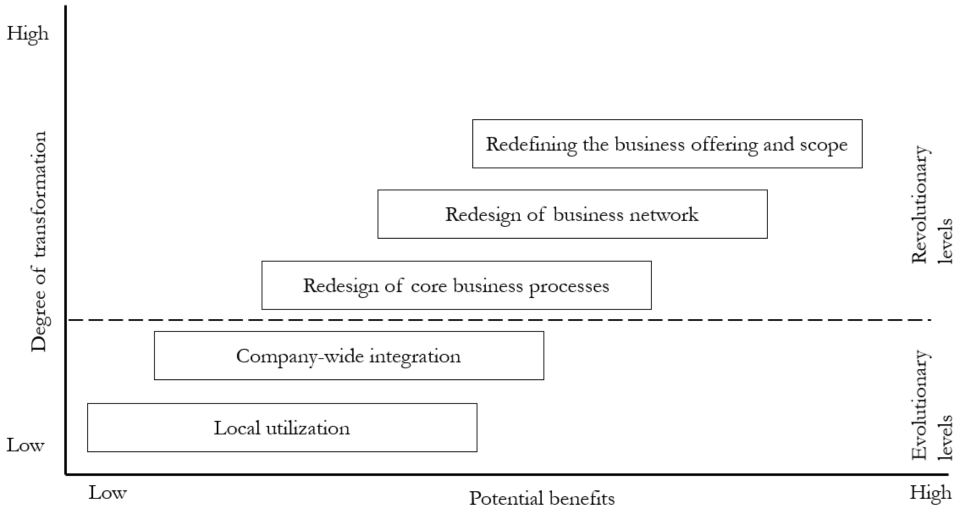


**Figure 1.** Five levels of IT-enabled business transformation (based on (Hess, 2022; Venkatraman, 1994)).

We are living in a time when technologies are developing faster than ever, and the pace is increasing continuously (McCain, 2023). In our society, DT has enabled the equipping of products with IoT through sensors, actuators, and even sophisticated software, which further enables them to communicate with each other, and with people. These so called smart products are driving a major technological and business disruption, which is bound to have a vast effect on companies from SMEs to big global enterprises, and on us as individuals and our societies all around the world (Pflaum and Gölzer, 2018; Westerlund et al., 2014).

Despite the elevated expectations of IoT as a revolutionary innovation (offering fridges that automatically write shopping lists, SMSs from fire detectors, eHealth care, and so on), offering hundreds of millions in revenue to single companies (Skaržauskienė and Kalinauskas, 2015) and creating multi-trillion markets (Seetharaman et al., 2019)), its adoption has been slower than predicted. While in the early 2010s the number of IoT connections was predicted to be 50 billion by 2020 (Evans, 2011), the estimate was decreased to 30.7 billion in a report in 2018 (Lueth, 2018) and the actual number that took place was just over 21 billion (Sinha, 2021). While there are several reasons for this tardiness, such as the unforeseen Covid-19 pandemic and the chip shortage it caused (Casper et al., 2021), there are also more long-term challenges, such as the lack of a common definition of what

IoT is, incomplete standardization causing connectivity issues, long-term research focus on technological issues, and scant understanding of applicable business models, for example (Banafa, 2016).

In the past business has mainly been a string of single transactions where products have been exchanged for money (Glova et al., 2014). However, today – and increasingly in the future –business will focus on providing services and continuous billing (i.e., as a service business model). This enables a vast number of different possibilities to connect customers and companies through IoT (Westerlund et al., 2014). Novel services offer a variety of diverse types of value. According to Service-Dominant Logic, the exchange of value does not necessarily require monetary transaction at all (Thomas et al., 2014; Vargo and Lusch, 2008). Instead, it can be a multilateral exchange of customer-experienced value. To maximize the novel business opportunities, open collaboration (e.g., through sharing data) between different companies across industries is required (Ju et al., 2016). This indicates that a business model which serves a single company may be insufficient and that the business model should be crafted on an ecosystem level. Instead of focusing on maximizing the profits of the leader firm, the ecosystem should focus on maximizing ecosystem-level value capture (Li et al., 2019). This creates a need to understand how these changes affect business model innovation and the culture of doing business in general. IoT-enabled ecosystems, which are comprised of smart products, individuals, and companies, are adaptive and especially complex systems (Smedlund et al., 2018), hence creating a successful IoT-enabled ecosystem is difficult.

The past decade has been a triumph for digital platform ecosystems. A platform ecosystem is a particular type of ecosystem, which operates on a digital intermediary platform where the value is co-created (Inoue, 2019). The "big five" (Alphabet (Google), Amazon, Meta (Facebook), Apple, and Microsoft) are known to be orchestrating enormously successful digital platform ecosystems. Together they had a tremendous market value of over $4 trillion in February 2021 and a total net income together of over $300 billion in fiscal year 2021 (Clement, 2022). These "born digital" companies have demonstrated that digital business can be very successful in monetary terms, although the IoT business has been difficult for them, too (Ians, 2022; Safeatlast, 2022). For example, Google has decided to close down its Google Cloud IoT Core service in August 2023 (Miller, 2022). Simultaneously, the diffusion of IoT falls behind the estimates year after year (Chui et al., 2021; Hasan, 2022). Table 1 illustrates how the number of IoT devices has progressed and how the estimates have shrunk as time has passed.

**Table 1.** Number of connected IoT devices projected and actualized.

| Report | Report's year | 2014 | | 2015 | | 2016 | | 2017 | | 2018 | | 2019 | | 2020 | | 2021 | | 2022 | | 2023 | | 2024 | | 2025 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cisco IBSG | 2011 | | 14 | | 25 | | | | | | | | | | 50 | | | | | | | | | | |
| IoT Market, Forecast at a glance* | 2014 | 11 | 14 | | | | | | | | | | | 32 | 50 | | | | | | | | | | |
| World Economic Forum | 2015 | | | | | | | | | | | | | | 50 | | | | | | | | | | 100 |
| Statista | 2016 | | | | 15,4 | | 17,7 | | 20,4 | | 23,1 | | 26,7 | | 30,7 | | 35,8 | | 42,6 | | 51,1 | | 62,1 | | 75,4 |
| State of the IoT 2018* | 2018 | | | 3,8 | 13,9 | 4,7 | 15 | 5,9 | 16,4 | 7 | 17,8 | 8,3 | 19,4 | 9,9 | 21,2 | 11,6 | 23,2 | 13,5 | 25,4 | 15,8 | 27,9 | 18,5 | 30,9 | 21,5 | 34,2 |
| State of the IoT 2020* | 2020 | 3 | 12,5 | 3,6 | 13,3 | 4,6 | 14,4 | 6,1 | 16 | 8 | 17,9 | 10 | 20 | 11,7 | 21,7 | 13,8 | 23,9 | 16,4 | 26,5 | 19,8 | 29,9 | 24,4 | 34,6 | 30,9 | 41,2 |
| State of IoT 2021* | 2021 | | | 3,6 | | 4,6 | | 6,1 | | 8 | | 10 | | 11,3 | | 12,3 | | 14,5 | | 17,3 | | 21,8 | | 27,1 | |
| State of IoT 2022* | 2022 | | | 3,6 | | 4,6 | | 6,1 | | 8 | | 10 | | 11,3 | | 12,2 | | 14,4 | | 17,3 | | 21,7 | | 27,0 | |

*IoT Analytics' report

**right-hand figure in per each year includes phones and tablets

*** grey figures are estimates in reporting year

Despite the promise of enormous business opportunities, realization lags far behind. It is still unclear what is hindering the DT of companies to capitalize on IoT-enabled ecosystems more extensively. It may be lack of knowledge or abilities to apply technology – or even both. Therefore, this research focuses on identifying the barriers to success and providing the means to remove (or at least lower) these barriers.

## 1.2 Research Objectives and Research Questions

This dissertation strives to provide an understanding of the challenges hindering the success of platform ecosystems. It also aims to advance the related ecosystem theories. It has been recognized that IoT-enabled platform ecosystems have not diffused as rapidly as predicted (Chui et al., 2021; Hasan, 2022; Lueth, 2014). For example, in 2017 Cisco reported that nearly 75% of IoT projects fail (Duke-Wooley, 2020). Therefore, this research concentrates particularly on IoT-enabled platform ecosystems (later in this dissertation, IoT-enabled ecosystems).

The research aims to increase knowledge on accelerating the capture of the extensive potential of IoT-enabled business, hence the research problem of this dissertation is:

*The ecosystem-level BMI in IoT-enabled ecosystems suffer from insufficient and fragmented scientific knowledge as well as inadequate capabilities in organizations.*

These gaps in knowledge and capabilities are hindering the ecosystems' BMI to maximize their actor retention and use of network externalities.

Both IoT, platform ecosystem, and business model innovation theories are still nascent and disperse (Omerovic et al., 2020; Tsujimoto et al., 2018). It can be said that they are all "products of this millennium". IoT was first introduced in 1997 (Ashton, 2009). A decade later, the academic literature started to grow exponentially (Mishra et al., 2016). The platform ecosystem does not have as clear a point of concept introduction, but ecosystem analogy was introduced in 1993 (Moore, 1993). Discussion regarding business models became popular during the first years of this millennium (see e.g., (Chesbrough and Rosenbloom, 2002; Magretta, 2002)). A few years later the focus turned towards innovating business models, leading to the publication of one of the seminal books on BMI: "Business Model Generation: a Handbook for Visionaries, Game Changers, and Challengers" by Osterwalder and Pigneur (2010). As the more intense theory development around these concepts only started in the early 2000s, so far, neither of the concepts have a commonly accepted definition nor taxonomy, although some attempts have been made (Dorsemaine et al., 2016; Hein et al., 2020).

Understanding the concepts is crucial for developing theories (Podsakoff et al., 2016). Therefore, a synthesis of the current understanding of these two key concepts is required. Hence, the first research question of this dissertation is:

> *RQ1: What characteristics of BMI should organizations consider when innovating IoT-enabled platform ecosystem business models?*

After understanding the nature of an IoT-enabled ecosystem through its key characteristics, it is important to understand how the ecosystem can create lucrative business. In this research, these characteristics include network effects, filtering, and governance, for instance (see Publication I). This requires knowledge of the value the ecosystem can offer and how the value can be captured by its members.

This leads to the other research questions:

> *RQ2: How do organizations approach the innovation of IoT-enabled ecosystem business models?*

> *RQ3: How should IoT-enabled ecosystem business models be innovated?*

This research develops a model for the ecosystem orchestrator to create the initial value proposition for the ecosystem, to identify the required actors, to jointly innovate an ecosystem-level business model, and to define the necessary implementation activities. The model can also be utilized by the whole ecosystem to develop itself strategically and iteratively towards resilient and long-lasting success.

This thesis is a compilation of six interconnected but individual studies. This synopsis describes how these studies are related to each other and how they contribute to resolving the primary research problem and respond to the related research questions.

Next the philosophical assumptions, research design and methodology as well as the theoretical approach are elaborated. Chapter 3 focuses on grounding the concepts to previous research. Chapter 4 includes short summaries of each of the original publications, followed by the key findings and their implications, which are discussed in Chapter 5. The thesis ends by summarizing the contributions of this research and evaluating the research in Chapter 6.

# 2 RESEARCH DESIGN AND METHODOLOGY

According to Eriksson and Kovalainen (2008), designing research includes multiple phases. First, the research topic and the research questions which need to be answered should be delineated. This, in combination with the beliefs and assumptions of the researcher, and the research stance, will then lead to selection of the research approach, methodology, and methods as well as the initial plan for gathering data (Eriksson and Kovalainen, 2008, pp. 25–31). It is also good to remember that the research design is an iterative process.

This section elaborates the rationale of the ontological, epistemological, and axiological assumptions leading to the chosen research paradigm, methodological design, and methods. It also illustrates the complete research process along with how the data collection and analysis was conducted for each publication.

## 2.1 From Philosophical Assumptions to Research Paradigm

This research was conducted under the philosophy of social sciences (Burrell and Morgan, 1979) at the intersection of the three social science domains of business and innovation, value theory, and IoT. First, it studies business and innovation platform ecosystems and the business model innovation process. Second, the research focuses on value theory. Value theory, as a philosophical discipline, expands in various directions from metaethics to consequentialist moral theories, but it also branches out to include economics, especially when understanding the structure of value is required (Aschenbrenner, 2012; Hirose and Olson, 2015). This supports the assumption of the applicability of the philosophy of social sciences also in value research. Finally, while IoT can be seen as a technological solution, in this research, it is viewed from the value enabler and business perspective for organizations. Therefore, the philosophy of social sciences is considered relevant in this context, too.

In social sciences, the researcher approaches the subject through assumptions of how the world is constructed and thereby should be investigated. These assumptions include ontological, epistemological, human nature related, axiological, and methodological assumptions (Burrell and Morgan, 1979; Saunders et al., 2019).

The word ontology originates from the Greek language and can be translated as the "study of being" (Lawson et al., 2007). The researcher should consider whether the "reality" is of an objective nature, or can it be investigated without the views of individuals, that is, a given reality or a "product of one's mind" (Burrell and Morgan, 1979, p. 1). An ontology can be considered to have two extremes: nominalism and realism. The first assumes that reality is structured by concepts and names, and the latter considers reality to be constructed of tangible, unchanging structures, which exist whether individuals acknowledge it or not (Burrell and Morgan, 1979). When considering the subject of this research, value leans strongly towards nominalism as it is a subjective concept and lies in the eye of the beholder. In nature, ecosystems can be considered as objective structures. However, in social sciences, business and innovation ecosystems are typically formed of organizations or individuals. For these reasons, this research follows a less extreme version, social constructionism, which states that "reality is constructed through social interaction in which social actors create partially shared meanings and realities" (Saunders et al., 2019, p. 137). Social constructionism questions the assumptions of how we see the world around us. It assumes that people have a role in constructing the categorization of artifacts, hence there are no objective natural categories (Burr, 2015). For example, there is no one correct answer to the question of whether something is valuable. Nor is there absolute truth in how an ecosystem should be constructed or even how to delineate its borders (i.e., who are the right actors of the ecosystem).

Epistemology derives from the Greek words episteme, which means knowledge, and logos which means "study of" (Wenning, 2009). It tries to reveal what is knowledge, how we know it is dependable, and what the limitations of knowledge are. Hence, epistemological assumptions define what can be considered to be acceptable, good, and legitimate grounds of knowledge (Burrell and Morgan, 1979; Saunders et al., 2019). Valuing whether something is good or bad is often relative to some standard (Zimmerman, 2015). While those standards can be defined on an individual level, opinions as acceptable knowledge need to be accepted in this research. Value, knowledge transfer, and relationships in ecosystems cannot be described solely with figures, hence some attributed meanings and communication with textual and visual data in different contexts are needed to develop reliable constructs. In this research, knowledge is assumed to be subjective, thus it approaches the subject from an anti-positivistic perspective (Burrell and Morgan, 1979).

Axiology is the study of value (in Greek 'axia' means value or worth) (Hart, 1971). When making axiological assumptions, the researcher needs to ponder the effects of human nature on the research. This means that the researcher should consider how their values, as well as the values of the research participants, may affect the research results. Is the research aiming at morally neutral results or can it be value-bound (Saunders et al., 2019)? Another view is to evaluate the role of a human being in creating science. Are humans creating their environment (voluntaristic view) or are they and their experiences just products of their environment (deterministic view) (Burrell and Morgan, 1979)? Like many other pieces of social science research, in this research a human is considered to be somewhere in between the two extremes. For instance, by developing recent technologies, like IoT, humankind is creating their environment. However, how recent technologies affect our social life and even culture, is a by-product that is exceedingly difficult to estimate. Nevertheless, this research accepts the value-bound and reflexive nature of the data, meaning that the data gathered, e.g., through interviews and focus groups, is bound to be subjective as the subject of the research does not – maybe even cannot – have objective, correct answers.

The methodological stance requires the researcher to evaluate their role in the data collection and to select an appropriate research methodology based on that role. In this research, the assumption is that the researcher should aim to obtain first-hand knowledge of the subject. As both the platform ecosystem and IoT are nascent research domains, the research will require some interpretation and self-reflection by the researcher. Thus, the research is positioned closer to the ideographic stance (Burrell and Morgan, 1979), i.e., the researcher is required to get close to the research subject to obtain primary knowledge and background information to be able to discover the results.

As a summary, the philosophical assumptions position this research closer to the subjective research approach in all dimensions. However, it is not at the very extreme of the continua as some of the assumptions have objectivistic elements.

Another approach in defining the appropriate research paradigm is to evaluate the assumptions of society itself. As illustrated in Figure 2, Burrell and Morgan (1979, pp. 16–19) call these dimensions the sociology of regulation and sociology of radical change. The radical change dimension is concerned with structural conflict, modes of domination, contradiction, deprivation, and potentiality, whereas, in contrast, the sociology of regulation aims at the status quo, social order, consensus, solidarity, actuality, and satisfaction of needs (Burrell and Morgan, 1979, pp. 21–23). This research aims to explain the social process of platform ecosystem business model innovation through understanding the viewpoints of the ecosystem actors. Hence, the sociology of regulation leading to the interpretive paradigm applies best in this context. (Burrell and Morgan, 1979, pp. 227–237)

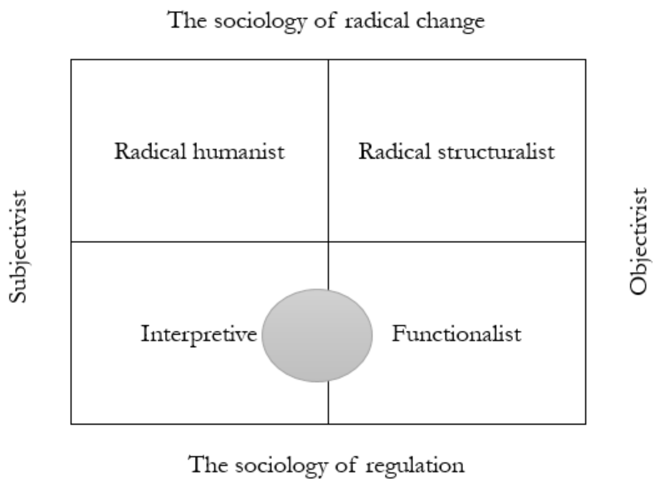


**Figure 2.** Positioning the research within four paradigms for organizational analysis (adapted from Burrell & Morgan, 1979, p. 22).

While most of the assumptions in this research lean on the subjectivist side, i.e., the interpretivist paradigm, organizations are, after all, mainly rational entities aiming to achieve their goals as efficiently as possible (Scott and Davis, 2006, pp. 35–58). Hence, the research aims to find rational solutions to the rational problem of enabling the capitalization of IoT for practitioners. This means that, especially when reviewing the underlying theories, the research should also pay attention to the functionalist paradigm area. For this type of "multi-paradigmatic research," a pragmatist research philosophy is the most appropriate (Saunders et al., 2019, p. 143).

Pragmatism was originally introduced by Charles Sanders Peirce in the late 19th century as the "pragmatic method or maxim" (Johnson and Onwuegbuzie, 2004; Peirce, 1905). Followed by the work of William James and John Dewey, it became "a full philosophical system" (ibid.). Pragmatism is also referred to as a worldview (Creswell and Poth, 2016), an approach, a guiding paradigm (Morgan, 2014), or simply a paradigm (Kelly and Cordeiro, 2020). In this research, the term paradigm is employed in an equivalent manner as recent literature uses the paradigmatic nature of pragmatism.

Pragmatistic research focuses on finding practical and relevant solutions and outcomes to research problems (Creswell and Poth, 2016; Peirce, 1905). Pragmatists acknowledge that experience transforms knowledge and that "reality" is complex, rich, and constantly evolving (Kelly and Cordeiro, 2020; Saunders et al., 2019). The reflexive research process starts with a problem and often, but not necessarily, utilizes a mixed-method approach (Johnson and Onwuegbuzie, 2004; Saunders et al., 2019). Pragmatists are positioned between objectivism and subjectivism. Morgan (2014) describes this as an intersubjective approach. He also argues that knowledge does not have to be context-dependent or universally generalizable, but something in between (Morgan, 2014). For pragmatists the "truth" is something that people find useful (Elkjaer and Simpson, 2011), not necessarily an absolute truth as presumed by objectivists.

The decision to choose pragmatism, as it seems to be a compromise of everything, should not be taken lightly (Saunders et al., 2019). However, this value-driven research requires an intersubjective approach, thus, pragmatism has been applied to this research.

## 2.2 Selection of Research Strategy and Approach

The research strategy describes the plan of how the research goals are to be achieved (Saunders et al., 2019, p. 189). The pragmatic research philosophy offers the possibility to use either a quantitative, qualitative, or mixed-method approach, the main reason for selection being the reliability, credibility, and relevance of the collected data (Creswell and Poth, 2016, p. 23; Saunders et al., 2019, p. 181). The understanding of the related concepts and the type of research questions in this research advocate the utilization of a qualitative approach, which supports interpretation.

Qualitative research focuses on exploring and comprehending the attributes of social problems through an emergent research design, relying on individual perceptions in different situations (Creswell, 2014; Stake, 2010). Typically, qualitative research uses open-ended questions, focuses on developing conceptual frameworks, and creates theoretical contribution through collecting empirical data, which the researcher analyzes through interpretation (Creswell, 2014; Saunders et al., 2019, p. 179; Stake, 2010). The researcher cannot be completely objective, as they are dependent on the research participants, their expressed meanings, and how the researcher achieves the conceptualization through analysis (Saunders et al., 2019, p. 180). Qualitative research, regardless of its limitations on the commensurability and cumulation of the research results, has gained popularity in social sciences especially during recent decades (Lincoln et al., 2018). Qualitative research suits the purposes of this research well, especially because it supports the reflexivity requirements of both the nascent research context and pragmatist research philosophy. Reflexivity is also a prerequisite of valid qualitative research (Eriksson and Kovalainen, 2008).

The approach to theory in qualitative research is often inductive, but it can also be deductive or even abductive (Saunders et al., 2019, p. 179). The key characteristics of these three approaches are presented in Table 2.

**Table 2.** Key characteristics of the three approaches to theory development (Saunders et al., 2019, p. 179)

| | DEDUCTION | INDUCTION | ABDUCTION |
|---|---|---|---|
| LOGIC | True premises lead to true conclusions | Premises are known, but conclusions are not tested | Premises are known and conclusions can be tested |
| GENERALIZABILITY | From general to the specific | From specific to the general | From the interactions of the general and specific |
| USE OF DATA | To evaluate a hypothesis of an existing theory | Exploration of the phenomenon through data to create a conceptual framework | A circular process of exploration of the phenomenon, creating a conceptual framework, evaluating it through new data |
| THEORY | Verification or falsification | Theory building | Theory modification |

Abductive reasoning is a combination of inductive and deductive reasoning in theory development and hence, particularly suitable in pragmatist qualitative research (Timmermans and Tavory, 2012) as it strives to overcome the limitations of inductive and deductive reasoning (i.e., empirical data is not necessarily enough to build a theory and strict theory-testing logic, respectively) (Bell et al., 2011, p. 25). Therefore, abductive reasoning is used in this research. Abduction is acknowledged as a legitimate methodology especially in interpretive research (Mantere and Ketokivi, 2013). This research relies strongly on existing theories, but combines them in a novel way, creates a conceptual model, and assesses it empirically to create a plausible theory through "[an] interplay of observational and conceptual work" (Van Maanen et al., 2007, p. 1149). The theories, however, are nascent and dispersed and the concepts are not yet established. Consequently, as the research aims to modify the current theoretical understanding, a circular and reflexive approach is required.

## 2.3 Using Social Exchange Theory to Understand Business Model Innovation in a Multilateral Ecosystem Context

As established in Section 2.1, while this research is conducted under the pragmatist paradigm, it can also be positioned between the interpretive and functionalist paradigms, hence the underlying theories can be found from either side of the sociology of regulation. In interpretive research, theories can be used for three purposes: (1) to guide the research design and data collection, (2) in data collection and analysis as an iterative process, and (3) to become the final product of the research (Walsham, 1995). In this research, all three uses are applied. The theories are lenses that give focus to the research and support the constructive nature of this research; as a result, this research contributes to the further development of the theories used.

Business model innovation has traditionally relied on the theory of Transaction Cost Economics (TCE) as it has helped to create an understanding of the economic activities within an organization and even within markets (Nagle et al., 2020; Williamson, 1981). TCE focuses on the contractual exchange of goods and services, where the monetary cost of transactions should be minimized, bearing in mind the uncertainty and frequency of the exchange as well as the degree of transaction-specificness of the transaction object (Williamson, 1981, 1979). It relies on two assumptions – bounded rationality and opportunism, which means that decisions are not made completely rationally due to lack of information and people may cheat to "win" (Siyu et al., 2022).

However, TCE assumes that the transaction happens between two – often vertically integrated – parties, it assumes that the parties are equally efficient, and it does not consider "free" transactions, where the motivation for the transaction is something other than money (Nagle et al., 2020; Zott and Amit, 2010). TCE is not sufficient in a multilateral ecosystem context (Benitez et al., 2020; Jacobides et al., 2018), nor does it necessarily apply in value exchange when value is perceived extensively, including the non-monetary dimension (Nagle et al., 2020), and it is insufficient in explaining relationship-based exchanges (Jeong and Oh, 2017).

To ground the research, the ecosystem context-specific properties should be comprehended. Furthermore, social and behavioral aspects are included in this research. While TCE neglects to consider the relational factors, the Social Exchange theory may even overemphasize them. However, as the focus is on value in a wide multidimensional meaning in a multilateral complex system, the Social Exchange Theory (SET) was chosen here as the theoretical stance.

The Social Exchange Theory was introduced in the late 1950s by Homans (1958). The principle is simple:

> "Persons that give much to others try to get much from them and persons that get much from others are under pressure to give much to them. This process of influence tends to work out at equilibrium to a balance in the exchange." (Homans, 1958)

According to SET, the "goods" exchanged can be either physical goods, non-economic, or non-material socio-psychological outcomes (Homans, 1958; Jeong and Oh, 2017). It recognizes that relationships evolve through time and evaluate reciprocal outcomes while aspiring to reach mutual commitments and trust, but to do so, all parties must follow the "rules" of exchange (Cropanzano and Mitchell, 2005; Jeong and Oh, 2017). What is particularly important is that the value of the "reward" changes over time. The more one receives, the less valuable it becomes per unit (Homans, 1958). Homans also found that if someone does not act as expected, the others will avoid rewarding that actor and eventually refuse to co-operate with them (ibid.).

While Homans studied individuals, Wu et al. (2014) studied supply chains. They found that collaboration and information sharing are strongly linked to supply chain performance (Wu et al., 2014). Furthermore, from an ecosystem sustainability perspective, it is important to understand that communication quality and financial dependence have a positive association with relationship satisfaction and trust. The better the relationship satisfaction is, the less likely the member is to leave, as positive relationship satisfaction correlates strongly with commitment. (Jeong and Oh, 2017) Satisfaction and commitment enforce trust, which is essential in value co-creation (See-To and Ho, 2014).

SET assumes that social interactions can be explained by the cost-benefit ratio. People are willing to begin a relationship if its cost is smaller than the expected benefits and relationships where the net benefits are maximized are preferred (Ghafari et al., 2019). Hence, it has similarities compared to the opportunism of a party assumed in the theory of TCE. However, SET "counts" both intrinsic and extrinsic benefits and costs, and non-monetary benefits and costs. According to SET, the result affects the intention to continue co-operation (Hsiao, Kuo-Lun, 2017). Hence SET is a beneficial framework for analyzing the ecosystem-level co-operation mechanics and motives of its actors (Cropanzano and Mitchell, 2005). Social exchange can be seen as part of the governance system of the ecosystem, as social governance systems are more effective in enhancing commitment to the ecosystem than traditional contractual governance or even economic mechanisms

(Autio and Thomas, 2020; Shahzad et al., 2018). However, sociological governance alone fails to minimize ex-post transaction costs because the actors may not trust each other enough (Shahzad et al., 2018). Nevertheless, utilizing social exchange as part of the governance system and analyzing the ecosystem value exchange may limit the problem of free-riding through highlighting the contributions and benefits gained by each actor (Cennamo and Santaló, 2019; Jacobides et al., 2023).

SET is an especially useful framework in the platform ecosystem context as a sense of unfairness may harm co-operation between actors, lead actors to leave the ecosystem, reduce shared value, and even drive the participants to leave the ecosystem (Zuquetto et al., 2022), which could lead to negative network effects. It has been established that value capture that is accumulated disproportionally by some of the actors causes misalignment in the co-operation, which may lead the ecosystem to fail (Jacobides et al., 2023). If the value distribution fails, it may bring about a forking, splintering, or fragmentation risk in the platform, resulting in loss of backwards compatibility, excessive product variety, or multiple standards (Jacobides et al., 2023).

## 2.4 Research Methods

In this section, an overview of the research process, methods used, and the rationale in selecting the research methods are elaborated.

As this dissertation research has been conducted as a compilation of sub-studies reported in separate peer-reviewed articles, an overview of the research process is relevant. The process, including related publications, is illustrated in Figure 3.

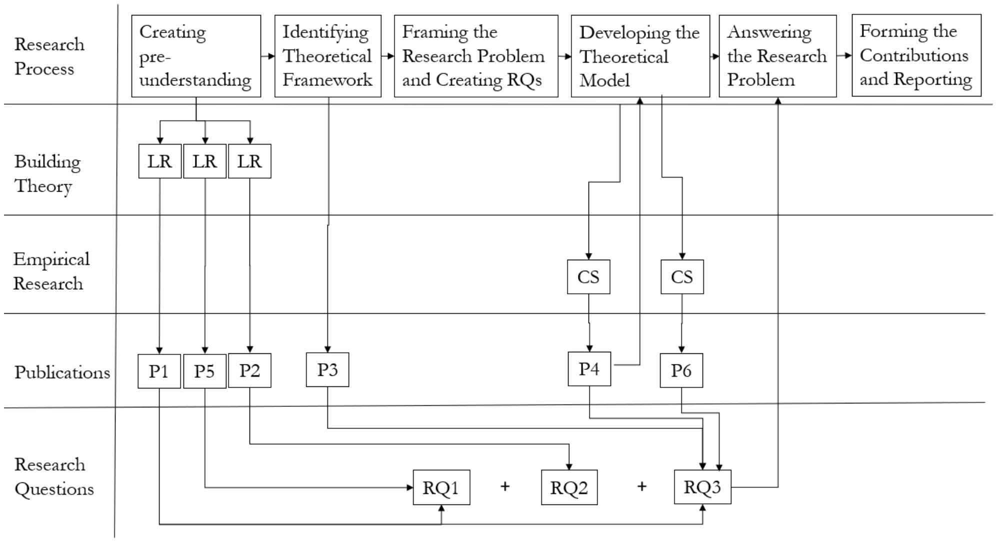


**Figure 3.** Description of research process implemented in this research.

The research began by creating the required pre-understanding and establishing the concepts (Van de Ven, 2016) of platform ecosystems, IoT, and business model innovation by conducting three literature reviews (Publications I, II, and V). After gaining understanding, the research problem and questions were created. Creating the research design and making the required ontological, epistemic, and axiological choices was the next phase of the research, as this created the foundation for the methodological choices and for the dependability, credibility, and confirmability of the research (Creswell, 2014).

Table 3 presents a summary of the research approaches of each publication by describing the methods used, and the data collection and analysis procedures in relation to the research questions. The research methods are described in detail in each of the publications.

Reviewing prior literature is a necessity in any research endeavor but when the concepts are still vague and inadequately defined, a profound review to summarize and synthesize the current understanding is essential for advancing theory development (Webster and Watson, 2002). Therefore, this research started with extensive literature reviews, which aimed to create an explicit description of the critical characteristics of platform ecosystem business model innovation and IoT. These two literature reviews (Publications I and V) answered RQ1.

**Table 3.** Research approaches applied in the publications.

| PUBLICATION | | QUESTIONS ADDRESSED | METHODS | DATA COLLECTION | DATA ANALYSIS |
|---|---|---|---|---|---|
| **I** | Business Model Innovation with Platform Canvas | RQ1, RQ3 | Literature review, multiple case study | Backward snowballed literature; interviews | Meta-synthesis |
| **II** | Business Model Frameworks in IoT context - a Literature Review | RQ2 | Literature review | Backward snowballed literature | Meta-synthesis |
| **III** | Co-creation of Ecosystem-level Value Propositions | RQ2, RQ3 | Literature review and a longitudinal multiple case study | Backward snowballed literature; findings from PI and public digital material; interviews | Abductive thematic analysis |
| **IV** | Conceptual Model of the Ecosystem Value Balance | RQ3 | Constructive research, a single case study | Semi-structured interviews | Abductive thematic analysis |
| **V** | Revisiting IoT Definitions: A Framework towards Comprehensive Use | RQ1 | Literature review | Backward and forward snowballed literature | Meta-synthesis |
| **VI** | Tale of two cities: Building value from an IoT ecosystem | RQ3 | Multiple case study | Focus group | Inductive thematic analysis |

Furthermore, a literature review was conducted to understand what kinds of frameworks were currently available for innovating business models in the IoT context. Together with Publication III (which identified different dimensions of the value proposition), these two articles answered RQ2. These three literature reviews framed the research by revealing the topic that required more research, i.e., the ecosystem-level value proposition and its effects on business model innovation in platform ecosystems.

Systematic literature reviews (SLR) are often conducted as database searches (e.g., the procedure introduced by Kitchenham (2004)); however, in underdeveloped research areas, SLR can cause plenty of noise and, consequently, increase the amount of work significantly without improving the reliability nor validity of the research (Jalali and Wohlin, 2012). Therefore, in this research, the literature reviews were conducted through snowballing procedures (Wohlin, 2014).

The second phase of the research process was to identify the theoretical frameworks to ground the research in relation to existing theories. This research is grounded in Social Exchange Theory (later SET) (Homans, 1958). SET was chosen as the theoretical approach as participating in an ecosystem is voluntary and hence should benefit each participant. This is presented in Publications III and IV. Ecosystems are multilateral and based on trust and the co-creation of value, and in IoT-enabled platform ecosystems the transaction costs are reduced significantly and proportionally as a function of the number of transactions. Therefore, the more traditional approach of Transaction Cost Economics (TCE) is not as appropriate as SET (Benitez et al., 2020; Jacobides et al., 2018).

The third phase was to explore the theoretical findings of the topics in a real-life context (Publications III, IV and VI) to answer RQ2 and RQ 3, thus the emergent case study strategy (Saunders et al., 2019, p. 198) was chosen. A case study method is a good choice when a real-life phenomenon needs to be understood profoundly, particularly when the boundaries between the phenomenon and its context are not evident (Yin, 2008). When conducted as an extensive case study, as in this research, it is also a useful method in theory development and for justifying an emergent theory (Eisenhardt, 1989; Kovalainen and Eriksson, 2008). An extensive case study is conducted as a multiple-case study as it aims to create "cross-case" conclusions to elaborate and explain the research phenomenon (Kovalainen and Eriksson, 2008; Yin, 2008).

IoT-enabled ecosystems were chosen as the research context early on during the planning phase. However, the focus of the case studies was delineated only after framing the specific topic through literature reviews. Although the unit of analysis in Publication I was whole ecosystems, only one representative from the orchestrating company was interviewed, as the main purpose was to verify the Platform Canvas framework. Publication III uses the same cases as Publication I, but the scope was focused on value creation throughout the whole ecosystem rather than focusing only on the orchestrators' views. Publication IV introduces the Ecosystem Value Balance (EVB) framework and assesses it through a single ecosystem-level case study. In Publication VI, a multiple case study is employed to examine the intersection of the EVB and IoT-enabled ecosystems, addressing the current research problem.

The context, purpose of the studies, chosen case study, and case selection rationales evolved during the research, as illustrated in Table 4.

**Table 4.** Summary of case study strategies and contexts.

| PUBLICATION | CONTEXT | RELATION TO THEORY | STRATEGY | CASE SELECTION |
|---|---|---|---|---|
| I | Platform ecosystem | Theory building | Multiple cases | Literal replication |
| III | Platform ecosystem | Theory building | Multiple cases | Literal replication |
| IV | Business ecosystem | Theory building and verification | Single case | Critical case |
| VI | IoT-enabled ecosystem | Theory verification | Multiple cases | Theoretical replication, intensity sampling |

Furthermore, as the research focused on developing a theoretical model constructively, the cases were selected to fit the requirements of each phase. A provably successful ecosystem was required to pilot the framework; therefore, a critical case selection was used in Publication IV. Publication VI incorporates both the IoT context and ecosystems, meaning that the cases were chosen expecting theoretical replication. Ergo, three different case selection strategies (i.e., critical case, literal replication, and theoretical replication (Yin, 2008, p. 54)) were used to strengthen the grounding of the theoretical framework (Saunders et al., 2019, p. 199).

The following phase of the research process was to develop a model (Publication III). The model was designed by combining the theoretical understanding of platform ecosystems and SET. It was provisionally evaluated with a single case study (Publication IV), followed by a study of two focus groups in the IoT context (Publication VI).

Finally, the results of six separate but interlinked studies were synthetized and reported in this thesis, which also includes, in addition to the results, an evaluation of the research.

## 2.5 Data Collection and Analysis

In this section, a justification of the selected data collection and analysis methods is briefly described. The data collection and analysis procedures are described in more depth in each of the publications. All the publications contain a brief synthesis of the literature to frame and ground the research in question. However, Publications I, II, and V are more comprehensive literature reviews, which aim to create a novel theoretical understanding by synthesizing the previous literature. Publications III, IV, and VI, on the other hand, are case studies. The collected data and analysis methods used in each study are summarized in Table 5.

For the *literature reviews*, the snowballing procedure was selected. This means that after defining the start set, both documents citing the start set articles and the texts and reference lists of the original articles are reviewed (Jalali and Wohlin, 2012) The snowballing procedure is likely to reduce "noise" caused by irrelevant publications, especially when the research context is under-defined (Wohlin, 2014). It has been validated by Badampudi et al. (2015) to be as accurate as database searches, as long as the start set has been appropriately defined. To minimize bias in the start set, Google Scholar was selected as the search engine (apart from Publication I, which was conducted through the Web of Science, and Publications III and IV conducted through Scopus) as it provides access to a wide range of publisher-independent, multi-disciplinary academic publications (Harzing and Alakangas, 2016).

There are a handful of methods for creating a synthesis. Quantitative research typically uses meta-analysis but meta-synthesis is more applicable in qualitative and mixed-methods research (Leary and Walker, 2018). Meta-synthesis strives to identify knowledge gaps, explain phenomena, and develop theories through interpreting qualitative findings and data sources (Leary and Walker, 2018; Walsh and Downe, 2005).

Qualitative research has been criticized for its deficiencies in generalizability. Meta-synthesis attempts to overcome this hurdle by providing more evidence-based justification through interpreting and quantifying qualitative findings across multiple research studies conducted by different researchers (Sandelowski et al., 1997; Sandelowski and Barroso, 2007).

**Table 5.** Summary of data collection, amount, and analysis methods.

| PUBLICATION | STUDY TYPE | DATA COLLECTION | AMOUNT OF DATA | DATA SOURCE | ANALYSIS METHOD |
|---|---|---|---|---|---|
| **I** | Literature review | Snowballing | 16 full seminal articles, 7 interviews, 10 interviewees, appr. 8h | Web of Science | Meta-synthesis |
| **II** | Literature review | Snowballing | 56 full articles | Google Scholar | Meta-synthesis |
| **III** | Literature review, multiple case study | Recent literature, secondary data, interviews | 60 full articles 7 interviews from publication I | Scopus, web pages, marketing material, interviews | Thematic analysis |
| **IV** | Single case study | Interviews, secondary data | 6 interviews, 6 interviewees, 4h | Scopus, interviews, marketing material, web pages | Thematic analysis |
| **V** | Literature review | Snowballing | 216 full articles | Google Scholar | Thematic analysis, Porter stemming |
| **VI** | Multiple case study | Focus groups | 2 focus groups, 10-14 members each, 10h of video recorded discussion | Workshops | Thematic analysis |

For *case studies*, data can be collected in a variety of ways. For example, Yin (2008, p. 102) proposes six different ways of data collection regarding studies: documentation, archival records, interviews, direct observations, participant observations, and physical artifacts.

As this research focuses on nascent research topics, the use of interviews as a data collection method was appropriate in Publications I and IV, since solving the research problem required insightful explanations that focus directly on the topic (Yin, 2008, pp. 105–109). One-to-one semi-structured interviews were conducted to collect data for these publications. The interviews were recorded, and the summarizing documentation was approved by the interviewees before the analysis phase.

In Publications I, III, and IV, secondary data was also used. Secondary data means data that is not collected directly from the research subjects (Saunders et al., 2019). In this research, secondary data includes ecosystem value proposition data collected from public web pages for Publication III, through which an understanding of the changes over time in the original cases of Publication I was created, and external material from the organizations (webpages and brochures) in Publication IV.

For Publication VI, the data collection was conducted through focus group workshops, which were video recorded. Since the research aimed to elicit what types of value potential are seen in the ecosystem and how they are expected to support the ignition of the expansion of the ecosystem, a focus group was selected as a data collection method. Focus groups are a particularly suitable method when the purpose of the research is to elaborate comprehensively on an individual's views and to collectively produce a common understanding of the subject at hand (Wilkinson, 1998).

Following the instructions of Saunders et al. (2019, pp. 467–469), four actions were taken to minimize the risk of the dominance of some of the members in the workshops. First, the participants in the focus groups had a similar status in their respective companies. Second, the group was divided into sub-groups during the "ideation" phases. Third, each of the sub-groups had a moderator to encourage the quieter participants to participate. Finally, all ideas were shared with the other sub-groups both through Flinga Wall (a digital tool for collaborative work) and verbally between each phase.

Case studies as a methodology allow adjustments to procedures and operationalization when studying a nascent phenomenon (Schwandt and Gates, 2017). In this research, the multiple-case study approach offered the possibility to adjust the data collection and scope after the theoretical understanding had increased. During this research an increasing number of academics (e.g., (Ikävalko et al., 2018; Matthyssens, 2019; Tsujimoto et al., 2018)) have concluded that ecosystem business models and value propositions should be designed and evaluated on the ecosystem-level rather than from a single actor perspective. Therefore, the focus was on the ecosystem level, although in Publication I only one representative from the orchestrator companies was interviewed. Furthermore, in the later phase of the study, the research aimed to maximize the openness during the focus group workshop; consequently, smart city ecosystems were considered to be the best option. Smart city ecosystems are coordinated by the public sector (i.e., city organizations) and include actors from the public, business, and third sectors (e.g., resident associations). Consequently, they have a minimal number of direct competitors and thus, a minimum risk of losing business advantage when sharing information of value proposition, creation, capture, and expectations (i.e., the vision of future value potential).

The cases were analyzed through thematic analyses. Thematic analysis is a process that aims to transform qualitative data into quantitative data by encoding themes or observations found from the collected data to organize and interpret the phenomenon, for example (Boyatzis, 1998). While it is a systematic process, it is also a flexible approach to analyzing qualitative data, which is used to create descriptions, explanations, and even for theorizing (Saunders et al., 2019). The process includes four phases: familiarization with the data, coding the data, searching for themes and patterns, and refining the themes and testing propositions (ibid.) The codes used in this research were both data and theory driven. Thematic analysis can be utilized with a large variety of types of information (Boyatzis, 1998). While it is often used to analyze transcribed interviews, in this study it was used for coding the focus groups directly from the recordings. The interviews (Publication IV) were summarized from audio recordings by the researcher and approved by the interviewees. The focus group video recordings (Publication VI) were analyzed using qualitative data analysis and research software (Atlas.ti, version 22.0). Atlas.ti has been recognized as an effective tool, especially for thematic analysis (Soratto et al., 2020). The videos were not transcribed as transcribing video recordings have more disadvantages than benefits. The main limitations in transcription compared to using videos as such include accuracy, trustworthiness, lack of depth in reporting, and, last but not least, inefficiency leading to delays in reporting and excessive use of money (Markle et al., 2011). Transcription formats tend to influence how the researcher explicates the meanings of the texts. While transcription leaves out non-verbal communication it may efface significant information, thus affecting how the meanings are interpreted (Loubere, 2017). In particular, when analyzing how different focus group members understand value, it is vital to see how confident they are when talking about their views.

In social sciences, the main entity under study, defining the level of abstraction where the research aims to find results, is called the unit of analysis (Gorichanaz et al., 2018). In qualitative research, the unit of analysis is the same as the case under research (see e.g., (Yin, 2003)). The unit of analysis can be seen as a crystallized version of the research purpose, on which selected individuals (or their actions can) elaborate (Grünbaum, 2007). The selection of the unit of analysis is an important part of research.

The purpose of this research is to increase knowledge for IoT-enabled platform ecosystems to be able to better internalize network externalities, innovate ecosystem-level value propositions, and increase the overall value capture of the whole ecosystem. Therefore, at least three different units of analysis are possible: 1) individual actors, 2) interactions between directly connected actors, or 3) the whole ecosystem and the interactions within it.

Jacobides et al. (2023) has demonstrated that individual actors tend to focus only on the products and services they offer and often fail to recognize the multilateral, multi-dimensional, and interdependent nature of the value co-creation in ecosystems (Jacobides et al., 2023). In ecosystems, the value does not only lie in the individual complements but also in the interaction between ecosystem actors (Adner and Kapoor, 2010).

Analyzing the value creation and capture between two actors would require an assumption that the connections are bi-lateral. Keskin and Kennedy (2015) have claimed that the two-sided market is an oversimplification of the real world (Keskin and Kennedy, 2015). Especially in platform ecosystems, which offer complex products and services (such as IoT-enabled ecosystems), the complementors may form sub-complementor groups inside the ecosystem, in which not all the actors are connected to the platform (Nerbel and Kreutzer, 2023).

As value (see Section 3.2) can be intrinsic and network externalities (see Section 3.1.2) can be indirect, unidirectional, or reciprocal, their identification requires an ecosystemic view. Therefore, the unit of analysis in this thesis was selected to be the whole ecosystem, although in Publication I the ecosystem orchestrators were the only ones interviewed.

More detailed descriptions of the analysis procedures for each sub-study are available in Publications I-VI.

# 3 RELATED RESEARCH

The theories and concepts can be seen as a foundation for reflective learning through inquiry, which when combined with the future orientation of the research objective, is typical for pragmatist research (Elkjaer and Simpson, 2011).

Concepts specify which features or characteristics define a phenomenon and how it is distinguished from other phenomena (Podsakoff et al., 2016). Although concepts are fundamental parts of theory building, unfortunately definitions are often missing from the research (ibid.).

To be able to answer the research problem, multiple theoretically underdeveloped concepts had to be combined: digital transformation, ecosystems, digital platform ecosystems, IoT, business model innovation, and data economy. Therefore, Figure 4 shows a general illustration of the relations between these concepts.

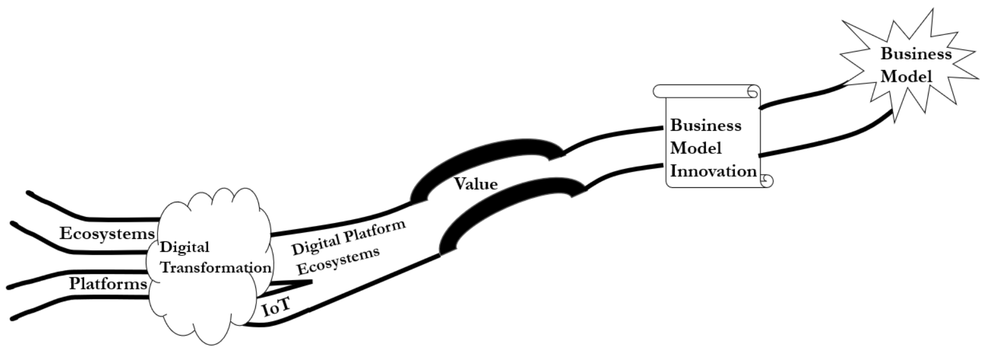


**Figure 4.** Illustrative presentation of the relations between the concepts of this research.

As can be seen from Figure 4, when ecosystems and platforms go through digital transformation, they are converted into digital platform ecosystems. These can sometimes be enabled by IoT, which originates from digital transformation. The identified value proposition bridges the digital platform ecosystems and business model innovation that are required to find an innovative and lucrative business model.

In this research, the key concepts do not have a universal definition, hence, to frame the research more clearly, this section aims to present the key concepts applied in this research in relation to each other through the theoretical lens of the Social Exchange Theory. This should facilitate the scrutiny of the latter sections.

## 3.1 Digital Age Ecosystems

In 1993, James F. Moore introduced the analogy of biological ecosystems to the business world. He proposed that a company is not only a member of a single industry, but also a participant in a cross-industrial business ecosystem, where the companies co-evolve their capabilities by both cooperating and competing at the same time (Moore, 1993). Since then, ecosystemic thinking has been introduced in several other contexts. There are several types of ecosystems. To name just a few, Valkokari (2015) compares business, innovation and knowledge ecosystems, Ranta et al. (2020) describes circular economy ecosystems, and Lusch et al. (2016) have studied service ecosystems. Digital transformation has brought a new 'dimension' to ecosystems.

### 3.1.1 Effects of Digital Disruption to Ecosystems

Although digital disruption can also affect the business, innovation, knowledge and even circular economy ecosystems, it is more apparent when Warenham (2014) discusses technology ecosystems, Hyrynsalmi et al. (2014) write about software and application ecosystems, Parker et al. (2016) elaborate the digital platform ecosystem concept, and Leminen et al. (2012) IoT-enabled ecosystems. In many cases, an ecosystem can be a combination of different ecosystem types. For instance, a circular economy ecosystem is likely to be a platform ecosystem but not necessarily a digital platform ecosystem. The definitions of each of the ecosystem types are still controversial, as is the taxonomy of ecosystems (Hein et al., 2020). Therefore, it is necessary to describe univocally how an ecosystem is defined in this research.

In short, this research follows the ecosystem definition by Jacobides et al. (2018, p. 2263), whereby:

> "[E]cosystems are groups of firms that must deal with either unique or super modular complementarities that are non-generic, requiring the creation of a specific structure of relationships and alignment to create value. The strength of ecosystems, and their distinctive feature, is that they provide a structure within which complementarities (of all types) in production and/or consumption can be contained and coordinated without the need for vertical integration."

Although Jacobides et al. use the word 'firms' in their definition, later on in the article, they refer to actors (Jacobides et al., 2018, p. 2264). In this research, a multi-actor network perspective (Tsujimoto et al., 2018) is taken. Ergo, the ecosystem consists of, in addition to firms, individual users, user communities, public entities (e.g., cities, government, policymakers), and private investors, etc. The ecosystem is seen as a meta-organization, which collects together all required actors to actualize the joint value proposition collaboratively (Adner, 2017; Cennamo and Santaló, 2019).

The ecosystems can be formed or they can emerge (Moore, 1998). However, Thomas and Ritala (2021) have argued that the legitimacy of the ecosystem requires an orchestrator to purposefully drive change and for the ecosystem to have a collective identity. Furthermore, the key to getting actors on board is to understand the motivators of the potential actors (Bogers et al., 2019). This means that even though the success of an ecosystem relies on cooperation and co-evolution, the self-interest of the actors should not be neglected. Hence, while the joint value proposition is important, the value propositions for the actors should also be understood (Frow and Payne, 2011; Hokkanen et al., 2021). Notably, SET supports this view, too, as understanding the expectations of each actor enables relationship satisfaction to be built, which increases the commitment to the community – in this case the ecosystem (Jeong and Oh, 2017). Therefore, the success of an ecosystem is based on reciprocal value.

For an ecosystem to be successful, its members should co-evolve their capabilities and innovate new ideas (Moore, 1998, 1996). As the actors are only loosely interconnected while simultaneously depending on each other, the success of the ecosystem strongly relies on mutual effectiveness, coherence, and trust between the actors (Iansiti and Levien, 2004a; Jeong and Oh, 2017; Tsujimoto et al., 2018). Ecosystems tend to be multidimensional where interdependent actors have multilateral interactions to achieve ecosystem-level goals. The strength of these complex interdependencies brings actors closer together and, thus, increases the probabilities of longevity and success (Valkokari, 2015).

Aligning both the cooperative activities and interests of the ecosystem actors without hierarchical control is challenging as the ecosystem should simultaneously be stable and flexible enough to adapt to external changes (Cennamo and Santaló, 2019). The activities are built around the ecosystem's value proposition (Adner, 2017). The actors co-create value by creating complementarities but simultaneously compete with each other to capture a sufficient amount of value for themselves (Hannah and Eisenhardt, 2018). Although there is no hierarchical control, the ecosystems should still have a joint understanding of their goals (i.e., shared vision) and the strategies to achieve them.

### 3.1.2 Idiosyncrasies of Digital Platform Ecosystems

During the final years of the last millennium, globalization, fast technological evolution, and progressive technological complexity called for a means to reduce complexity (Mäkinen et al., 2014). Platform thinking was seen as one solution. As Sawhney (1998) explained:

> "Platform thinking relies on a simple insight – understand the common strands that tie your firm's offerings, markets, and processes together, and exploit these commonalities to create leveraged growth and variety."

The first phase of the platform-based approach was to use common components, or even modules, as parts of *product platforms* to increase efficiency in product development, while simultaneously reducing variety in the supply chain (Mäkinen et al., 2014).

Since the early 2000s, the term platform has been harnessed to describe the products, services, and firms intermediating interactions between two or more groups of actors (Rochet and Tirole, 2003). These proficiently matched interactions are enabled by an open infrastructure and governance rules for value co-creation (Parker et al., 2016). The multisided nature of platforms creates their quintessential characteristic of network effects, meaning that increasing the number of users creates a self-reinforcing cycle (Evans et al., 2016), hence they scale more efficiently, reduce transaction costs, and thus often beat the traditional pipeline-type method of doing business (Parker et al., 2016).

However, all platforms are not digital ((e.g., a traditional city center marketplace or a shopping mall can both be considered platforms) (Van-Alstyne et al., 2016)). In the context of digital transformation, this research focuses on digital platforms. Digital platforms utilize data over the internet to create and capture value, thus they are radically transforming business – or even the whole society at large – when billions of people all over the globe are subjected to their effects (Liu et al., 2021; Ruutu et al., 2017).

The scholarly interest in studying digital platforms has been increasing, especially during the past decade, without reaching a commonly accepted definition (Liu et al., 2021). Definitions have evolved in various disciplines (such as economics, technology management, and information systems) and perspectives – such as market-based, technical, and socio-technical (Hein et al., 2020). In 2018, the newest paradigm arose, when scholars started to discuss digital platform ecosystems introducing new attributes such as participants being autonomous, collective contribution to the value proposition, and the interdependencies between the platform and its actors (ibid.).

While the definitions vary, so do the typologies of digital platforms. *Transaction platforms* (Gawer, 2021; Hänninen, 2019; Thomas et al., 2014) are platforms that intermediate transactions between customers and suppliers or service providers (e.g., AirBnB or Netflix), hence are likely to be the most well-known among laymen. *Innovation platforms* (Gawer, 2021; Hänninen, 2019; Thomas et al., 2014) are those that nurture the emergence of new innovations, e.g., technologies, products, or services with which others can innovate. Microsoft and SAP are examples of innovation platforms. Evans and Gawer (2016) have identified two more types of platforms: integrated and investment platforms. The *integrated platform* is a combination of innovation and transaction platforms (e.g., Amazon) and the *investment platforms* are those that function as a holding company or have a platform portfolio strategy (e.g., Softbank).

Regardless of the type of digital platform, they collect an enormous amount of data. For example, data on millions of people can be extracted easily from social media (see e.g., (Cinelli et al., 2020)). This data allows platform actors to enter the data economy, opening up a vast new market for them.

The (digital) platform ecosystems have been called "inverted firms" as they are able to internalize the value "spillover" (i.e., network externalities) created within the ecosystem (Parker et al., 2017). These externalities are features that change the value of a product or service for the ecosystem actor when the number of actors using the same or similar product or service changes (Jacobides et al., 2023; Katz and Shapiro, 1994; Liebowitz and Margolis, 2002). The change itself, when the externalities are internalized, is a network effect (Liebowitz and Margolis, 2002). The network externalities are especially significant in ecosystems when the complementary goods are an important value-driver, and in cases where technological compatibility is required (Farrell and Saloner, 1992).

The network externalities can be either positive or negative, and either unidirectional or reciprocal (Jacobides et al., 2023). A negative externality, for example an increasing amount of traffic, causes more environmental (e.g., pollution, number of roads) and social impacts (e.g., frustration in queues).

A positive externality can be found in IoT-enabled wearables. A consumer may buy a smart watch to monitor the amount and efficiency of their exercise. However, when many others in the same ecosystem buy a smart watch, the consumer can compare results with others or find new exercise routes based on the data of other users. This example is also an example of reciprocal externality. Wu et al. (2017a) have demonstrated that the larger the consumer base in a wearable ecosystem is, the more frequently the products and services are updated; the larger amount of data enables more services and consumers can even capture social value from interaction with other consumers, ergo, in addition to price and quality, the network externalities also affect the value capture experienced (Wu et al., 2017a).

The network effects can be either positive or negative and can affect either the same side (direct) or cross-side (indirect) of the platform (Kouris and Kleer, 2012; Wu et al., 2017a). Let us consider a second-hand market platform as an example: An actor has sold goods on the platform and everything has gone well (good price, convenient, etc.). The actor recommends the platform to a friend, who also joins the platform (same side effect). When the number of sellers increases, it causes positive cross-side effects, as the supply on the platform increases, which is likely to attract more buyers. The increased demand is likely to increase the supply further. A positive self-enforced cycle has emerged. However, when the experience is negative (e.g., someone happens to buy a broken product, the seller was slow to respond, etc.) it is likely that the buyers will leave the platform (negative cross-side effect). causing diminishing demand or at least longer selling times, which may lead to other negative cross-side effects as the sellers no longer have customers and thus leave the platform.

The network externalities and related network effects can be difficult to identify when the independent actors focus on their own products and are more used to considering bilateral relationships, which may hinder the actors' value creation for customers in a multilateral interdependent environment (Jacobides et al., 2023). As an example, from an IoT-enabled ecosystem: A refrigerator manufacturer may identify the importance of the refrigerator "knowing" what products are in it. The manufacturer may even recognize the importance of the refrigerator alerting the owner when the milk level is low, but it may not recognize the possibilities of recommending new products, other brands, etc. to the refrigerator owner. If we add internet operators (e.g., mobile network providers), advertisers, banks, food delivery companies, and smart watches and phones to the ecosystem and each of the actors "brings their offering to the table", the amount of externalities becomes visible. With the data provided there is a vast variety of possibilities. Based on the demographics of the refrigerator users, the advertisers can target their message to potential customers, the refrigerator can send a shopping list proposal to the owner or even make an order automatically, the groceries can be paid for and home-delivered. The shopping list can even be optimized to support the users' lifestyle, e.g., through proposing products based on the weight and physical activity level of the users.

While, intuitively, fast and large positive network effects would be desirable, it is not necessarily so. Even the positive externalities need to be restrained to ensure complement quality, innovation output, and customer satisfaction (Jacobides et al., 2023; Nerbel and Kreutzer, 2023). Therefore, the platform should have appropriate governance principles in place. This means that the platform ecosystem orchestrator should ensure that the actors understand their roles, there are rules for co-operation (ownership rights, revenue management, what and how data is shared, conflict resolution principles, etc.), all actors understand the level of openness of the ecosystem, and technological interfaces and standards are in place (Jacobides et al., 2023; Parker et al., 2017; Rietveld and Schilling, 2021). Insufficient governance will cause innovation bottlenecks, unfair value distribution, and, in the worst case, a complete destruction of the platform ecosystem (Jacobides et al., 2023). On the other hand, developers may find the platform unappealing if the governance is too strict, thus constraining the network effects excessively (West, 2003).

The orchestrator faces difficult strategic questions such as which complements are needed in the platform ecosystem, how many complements ensure customers join the ecosystem but still offer enough incentives to the complement suppliers, and how to maintain sufficient quality, etc. (Rietveld and Schilling, 2021). In platforms utilizing high tech, such as IoT, the balancing is even more challenging as the actors are required to make investments to design products that are compatible with the standards and technologies selected for the platform (Wu et al., 2017a), therefore the incentives to join need to be clear. When the orchestrator is successful, it gives the orchestrator the opportunity to tune the value distribution within the ecosystem and consequently gain more power and capture more value for itself (Rietveld and Schilling, 2021). However, if the balance shifts too much, the actors may consider that the changes in value distribution have become unfair, which may cause them to leave the ecosystem (Iansiti and Levien, 2004b).

Thus, in summary, the governance of a platform ecosystem is a challenging balancing act, where the orchestrator strives to maintain the co-operation motivation of competitive, independent but interdependent actors through multi-actor trade-offs in a continuously evolving environment (Jacobides et al., 2023; Zhang et al., 2022).

### 3.1.3 Internet of Things as a Value Enabler

As mentioned earlier, the Internet of Things is one manifestation of digital transformation as it enables new business opportunities as a manifestation of digital technologies (in the modern world). The term (IoT) was first introduced by Kevin Ashton in the late 1990s (Ashton, 2009; Brock, 2001). In 2005, the International Telecommunications Union (ITU) stated that ubiquitous digital devices, i.e., 'things', such as sensors and actuators, would become the source of the majority of the data inputted into the internet (International Telecommunication Union (ITU), 2005). In the same report, ITU revealed a vision for the Internet of Things, according to which the ubiquitous network is accessed "anytime, anywhere, by anyone and anything" (ibid.). While the vision seems easy to comprehend, what it actually means is still "under construction." The academic community has not yet reached a consensus on the definition of IoT, although both diversification of the subject areas and the sheer volume of publications has increased over the years – the volume exponentially (see, for example, Publication V). Simultaneously, several terms describing a similar concept have emerged. For example, it is not clear how IoT and Internet of Things and Services (IoT&S) (De Leusse et al., 2009; Jia et al., 2011) are related, or whether business is included in one, neither, or both of them.

The starting point of this research is the IoT definition made by ITU (2012), which states that IoT is:

> "a global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies.
>
> Through the exploitation of identification, data capture, processing, and communication capabilities, the IoT makes full use of 'things' to offer services to all kinds of applications, whilst ensuring that security and privacy requirements are fulfilled."

There are several noteworthy details in this definition. First, while IoT is an infrastructure, it is also seen as a business enabler through advanced services that can offer value. Between the lines, this can be seen as a promise for business models. Second, it explicates the difference between physical and virtual things. IoT connects everyday objects like cars or freezers and their surrounding environment (i.e., physical things) through sensors, actuators, and other virtual things in the virtual "information world." All things are interoperable as the collected data is stored, processed, and accessed in the information world. Third, standardized technologies are required to ensure interoperability. Finally, data security and privacy set requirements that need to be fulfilled. The data collected and analyzed can be productized, enabling the data economy.

What is not stated clearly in the definition but is described in the ITU (International Telecommunication Union (ITU), 2005) document is the role of humankind (see Figure 5). The "thing" creating and maintaining the communication can be a person, too. Person-to-person connection is created without a computer (e.g., with a smartphone) and human-to-thing connection by using generic equipment like wearables (ibid.)

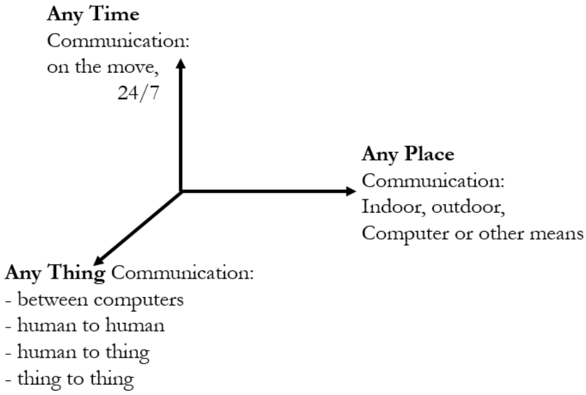


**Figure 5.** Dimensions of IoT (ITU (International Telecommunication Union (ITU), 2005)).

Earlier, IoT research focused on technology development. Only in the past few years have researchers acknowledged the ecosystemic nature of IoT (Bröring et al., 2017; Hodapp et al., 2019; Ikävalko et al., 2018). While technological development has been, and to some extent still is, necessary, the diffusion of IoT requires successful business models, thus understanding value co-creation, value capturing, and who are the required ecosystem actors.

While sensors and actuators are outstanding in collecting data, and the clouds are capable of storing it, it should be remembered that data creates value only when it can be exploited. Ergo, after collecting it, it has to be annotated, prepared, organized, and integrated before exploitation through analyzing, visualization, and decision-making (Miller and Mork, 2013). Therefore, this research focuses on the preconditions of the IoT-enabled ecosystem and business models, rather than on the technological development of IoT devices or interconnections. It aims to identify how to offer value to digital platform ecosystem actors through IoT.

## 3.2 Value – Bridging Technology and Business

Value as a concept can be complex, as value theory has a wide range of philosophical, epistemological, aesthetic, and ethical perspectives (Hirose and

Olson, 2015). This research approaches value as defined in the Collins dictionary (2021):

> "The worth of something in terms of the amount of other things for which it can be exchanged or in terms of some medium of exchange."

While many other definitions exist, too, this definition emphasizes that valuation is done before the exchange and that the exchange is not necessarily related to money. This interpretation is supported by Almquist et al. (2018), Cennamo et al. (2018), and Den Ouden (2012), for example.

Value can be either attributive or predicative, meaning that oftentimes value is relative to some standard (attributive) but it can also be absolute (predicative) (Zimmerman, 2015). An example of attributive value is that one can be a good tennis player at county level but not necessarily good enough for the ATP tour. There are only a few predicatively good things, i.e., things that are good for the world. A charity could be considered to be one. Value can also be either intrinsic or extrinsic, meaning that something can be valuable in itself and for its own sake (intrinsic) or valuable as a means for something else's sake (Rønnow-Rasmunssen, 2015). For example, the intrinsic value of pleasure and satisfaction can be attained through the extrinsic value of tasty food, a holiday trip, or achieving a goal (for example at work). Furthermore, value can be "good for someone" or good for a larger group or society (Nagel, 1989, p. 72). The fourth aspect of value is its temporal nature. Valuation changes based on the duration, tense (past, present, future), and temporal order (before, simultaneous, after) (Bykvist, 2015). As an example, if one is struggling now, even a small positive thing is valuable. On the other hand, sometimes even a bigger reward can be difficult to value if it will be achieved far in the future. To "add the cherry on top" of the complexity of the concept, a value can be either a means to attain some other utility (value in exchange) or the utility of an object (value in use) (Stigler, 1950). A good example of this is a diamond. It is often quite useless in terms of use. Its main function is to look beautiful. However, it has a remarkably high value in exchange as 1g of diamonds is worth tens of thousands of USD.

As the context of this study is digital platform ecosystems, value is considered to be co-created by the value stakeholders, i.e., ecosystem actors, following Service-Dominant (S-D) logic (Frow and Payne, 2011; Lusch and Vargo, 2006). S-D logic emphasizes that the "market provider" and "market beneficiary" create value together, as the beneficiary is the one who determines whether something is valuable (Vargo and Lusch, 2008). It also states that all actors are “resource integrators” and thus through integration they convert their specific sub-offering and competencies into complex service offerings (ibid.) It can be said that S-D-logic transforms the focus of value-in-exchange to value-in-use (Blaschke et al., 2019).

Valuation occurs all the time and is affected by the personal values, preferences, needs, usage situations, and financial resources of the party to whom the value is offered (Pura, 2005). Different parties find different things valuable. Sheth et al. (1991) classify value in five different dimensions: functional, emotional, social, epistemic, and conditional value. Pura (2005) builds on these by adding financial value to the dimensions. Table 6 illustrates some examples of each of the value dimensions. The valuation can be done by one, some, or all of the dimensions.

Emotional value originates from feelings. One of the most important emotional values is trust, as it is a pre-requisite of value co-creation (See-To and Ho, 2014). Emotional value also includes aspects like risk mitigation, sense, or expectation of achievement and motivation. Many of these are intrinsic and highly attributive values.

**Table 6.** Examples of value dimensions (derived from Almquist et al., 2018, 2016; Pura, 2005; Rintamäki et al., 2007; Sheth et al., 1991).

| VALUE DIMENSION | EXAMPLES |
|---|---|
| **EMOTIONAL VALUE** | Motivation, risk reduction, sensory appeal, loyalty, wellness, nostalgia, aesthetics, fun/entertainment, self-actualization, badge value, cultural fit (e.g., ethics), stability, responsiveness, achievement, attention, fame, trust |
| **EPISTEMIC VALUE** | Data, information, knowledge, novelty, learning, insight, innovativeness, transparency, interesting, collaborative filtering |
| **FINANCIAL VALUE** | Make money, reduce cost, increase brand value, gain investors |
| **FUNCTIONAL VALUE** | Time savings, simplicity, usability, convenience (reduce effort, avoid hassle), quality, integration, security (e.g., data security), accessibility, customization, scalability, meeting specifications, flexibility, availability, durability |
| **SOCIAL VALUE** | Reference, interaction, sense of belonging, group identification, engagement, status, network expansion, reputation, social responsibility |

The importance of epistemic value is increasing as the data economy is becoming mainstream. In addition to self-evident data, information, and knowledge, epistemic value also includes aspects like innovativeness and novelty. Financial and functional values are those that have traditionally been seen as driving valuation.

Financial value includes aspects of making more money or spending less but also includes increasing brand value and attracting more investors. Functional value emerges from the ease of use, efficiency, customization, flexibility, and meeting specifications. (Almquist et al., 2018, 2016; Sheth et al., 1991) Social value has two streams. Traditionally social value has originated from a sense of belonging and group identification, like that created by being a member of a fan club (Sheth et al., 1991). Recently, social value has also been associated with social responsibility and quality of life (Fulgencio, 2017; Hiteva and Foxon, 2021; Ranta et al., 2020). An excellent example of multiple values exchanged in an ecosystem is any social media platform. Individuals use the "free" platform to obtain social or emotional value, for example, but pay for the use through providing data of themselves. The platform collects and analyzes the data and sells the knowledge to third parties by offering precisely targeted marketing. Third parties save money and gain visibility – possibly even increase sales. If one side is unhappy, then the whole concept collapses.

Finally, while value is easily seen as a positive thing, it should be remembered that value can be experienced as positive or negative (Sheth et al., 1991). For example, if a machine does not function as expected, it can cause negative functional value (lost capacity), negative financial value (lost sales), and negative emotional value (frustration).

The complexity, especially its subjective and temporal nature, causes challenges in finding successful business models. The other side of the coin is that understanding the multiple dimensions of value may help in finding completely new ways to satisfy ecosystem actors.

## 3.3 Business Model and Its Innovation

The cumulation of business model theory has suffered from a lack of construct clarity and heterogeneity of definitions (Foss and Saebi, 2018). Although there is no consensus of the specific definition of business model (BM), it can be considered to be "a story of how a business works" (Muegge, 2012), hence describing the value proposition and the mechanisms of how value is created, delivered, and captured (Burmeister et al., 2016). Foss and Saebi argue that the purpose of BM is to describe what complimentary activities are required to enable the above-mentioned mechanisms (Foss and Saebi, 2018).

For the purposes of research, the definition by Weil and Vitale (2001, p. 34) is employed:

> "a description of the roles and relationships among a firm's consumers, customers, allies, and suppliers that identifies the major flows of product, information, and money, and the major benefits to participants."

This definition was chosen for two reasons. First, unlike some other definitions, it emphasizes the ecosystemic approach to BM by referring to "allies". For example, seminal BM papers (see e.g. Amit and Zott, 2001, p. 511; Teece, 2010, p. 173) emphasize the single firm perspective, which is not sufficient in the ecosystem research context. Second, in addition to describing what a BM is, it also describes what BM is for, i.e., to accomplish "major benefits." While there are nearly as many business models as there are companies, this research focuses on the process of innovating a suitable BM for each particular situation.

Digital transformation is disrupting the rules of business through novel technologies, adding possibilities to create revenue from digital, and demanding new business models to be innovated in nearly every industry (Hanelt et al., 2021; Hess, 2022, p. 81). It challenges companies to re-consider their way of doing business. Smart products affect companies and the competitive forces within the market through redefining industry boundaries, changing interaction practices, requiring more coordination through the value chain and increasing cross-functional collaboration, and therefore requiring a "smart-compatible" strategy and business model (Porter and Heppelmann, 2015). There are three ways a company can enhance their business models with digital products and services: supplement established products with digital value-added services, combine analog and digital products or services, and self-evidently, offer completely new digital products and services (Hess, 2022, pp. 49–52). Let us take the car industry as an example. Traditionally, car manufacturers built a car and sold it. Digital transformation has made cars a potential gold mine of continuous revenue for manufacturers, as they can collect a massive amount of data from the use of each car (i.e., contextual data of who uses it, where, when, and how, etc.). The manufacturers and third parties can monetize the analysis of the data through improved predictive car maintenance, enhanced in-vehicle experience, or more efficient fleet-management, for example (Shiklo, 2022). Consequently, while technological development creates challenges, it also offers opportunities as long as the companies remember to evaluate their business models and innovate new ones. However, when the business model is based on "smart products and services", as in IoT-enabled ecosystems, no single company can create the offering alone; rather the ecosystem actors innovate the business model together (Herterich et al., 2022).

Business Model Innovation (later BMI) is a process through which the business model is changed either voluntarily or to respond to emerging changes (Demil and Lecocq, 2010; Teece, 2010). The object of BMI is to find novel changes in the relations of BM activities and mechanisms (Foss and Saebi, 2018). BMI is affected by both macro-level and micro-level factors (Wirtz and Daiser, 2017). The macro-level factors can be seen as changes affecting multiple industries such as globalization, regulation, market shifts, new technologies, and naturally digital transformation. Micro-level factors are more industry-level factors such as changes in customer needs, competition, firm dynamics, and product and service innovations (ibid.). Therefore, BMI requires the reforming of products (whether physical, digital, or service products), technologies, information flows, and so forth across the borders of an individual firm (Clauss, 2017; Rummel et al., 2021).

Perhaps the most well-known framework for BMI is the Business Model Canvas (BMC) (Osterwalder and Pigneur, 2010). While there are dozens of other frameworks (see for example, Publication II), many of those are built on the BMC. The BMC has nine elements. The core is the value proposition. The left-hand side of the framework describes key partners, activities, and resources as well as the cost structure they create for the value proposition. Customer segments, customer relationships, distribution channels, and the expected revenue streams are described on the right-hand side. With the BMC, a company can see at a glance how their business is operating (Osterwalder and Pigneur, 2010).

However, there are limitations in the BMC. First, it is a static model, which fails to describe the dynamics between the elements and thus misses the link between cause and effect (Westerlund et al., 2014). It does describe what is needed for the BM but not how the BM works. Second, the BMC tends to be created from a single company perspective (Weiler and Neely, 2013), showing how the BM benefits that particular actor but not evaluating the expectations of other actors. This is a challenge, especially in a multilateral ecosystem context. Consequently, multiple attempts to develop the BMC further to better fit the ecosystem context has been made (see e.g., Almeida et al., 2019; Gierej, 2017; Metallo et al., 2018; Schiavone et al., 2019; Turber et al., 2014).

Another well-known framework for BMI is the Activity System Design (ASD) framework (Porter, 1996; Zott and Amit, 2010), whose benefits are that it provides BMI with a common language, concepts, and tools, highlights the importance of BMI as a managerial task, and emphasizes system-level design. The design elements of ASD are content, structure, and governance, i.e., what activities are to be performed, how they are linked, and who is responsible for performing them. In addition to the elements, ASD includes four design themes: (1) novelty, as in adopting innovation; (2) lock-in, how to build the elements in a way that retains the stakeholders; (3) complementarities to bundle activities for increased value; and (4) efficiency to reduce transaction costs. While being an improvement on the BMC through having a holistic view including all stakeholders, ASD still lacks the consideration of the social aspects of the stakeholders' decision-making process (ibid.).

Cicero (2016) and his colleagues have introduced a platform ecosystem-specific framework for BMI. Their Platform Toolkit 2.0 is very comprehensive, including over a dozen different canvases and hundreds of pages of instructions for practitioners. While comprehensiveness and detailed instructions help practitioners to proceed, this level of complexity may be overwhelming and be seen as "too much work". Furthermore, while the toolkit focuses on value propositions, and even network effects, it omits the evaluation of value capture by different actors. It is also planned to be used by the orchestrator alone, which may limit the view of different value propositions and capture possibilities.

Teece (2017) summarizes that the challenges in BMI are three-fold. First, it needs to be thoroughly understood what customers want and what technological and organizational resources are required to fulfill those needs. Second, the existing BMs on the market should be understood – not only the one used by the company in question. Third, while strategy is not a BM, they need to be tied together – both affect each other. BM viability should be evaluated before being applied to all market segments. Introducing a new BM may require a separate organizational unit to be established. Finally, a successful BMI is not just science and analysis, it requires intuition, too. (Teece, 2017)

Based on these shortcomings of the prevalent BMI frameworks, there is a need for an improved BMI framework model, which would pay particular attention to the special requirements of BMI in an ecosystem context and the fair allocation of the captured value suggested by SET. It should also be able to be utilized as a strategy management tool as BMI should be agile, experimental, and iterative, especially during digital transformation (Rummel et al., 2021).

## 3.4 Recapitulating Existing Research Gaps

As described in the earlier chapters the research gaps are multi-dimensional, hence it is worthwhile to summarize them briefly. Seven research gaps have been identified.

1) The research domains are nascent and therefore the theoretical understanding of the concepts is underdeveloped. For example, there is no consensus on the characteristics of platform ecosystem, their BMI, nor those of IoT (Foss and Saebi, 2018; Liu et al., 2021; Motta et al., 2019).
2) Thus far the BMI has been seen as a one-off exercise, though the continuously evolving ecosystems are likely to benefit from more recurring BMI, which requires clarification on whether the BMI process is linear, iterative or includes concurrent phases (Porter and Heppelmann, 2015; Rummel et al., 2021).
3) Currently there is deficient knowledge on, how to motivate the actors to join and remain in the ecosystem. Bogers et al. (2019) have recognized it is essential to understand the motivators of the potential actors. However, there is deficiency in knowledge on how to create the required understanding (Hokkanen et al., 2021).
4) To large extent, value is considered to be monetary, albeit S-D Logic recognizes value has other dimensions, too (Frow and Payne, 2011; Lusch and Vargo, 2006).
5) The academic knowledge on ecosystem-level value co-creation is still scarce (Almeida et al., 2019; Westerlund et al., 2014), though it is known that IoT-enabled ecosystems offering smart products and services do require

ecosystem actors to innovate the business model together (Herterich et al., 2022; Rummel et al., 2021).

6) The means to identify and enable maximum positive externalities and network effects, require clarification as companies are more likely to further develop their products when the number of users is larger (Wu et al., 2017a).
7) The traditional TCE analysis neglects the extraordinary complexity of ecosystems (Jacobides et al., 2018). IoT adds a new layer of complexity to the already complex unit of analysis (Markfort et al., 2022).

This research strives to find a model through which all above mentioned challenges can be reduced – if not even removed – in innovating business models for IoT-enabled platform ecosystems.

# 4 SUMMARIES OF ORIGINAL PUBLICATIONS

This section presents summaries of the articles that form this dissertation. Each of the articles was an independent study published in various publications, hence they have some variance in writing style and research design, for example. The contribution of each publication to the research questions of this dissertation will be elaborated in the following Section 5.

## 4.1 Publication I: Business Model Innovation with Platform Canvas

The purpose of Publication I was to explore business model innovation in platform ecosystems. The research was conducted as a literature review, and the framework was verified through a multiple case study. Although the study concentrated on ecosystems enabled by digital platforms, it focused mainly on business perspectives rather than technical issues.

The ecosystem definition in the article was based on the theoretical framework by Jacobides et al. (2018) according to which an ecosystem is formed by interdependent, multilateral organizations. It is not fully coordinated, but it has shared rules of operation. The core of the ecosystem is its ability to offer combinations of modular complementarities. The role of the platform in these ecosystems is to facilitate the multi-party exchange of value, which can be goods, services, or even social currency. (Jacobides et al., 2018) The platforms help companies to create integrated offerings to provide more value to the customers (Ju et al., 2016). Companies cannot provide the value alone as all their actions affect the overall ecosystem. The interconnectivity within the ecosystem causes the members to have shared faith in it (Rong et al., 2015).

The platform itself can be considered as a business model innovation as it enables actors outside the platform provider company to create value through interacting with each other (Choudary, 2015). The technical modularity allows independent parties to produce a component of the complete offering and, thus, reduce the friction in the market and other barriers to participation (Evans and Schmalensee, 2016). By enabling cooperation, the platforms provide opportunities for value co-creation with users. Engaging customers can create novel forms of value (Parker et al., 2016).

To support business model innovation in the platform context, this article presents the results of a comprehensive literature review, through which the critical characteristics of a platform ecosystem were identified. The literature review (process illustrated in Figure 6) was conducted through a backward snowballing procedure (Wohlin, 2014). Through this review, sixteen original seminal sources were identified. The sources and the characteristics identified in each of them are described in Table 1 (p.5 of the original Publication I included at the end of this thesis).

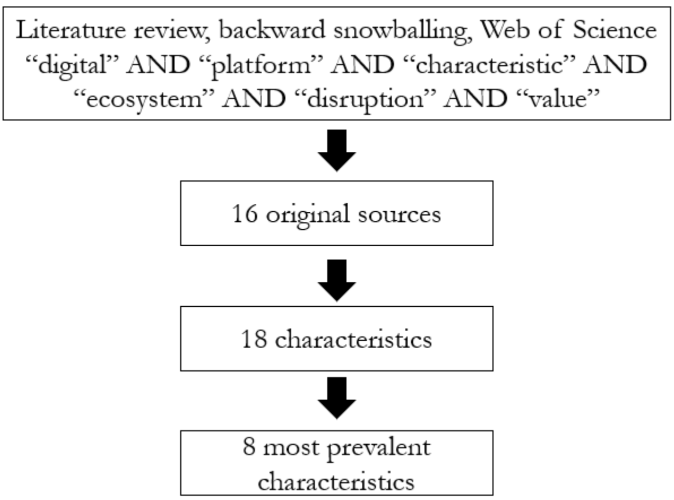


**Figure 6.** Process to identify the essential characteristics.

From these sources, eighteen critical characteristics of establishing a platform ecosystem were identified. To reduce the number of characteristics to a more manageable number they were arranged into the order of prevalence. A second list was compiled from the most cited sources and the characteristics emphasized in them. The lists had six common characteristics. While the typical number of characteristics was 6.8, the seventh characteristic from both lists was also included in the final eight most essential characteristics. These characteristics were used to construct an easy-to-use Platform Canvas framework.

The eight characteristics of the Platform Canvas consist of (1) value, (2) monetizing, (3) producers, (4) users, (5) filtering, (6) governance, (7) resilience, and (8) network effect, as illustrated in Figure 7.

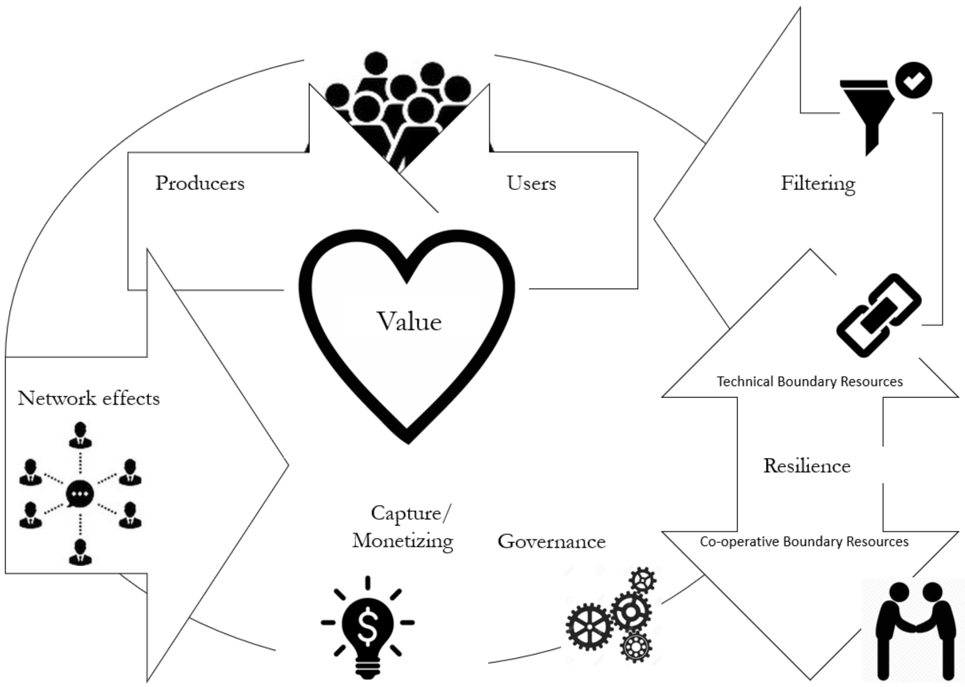


**Figure 7.** Platform Canvas (Publication I).

The Platform Canvas was evaluated by interviewing representatives of seven platform orchestrator companies.

Innovating a platform business model should start by thoroughly understanding the value for both producers and users in different interactions. This includes understanding the friction the platform reduces, the services the platform offers, and how it keeps the interest of its users. Only after understanding these aspects can the system side of the platform be designed.

The Platform Canvas offers guidance for the platform participants through the business model innovation process by challenging them to open their thinking and by bringing clarity to the complexity (e.g., dual role of participants) of platform ecosystems through facilitative questions for each characteristic.

## 4.2 Publication II: Business Model Frameworks in IoT Context – a Literature Review

The purpose of Publication II was to explore business model innovation in the Internet of Things (IoT) context. Based on public discussion and increasing scientific attention, it can be assumed that IoT is expected to have a significant effect on businesses. However, a prosperous business requires proper business models. This study elaborated on the differences in business model development between traditional and IoT-driven businesses.

There are three prerequisites for a technology to succeed. First, the technology itself must be mature enough to be available. Second, there must be a strong enough market demand. Finally, there have to be adequate business models to connect supply and demand. (Palattella et al., 2016) In the case of IoT, research has focused predominately on developing the technology and less attention has been paid to business model research (Whitmore et al., 2015). There are, however, nearly unlimited possibilities to connect virtual and physical "things", customers, and businesses together as IoT can create new types of business, services, and even social opportunities (Benkler, 2006; Westerlund et al., 2014). Capturing these possibilities requires the enhancing of openness and collaboration across industries (Ju et al., 2016), consequently complicating business models by creating the need to innovate ecosystem-level business models. Furthermore, digital transformation increases the possibilities of turning data into value as well as customer involvement. Together, these convert traditional cooperation into more complex multilateral ecosystems (Pflaum and Gölzer, 2018).

As the definitions of both business model and IoT have considerable variation and the purpose of this study was to develop conceptual understanding further, the study was conducted as a meta-synthesis type of literature review (O'Gorman and MacIntosh, 2015) through the process illustrated in Figure 8. Through backward snowballing (Wohlin, 2014) and integrating interpretive qualitative data, the study created an interpretive synthesis of IoT business model development frameworks. In all, the study identified 13 IoT-related business model frameworks.

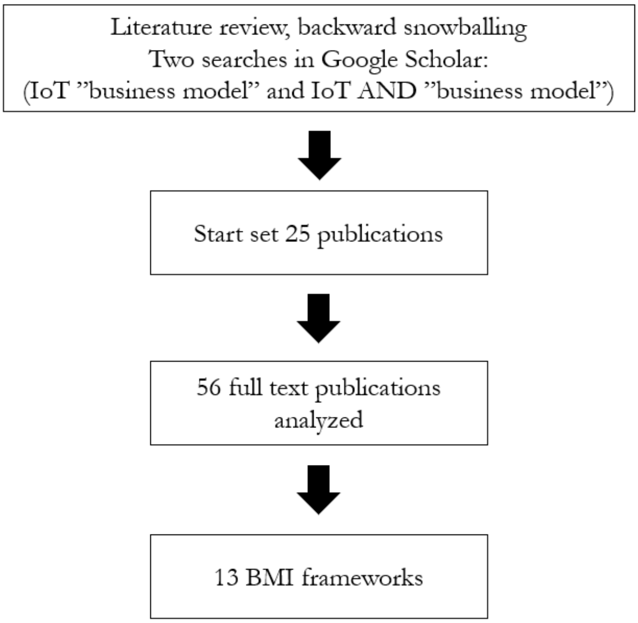


**Figure 8.** Data collection process of Publication II.

The main findings were as follows: (1) Traditional component-based frameworks (such as Business Model Canvas (BMC) (Osterwalder and Pigneur, 2010)) focus on model architecture and fail to describe the connections and dynamics between the components. Nevertheless, among practitioners, the BMC appears to be the most popular procedure in defining a business model. (2) Co-creation of value requires a system-level perspective in business model development. (3) While many of the frameworks regard value capture as equal to capturing money, some academics consider it to include the capture of non-monetary value, too (Burmeister et al., 2016).

Two ecosystem-level frameworks were identified, although both had critical shortcomings. Chan's model (Chan, 2015) is designed around the strategy and value chain, but each of the participants is evaluated separately and it assumes that the value is created linearly in one direction. It does, however, consider both monetary and non-monetary values. The second model, EBM (Bahari et al., 2015), acknowledges that value is created and captured multi-directionally, but it assumes the value always to be monetary.

To summarize, IoT requires an ecosystemic, multi-dimensional, value-guided approach in developing business models. Participants need to remember to create complementary relationships with each other as they coexist and have shared faith.

## 4.3 Publication III: Co-creation of Ecosystem-level Value Propositions

Publication III elaborates on why enabling value capture for all ecosystem participants is important. It also delineates the importance of different dimensions of value.

Although many academics have claimed a joint value proposition to be a salient factor of ecosystem success (Den Ouden, 2012; Polizzotto and Molella, 2019), the academic literature tends to focus on it from the perspective of either the ecosystem leader or end-customer, neglecting the needs of other ecosystem participants. While ecosystem participants co-operate, collaborate, and even compete within the ecosystem, they also should strive to maximize the value for the ecosystem as a whole, not just for individual participants (Li et al., 2019).

Social Exchange Theory (SET) (Homans, 1958) proposes that all actors should find the value that they capture sufficient for the investments required in creating value and that the distribution of value is equitable based on the actors' efforts. Hence, it supports the perception of the need to evaluate the ecosystem-level value proposition, ensuring appropriate balance for all participants. SET as a theoretical approach applies to the coevolving and dynamic nature of ecosystems well, especially when analyzing the co-creation of value and interdependencies (Benitez et al., 2020).

It is worth noting that, according to Thomas et al. (2014), the exchange of value based on Service-Dominant Logic (SDL) includes value other than monetary as well. Furthermore, SDL states that the customer should also be a co-creator of value (Vargo and Lusch, 2008). As the value can be an exchange of user-experienced value, too, and the value exchange can, in an ecosystem context, be multilateral, evaluation of the appropriate value balance is challenging (Autio and Thomas, 2020).

Value in the study by Sheth et al. (1991) is considered to have five dimensions, i.e., conditional, emotional, epistemic, functional and social value, supplemented by financial value, which was identified by Pura (2005). Conditional value is exchanged when the customer perceives value differently in different circumstances. Emotional value is captured when a utility evokes feelings. Epistemic value is about a sense of novelty and all data, information, and knowledge related aspects. The perception of the products, i.e., usability, quality, and availability, leads to functional value. Network expansion, reputation, and social responsibility are parts of social value. Financial value is probably the easiest to comprehend: to put it simply more profit or less cost.

This study identified different value dimensions by means of a literature review and compared the theoretical findings to eight case ecosystems. The literature search (ecosystem AND "value proposition") in Scopus identified 199 articles of which the sixty most recent were reviewed. The subject has attracted global interest, but it seems that value in the ecosystem context has not been established as a research domain.

The identified descriptions of value propositions were classified into the previously mentioned six categories. Financial (n=42) and functional (n=42) propositions were the most common, followed by epistemic propositions (n= 37). Social (n= 30) and emotional (n=29) propositions were less popular. Conditional value was not identified in the ecosystem literature.

Comparing the results found from the literature to the seven case ecosystems, the order of prevalence remained the same. Not only are the financial and functional values described most often, but each of the ecosystems also offers several types of financial and functional value. Furthermore, the variety has been increasing in the past few years (compared to Publication I). The epistemic value was also well-identified, although one IoT-enabled ecosystem did not mention any epistemic value proposition. Offering social value has increased. However, offering value together through co-design or co-creation, for example, has typically not been recognized. Emotional value propositions focus on risk mitigation and safety. Rather surprisingly, none of the ecosystems mentioned trust or trustworthiness, although trust can be considered to be the foundation of value co-creation (See-To and Ho, 2014). Conditional value was not identified from the literature, nor was any conditional value offered in the case ecosystems.

More research is required to create a profound understanding of ecosystem value co-creation and the distribution of value dimensions. A better understanding of epistemic, social, and emotional value may be a key factor in designing successful ecosystems.

## 4.4 Publication IV: Conceptual Model of the Ecosystem Value Balance

This publication builds on the findings of Publication III.

While ecosystems are open to their environments and the business models of their actors may overlap, they are difficult to design (Langley et al., 2021; Tsujimoto et al., 2018). Actors should also find that value sharing in the ecosystem is equitable for all. Furthermore, the actors presume their efforts in value co-creation are reasonable compared to the value they capture, ergo they gain at least as much value as they invest – preferably more (Li et al., 2019). However, sufficient tools to approximate the equilibrium of the value proposition on the ecosystem level do not exist. This study proposes an initial framework for assessing the value balance of an ecosystem.

The framework was created through a constructive process and empirically evaluated with one well known successful ecosystem focusing on recycling beverage plastic bottles and cans in Finland. The ecosystem is orchestrated by Palpa (Suomen Palautuspakkaus Oy).

The seven-step procedure proposed by Lukka (2003) was chosen as the research method as it is a design-oriented framework especially applicable in management science (Piirainen and Gonzalez, 2014). The theoretical understanding was created through a literature review in Scopus using the search string ecosystem AND “value proposition”.

The framework was created through five iterations based on the three main constructs identified in the prior literature, i.e., the sacrifices required for value creation, captured value, and value potential. The framework can be used to assess whether the actors are, or can be in the future, satisfied with their value balance. It also reminds the ecosystem actors to consider all dimensions of value. Moreover, it helps the ecosystem actors, especially the orchestrator, to identify which type of new offering and actors are required. The framework is illustrated in Figure 9.

The framework was applied through interviews to a case ecosystem to evaluate the balance within an established ecosystem. The case ecosystem is known to be successful and assumed to be in the authority phase. Hence, the value creation and capture were assumed to be in balance throughout the ecosystem and new potential value to be in a diminutive role.

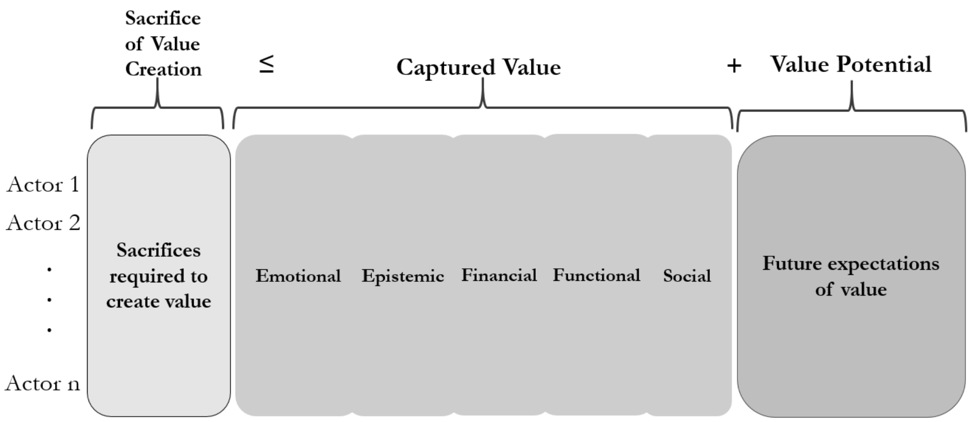


**Figure 9.** Illustration of the Value Balance framework (Publication IV).

The results support the assumptions through the balanced distribution of value. All actors offer and gain value within the ecosystem. Only one type of new potential value was identified and even there the ecosystem had already taken actions to fill the gap. As the case ecosystem is a circular economy ecosystem, it was no surprise that the social and emotional values were emphasized. A new type of financial value was identified. While financial value is usually seen as cost reduction through discounts of increased efficiency, the case ecosystem utilizes tax exemptions. This illustrates that a government can have a significant role in an ecosystem. Furthermore, co-design was associated with multiple value dimensions. This indicates that there is more emphasis on co-operation and value co-creation in creating satisfaction when acting in an ecosystem.

There is still, however, a need to continue the research on ecosystem-level value propositions and distribution. The framework needs to be refined and validated. In the study, four avenues for future research were identified. First of all, more understanding of how valuable something is should be studied as valuable is a relatively ambiguous subject to quantify. Second, the ecosystem balance framework should be evaluated in different ecosystem life cycle phases, especially in ecosystems in the pioneering and renewal phases, as that is when the value propositions are most critical (Moore, 1996). Third, value balance should be studied in more diverse ecosystems as it is likely that the importance of different dimensions varies depending on the mission and structure of the ecosystem. Finally, how the value balance changes over time should be studied to understand what happens when the ecosystem strives to fulfill the expected potential and new potential emerges.

To ensure the usability of the framework for practitioners, a concept for its application also needs to be designed.

## 4.5 Publication V: Revisiting IoT Definitions: A Framework towards Comprehensive Use

Publication V focuses on creating a definitional framework for IoT, which aims to support the broader diffusion of IoT systems and the development of their future business applications.

IoT is expected to have a transformational impact on our lives. It is predicted to change the way we do business, influence the global economy and affect information, and even social, processes (Carayannis et al., 2018; Lu et al., 2018; Westerlund et al., 2014). Thus, it is likely to bring a wide range of opportunities in most aspects of our lives. These substantial opportunities have attracted interest among academics and business professionals alike. This study summarizes the predictions of IoT diffusion from 2014 to 2021. It argues that, despite ever-increasing interest, the speed of IoT diffusion is decelerating. One cause for this may be the lack of universal consensus regarding the definition of the IoT. The factors affecting diffusion include observability, complexity, trialability, compatibility, and relative advantage (Rogers, 2003). Evaluating the possible superiority of these factors in a novel IoT system requires a profound understanding of what IoT is as a concept. To improve comparability, IoT needs a commonly accepted definition. The definition should include all necessary and sufficient attributes but simultaneously be parsimonious (Brennan, 2017; Podsakoff et al., 2016). For these reasons, this study identifies the most relevant elements required in designing an IoT system.

The study applies a similar process to that used in examining the definition of crowdsourcing (Estellés-Arolas and González-Ladrón-de-Guevara, 2012), thus, it was conducted in four phases. As a research method, thematic analysis was chosen as it offers a systematic, but flexible, approach to analyzing qualitative data (Boyatzis, 1998; Saunders et al., 2019). The research process is illustrated in Figure 10.

The first phase of the process was to identify existing definitions through a literature review. The review was conducted by applying backward and forward snowballing, which have been demonstrated as an adequate method, especially in cases of under-defined concepts (Badampudi et al., 2015; Wohlin, 2014). Since the aim was to find a wide range of publisher-independent and multi-disciplinary academic publications, Google Scholar was selected as the search engine. The start set of the literature review was twenty-nine publications, leading to the review of a total of 216 full papers and identification of 122 descriptions of IoT.

The objective of the second phase was to identify the terms and phrases most frequently used in the IoT descriptions. The analysis was begun by processing the descriptions with Voyant, a web-based reading and analytics software. Voyant counted the frequency of each word. However, it considers singular and plural forms as two different words, for example. Hence, a Visual Basic implementation of the Porter Stemming Algorithm (PSA) was used to normalize the words through the process of stemming (i.e., removing the inflectional endings from their morphological base term) (Mustafee, 2003). After stemming and de-stemming the data, the results were analyzed and manually organized into groups to calculate the total occurrences and the most relevant word assigned as the stemmed group heading.

In phase three, the descriptive categories were identified. The stemmed data included 731 stems. Of these stems describing IoT, those used more than twenty times accounted for 50% of the total word count, but only 6.3% of the stems. Arguably, they can be considered to have a sufficient share to identify the fundamental categories. The destemmed words of these stems were arranged into groups by meaning, leading to eighteen different categories. Of these, the ten most frequent ones were chosen as final categories, as they were also the most descriptive. These ten categories are interaction, virtual thing, services, physical object, standardized technologies, information, data, ubiquitous, user, and uniqueness.

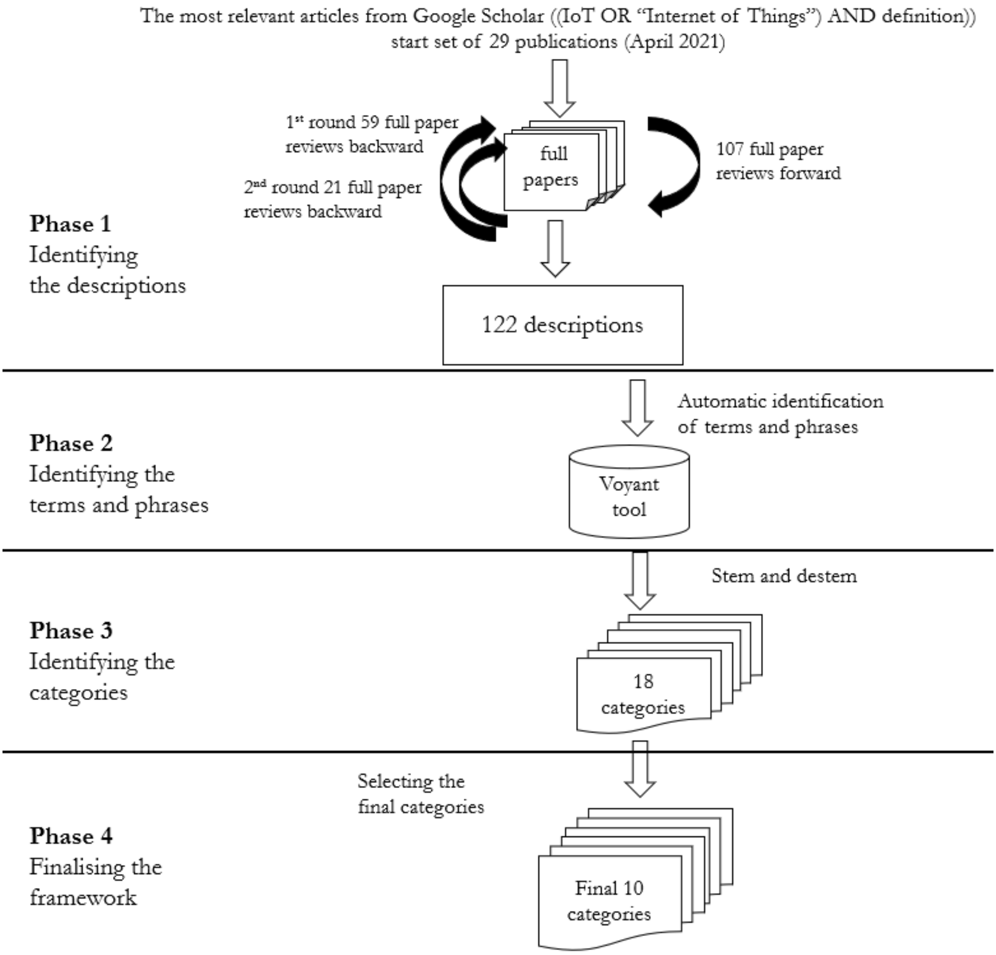


**Figure 10.** Research process of Publication V.

In the final phase, the framework was completed by creating an explanation of each of the categories. Interaction means that virtual things are connected to each other and can interact through either a wired or wireless connection. Virtual things are the active participants that collect data from physical objects. Virtual things can also in some cases store data. Services are the functionalities of the IoT system, which create customer value. For instance, they can be innovative applications or visualizations. A physical object is a product where virtual things are embedded, e.g., fridges, cars, or welding machines. Standardized technologies enable data collection. These can include protocols, programming languages, or architectures etc. Information includes information itself and its processing such as data analytics or cloud computing. Data, on the other hand, is the actual bits and bytes representing temperature, location, or vibration and so on. The data should be available anywhere, i.e., be ubiquitous. The user is the one who "pays the bill" and is interacting with machines. Finally, all objects and things must be uniquely identified for data collection and analysis purposes. Usually, each object has a unique IP address.

The study posits that IoT developers should change their focus from technology development to designing a value offering. The design flow (illustrated in Figure 11 below) should start from understanding user needs and the services that the system can offer. The technology issues can be solved when the value proposition is clear. IoT will not become an integral part of our everyday life until it can utilize appropriate business models (Jia et al., 2011).

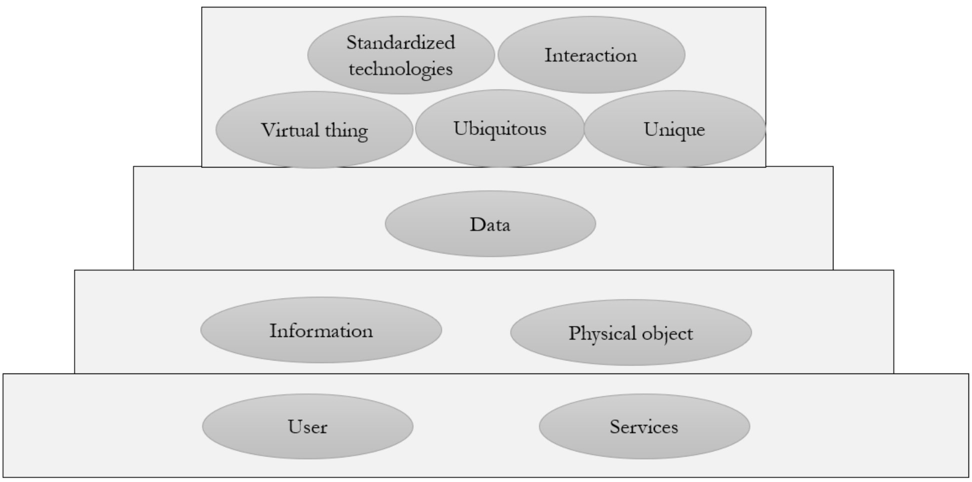


**Figure 11.** Design flow for a value based IoT system (Publication V).

The study did not (despite extensive data) identify security, safety, or privacy as an important category. Nevertheless, it can be assumed that their importance will increase when the future of autonomous cars, ships, and other machines approaches. Thus, depending on the environment, it might also be necessary to design these factors into the system.

## 4.6 Publication VI: Tale of Two Smart Cities: Building Value from an IoT Ecosystem

This research builds on the previous articles by employing the Ecosystem Value Balance framework in IoT-enabled smart city ecosystems.

Digitalization has made it possible for local governments to strive to improve public services, the life of residents, and increase the competitiveness of the region through novel technologies by implementing a smart city strategy (Appio et al., 2019). Smart cities offer opportunities for companies, the third sector, and citizens to implement innovative co-created multi-actor value propositions in an ecosystem context (Appio et al., 2019; Cohen et al., 2016; Linde et al., 2021). This requires that all participants agree on the legitimacy of the ecosystem. As a result, society will become more collaborative, inclusive, and transparent (Camboim et al., 2019).

In this research, two Finnish smart city ecosystems were examined to identify the value propositions and what kind of value capture is enabled at an early stage of the ecosystems. The Ecosystem Value Balance framework was employed to facilitate data collection and analysis.

The cases (cities of Turku and Tampere) were purposely selected. Both of them have played a leading role in an EU Horizon funded climate-neutral and smart cities program. Their ecosystems include industry partners, service providers, and non-governmental organizations. They have, however, a different approach to ecosystem development, as Tampere has chosen a more comprehensive approach and Turku has focused more on a smart traffic ecosystem. This was expected to highlight possible differences in actor expectations.

The data was gathered in focus group workshops organized virtually on MS Teams. Each workshop took approximately four hours and had ten to fourteen participants plus three moderators. The focus groups were divided into sub-groups during discussions, and between each phase of filling out the Ecosystem Value Balance, the sub-groups shared their thoughts with the whole focus group. All of the discussions were video recorded, and the ideas were also documented on Flinga boards. The data was coded and analyzed using Atlas.ti qualitative data analysis software. The analysis was conducted for both cases separately, supplemented by a cross-case analysis.

The results show that, at the beginning of the life cycle, monetary, epistemic, and social investments were required. The earliest captured values were epistemic, social, and functional. At this stage, financial value was seen as a potential value. This is quite natural, as smart cities are innovation ecosystems. It can be argued that they should shift their mission to business solution co-creation as proposed by Benitez et al. (2020) in the Industry 4.0 context.

At this stage, in Tampere, the sacrifices were predominately made by the city organization and the IoT platform provider. The city was also able to capture most of the value, although not as much as it had invested. It seems that the actors able to capture most value were the consumers, through access to more fluent services. The majority of the value sacrificed was financial, functional, and social. This was an expected result, as at the beginning the technology requires substantial investments, and the co-innovation was focused on novel services. The current balance is still negative, but the actors believe the potential balance will become positive.

In contrast, the focus group of Turku did not have an IoT platform provider, but complementary platform provider representatives. The results show that also in Turku, most of the sacrifices were made by the city and the platform provider. They were also able to capture some value. Additionally, the consumers and service providers were seen to have captured value – surprisingly, they emphasized the capture more often than the sacrifices. In total, the balance was negative, but it was felt that it would become positive when the potential was realized. The focus group emphasized epistemic and social sacrifices. Rather surprisingly, the financial potential received less attention than the functional, social, emotional, and epistemic values.

Based on this study, there are five pre-requisites for potential to be achievable: (1) The ecosystem should have a clear, jointly agreed common purpose; (2) It should succeed in external communication to attract new actors; (3) It should have low entry barriers for new actors to be able to join easily; (4) Information sharing within the ecosystem should be seamless; and finally, (5) the co-operation between ecosystem actors should be active.

The joint value proposition and shared mission was found to be the most important activity for the ecosystem actors to agree on. The focus group participants found the value balance framework beneficial in describing the overall value propositions of the ecosystem, as it offered a framework for verbalizing and communicating expectations and abilities.

# 5 DISCUSSING KEY FINDINGS AND THEIR IMPLICATIONS

This dissertation contains three research questions. This section combines the answers to each of the questions from the publications and discusses the implications of these findings more thoroughly. In addition, the research problem is discussed at the end of the chapter.

As stated earlier, the first research question is:

*RQ1: What characteristics of BMI should organizations consider when innovating IoT-enabled platform ecosystem business models ?*

Digital transformation induces technological and social changes, which drive business model changes (Kotarba, 2018). IoT is one of the enablers for novel business models. To fully capitalize on the benefits of IoT, business models should be innovated on an ecosystem level (Turber et al., 2014). The same applies to platform business models (Yrjölä et al., 2021).

Based on this research, there are eight key characteristics in innovating platform ecosystem business models: value, monetizing, producers, users, filtering, governance, resilience, and network effects (Publication I). The research also found that the critical characteristics of IoT are user, services, information, physical object, data, virtual thing, interaction, standardized technologies, unique, and ubiquitous (Publication V).

This research proposes that all the above-mentioned characteristics to be considered when innovating business models for IoT-enabled platform ecosystems. Table 7 illustrates which characteristics are related to each other and, hence, need to be considered simultaneously.

When creating a value proposition, one needs to consider what kind of information is valuable for the ecosystem actors, which interactions are required, and what services may fulfill the value expectations. Based on Service Dominant-

Logic, the customer and producer co-create value together (Vargo and Lusch, 2004). This also applies in IoT-enabled platform ecosystems (see e.g., (Ikävalko and Turkama, 2018; Markfort et al., 2022)). Furthermore, IoT brings physical objects and embedded virtual things to this "equation", as products can be essential for value delivery. Wearables, such as smart watches, are a good example. The manufacturer of the watch, the application designer, and the consumer (as a data source) are all part of the value producing side. However, without the watch both collecting the data (e.g., heartbeat, and exercise time) and displaying the results (e.g., burnt calories) to the consumer, value delivery would not be possible. This example demonstrates the importance of understanding different value dimensions (see Publications III and IV).

**Table 7.** IoT elements in relation to platform ecosystem BMI.

| PLATFORM BUSINESS MODEL CANVAS | IOT CHARACTERISTIC CATEGORIES RELATED TO BMI |
|---|---|
| **VALUE** | Services, Interaction, Information |
| **USER** | Physical object, Virtual thing |
| **PRODUCER** | Physical object, Virtual thing |
| **NETWORK EFFECTS** | Services, Interaction, Ubiquitous, Data |
| **CAPTURE** | Services, Data, Information, Interaction |
| **GOVERNANCE** | Interaction, Standardized technologies |
| **RESILIENCE, BOUNDARY RESOURCES** | Standardized technologies, Unique |
| **FILTERING** | Information, Services |

The enablers for network effects are ubiquitously available data, interaction, and services. Returning to the smart watch example, the possibility to compare the results with a friend – no matter where they are, or to have access to innovative predictive healthcare solutions (Wu et al., 2017a), may attract more users. It has also been demonstrated that a company is more likely to update its products and services faster, and even increase the number of services, when it has a larger number of users (Wu et al., 2017b). Therefore, identifying the sources of positive externalities causing network effects in IoT-enabled platform ecosystems requires a broad view.

When describing the value capture of an IoT-enabled platform ecosystem, we have to return to SET (Homans, 1958) and the dimensions of value (Pura, 2005;

Sheth et al., 1991). As described in Publications III, IV, and VI, each of the ecosystem members should be able to capture value proportionally in relation to the value they sacrifice. However, value is not necessarily only monetary (Vargo et al., 2008; Vargo and Lusch, 2004). Therefore, e.g., the worth of services (functional value), data (epistemic value), information (epistemic value), and interaction (social value) are all important in evaluating the value capture. As capture is based on a functioning ecosystem, it requires interaction between the participants.

Platform governance can be seen as a set of mechanisms that are mandatory in enabling a diverse set of actors to cooperate, coordinate, and integrate (Jovanovic et al., 2022), i.e., managing the interaction between actors. The governance system includes the rules and enforcement principles of the platform ecosystem, enabling trust and, consequently, value co-creation (Evans and Schmalensee, 2016). The governance system helps the platform orchestrator to balance trust and openness, while also managing the cost of control (Cusumano et al., 2019, pp. 185–190). Tiwana (2013, pp. 139–141) presented five "rules" that have to be considered when creating a governance system: (1) The control system for balancing costs and benefits of the governance should be simple; (2) The control system should be transparent throughout the ecosystem to encourage the actors to remain in the ecosystem; (3) It should be realistic and include as few non-negotiable rules as possible; (4) It confirms the shared values; (5) It should be fair to all actors. However, while governance is supposed to be "good for all", it also increases the power of the platform orchestrator. This power imbalance – whether a technical or information imbalance – allows the platform orchestrator to exploit the ecosystem as other actors often have only two choices – to accept the rules or leave the ecosystem – and leaving may incur major costs (Cutolo and Kenney, 2021). Hence, for the platform ecosystem to be successful, multilateral trust should not be exploited.

In the IoT context, governance often means selecting standardized technologies and defining the ground rules of interaction to enable data collection and utilization. Publication V summarizes the standardized technologies to include a selection of the protocols, data architecture, interfaces (such as Application Programming Interfaces i.e.. APIs), programming languages, and addressing schemes used.

Standardized technologies also affect the resilience of the platform ecosystem. Resilience describes the platform's ability to adapt to changing environmental factors (Graça and Camarinha-Matos, 2017). Publication I summarizes these factors to include modular architecture, plug-n-play capability, durability, maintainability, and evolvability. Resilience is important as high adaptability to change can help the ecosystem to benefit from market turbulence (Simon, 2013). One way to enhance modularity is to let the sub-systems (i.e., modules) be designed independently according to common design rules and connected to the other modules through APIs (Parker et al., 2016, pp. 52–57). APIs and Software Development Kits (SDKs) are typical boundary resources used to facilitate the integration of sub-systems (Hein et al., 2019). In all types of platform ecosystems, co-operational boundary resources (such as agreements on immaterial rights, data sharing principles, and benefit sharing arrangements) are also required (Huhtamäki et al., 2016).

The final characteristic to be considered when innovating an IoT-enabled platform ecosystem business model is filtering. Filtering is a part of the core interaction, which can be considered to be the most important activity on a platform (Parker et al., 2016, pp. 38–41). It is an algorithm which matches the required value (and only that) to an actor, i.e., it manages the information exchange to launch the services (ibid.). Filtering is of utmost importance in IoT-enabled platform ecosystems as the amount of data collected and analyzed is massive (Tarkoma and Katasonov, 2011).

*RQ2: How do organizations innovate IoT-enabled ecosystem business models?*

This research identified six shortcomings in the current BMI frameworks: (1) disregarding the multilateralism of value co-creation, (2) focusing only on financial and functional value and omitting other value dimensions, (3) disregarding the fairness of value distribution, (4) describing the BM components but not the dynamics between them, (5) considering the BMI to be a one-time “exercise”, and (6) overlooking the technological requirements. The following paragraphs elaborate on these findings.

During the research, an increasing number of scholars published articles emphasizing the importance of ecosystem-level business model design (see e.g., Favoretto et al., 2022; Paiola et al., 2022). However, Publication II acknowledges that business model innovation frameworks are still often designed from the orchestrator perspective, focusing on creating value for the customer in a dyadic relationship and neglecting third-party actors, and, thus, the value co-creational aspects (see e.g., Hartmann et al., 2016; Kiel et al., 2017; Zhang and Wen, 2017). This finding is supported by Markfort et al. (2022), and Cheah and Wang (2017), for example. Ikävalko et al. (2018) also pointed this out on the conceptual level, specifically in the IoT context. While the dyadic perspective has been the traditional way in pipeline businesses, it is no longer sufficient in platform businesses (Hui, 2014; Iivari et al., 2016; Westerlund et al., 2014). As an example, let us consider Wolt, a home-delivery platform. There are at least three actor sides on the platform: consumers, restaurants, and the delivery personnel. If Wolt focuses too much on maximizing its profits and keeping restaurants happy, for example, either the customers may find the food too expensive, or the delivery persons will not be paid enough. Either way, the ecosystem will probably not succeed. It is a delicate balance of keeping all actors satisfied enough to continue participating in the value creation.

This leads to the second deficiency in the current BMI frameworks (dealt with partially in Publications III and IV), i.e., how the concept of value is apprehended. According to Service-Dominant Logic, although monetary exchange is not necessary in value exchange (Thomas et al., 2014), the current literature tends to focus on financial and functional values (see e.g. (Keränen, 2017)), disregarding emotional, epistemic, and social value, which, however, are important types of value (see e.g., (Cheah and Wang, 2017; See-To and Ho, 2014)).

Third, the ecosystems have been analyzed on the grounds of transaction cost economics (TCE), which does not pay attention to the complexity of ecosystems (Jacobides et al., 2018), hence the co-evolving and dynamic nature of ecosystems would benefit from utilizing SET (Benitez et al., 2020). The current theoretical approach omits the importance of fairness in co-evolving reciprocal relationships, which SET can provide (Jeong and Oh, 2017)

The fourth deficiency the research showed is that the current frameworks tend to oversimplify the business model "structure" (see Publication II). Business Model Innovation frameworks in the IoT context are typically focused on the model architecture, and describe each business model component separately (Westerlund et al., 2014). Based on the sample in Publication II, the business model innovation frameworks in the IoT context seem largely to be modifications of BMC without demonstrating the linkages between ecosystem actors nor the dynamics between the BM components, even though this is a known shortcoming. However, BMC based frameworks have also been created since Publication II (see e.g., Aagaard et al., 2018; Haaker et al., 2021)), aiming to remediate the deficiencies of BMC in the IoT context.

The current culture of BMI leads to a static snapshot of an evolving BM (Markfort et al., 2022; Paiola et al., 2022; Zott and Amit, 2007). This means that BMI can be seen as a "once and done" activity for new companies, where BMs are considered stationary (Zott and Amit, 2007). This may, however, be challenged during the digital age (Rummel et al., 2021).

Moreover, the current BMI frameworks neglect the technical features of the IoT architecture (Aagaard et al., 2018)

The current situation is understandable, as concluded in Publication III, as even academic knowledge of value co-creation on the ecosystem level remains scant.

*RQ3: How should IoT-enabled ecosystem business models be innovated?*

The digital transformation is changing the world around us. Therefore, companies need to adapt to the changes with innovative business models. As argued in the introduction, IoT has not yet been able to redeem its promise. It can be said that commercializing IoT has been a challenging task – not only to SMEs and incumbents, but also to 'digital-native' companies (Ians, 2022; Markfort et al., 2022; Paiola et al., 2022). IoT adds a 'layer of complexity' on top of the already complex BMI of platform ecosystems. In addition to the ecosystemic requirements of IoT, it is known to increase the availability of data, and change the monetary model towards service-based billing (Markfort et al., 2022). Therefore, a BMI framework overcoming the deficiencies of the current models is required.

To ensure multilateralism and reciprocity of value creation, recognition of all value dimensions, and a fair distribution of value, this research proposes that the Ecosystem Value Balance (EVB) be the core of BMI. The EVB ensures that the expectations of all actors, and their willingness and ability to take part in value creation, are understood. These expectations should be understood in order to be in line with the Shapley Value theorem (see e.g., (Hart, 1989)), which emphasizes that the actors evaluate a priori whether participation in a "game" (i.e., value exchange) is going to be fair (Hart, 1989.) EVB also points out whether new actors are required to fulfill value expectations. Furthermore, the EVB can highlight the (un)fair distribution of value and therefore help the ecosystem to balance it, hence increasing trust and motivation to participate.

However, the EVB alone cannot remove all deficiencies. To describe the dynamics around the value proposition, and to ensure that governance and technological aspects are considered, the characteristics of the Platform Canvas have to be included. Furthermore, to answer the challenge of BMI as a "one-time exercise", this research agrees with Andreini et al. (2022), and proposes that BMI be developed in a dynamic, agile, and iterative manner. Figure 12 illustrates the proposed BMI framework and process.

Hence, the first step in designing an IoT-enabled platform ecosystem is to understand what kind of value all actors can provide, and the value they expect to capture. As argued in Section 2.3., a traditional TCE-based analysis of value exchange, while contract based and focusing only on monetary value, is not applicable in the digital platform ecosystem context. While TCE focuses on mitigating the risks in a dyadic business, ecosystems focus on maximizing value by engaging complementing actor groups through value co-creation (Jacobides et al., 2018). Moreover, the analysis should consider the fairness of value distribution; hence SET is more applicable in creating an ecosystem-level value proposition (see Publication IV).

Furthermore, when analyzing the value expectations and capture possibilities, multiple dimensions of value should be considered. S-D logic suggests that value exchange can actualized without a monetary transaction (Thomas et al., 2014). Publication III introduced five value dimensions (emotional, epistemic, financial, functional, and social value) that should be considered when creating an ecosystem-level value proposition. Consequently, illustrating the value expectations and capturing possibilities by using an EVB framework can highlight the expectations that cannot be fulfilled by current members, denoting a need for additional members (see example in Publication VI). It can also highlight whether one member is capturing an excessive share of the total value, which may be a risk for the success of the ecosystem.

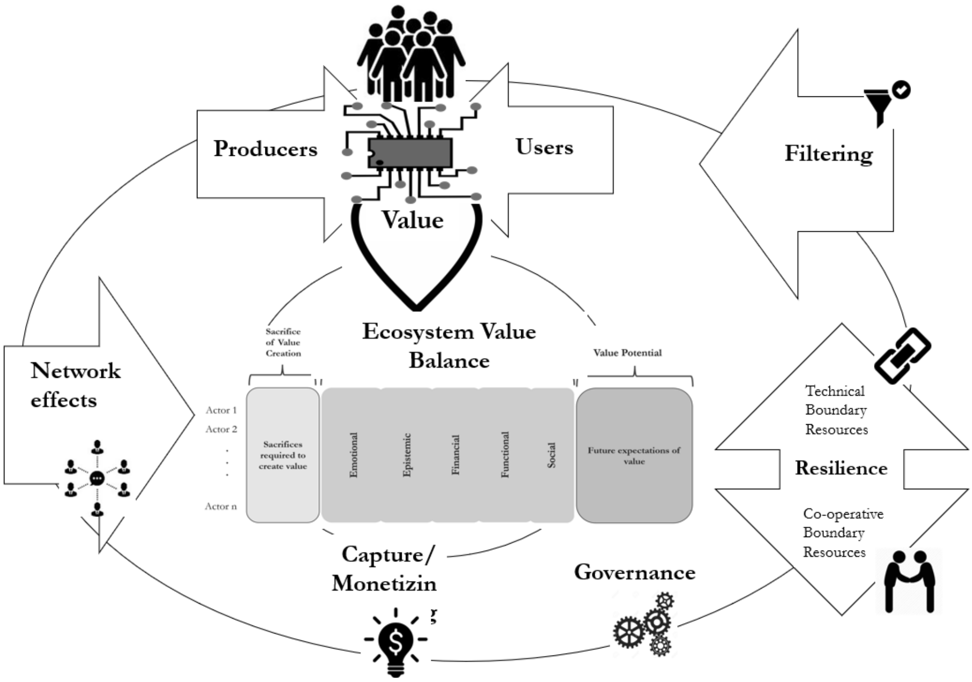


**Figure 12.** Proposed BMI process and framework for IoT-enabled platform ecosystems.

When the ecosystem-level value proposition and actors are known, it is time to consider the means *how* value can be delivered. This means that the actors should identify what information is required to deliver the value, and which physical products are available for delivering the required information. At this point, the actors should also agree on the basic governance of the ecosystem – whether access control principles, governance systems, or penalty principles. The purpose of governance is to enable trust, which is a precondition of value co-creation. (See-To and Ho, 2014) Governance should aim to balance the incentives and platform control in a manner that engages the actors to participate in value co-creation, but simultaneously ensures sufficient control over the actors and processes to maintain quality (Hodapp et al., 2019; Tiwana, 2013, pp. 117–125). While governance aims to reduce information asymmetry to increase trust, it does give the platform orchestrator the possibility to increase its control over information and technology (Cutolo and Kenney, 2021).

The third phase is to ensure the resilience of the platform ecosystem by specifying the technical and co-operational boundary resources. In addition, a decision is required about which standardized technologies are to be used to enable high-quality data. Also, the specifications for the virtual things should be created at this stage (see Publications I and V). Boundary resources, such as application programming interfaces (APIs), software development kits (SDKs), design review guidelines, and trademark licensing principles are tools that support the above-mentioned governance principles (Hein et al., 2020).

Finally, filtering capabilities have to be designed to provide a fluent user experience. Filtering is essential for efficient value exchange as it enables a massive amount of data to be transformed into meaningful and valuable information through algorithms. In this way it improves the speed and accuracy of matching the actors and values. This creates a positive cycle, where efficient filtering improves both the accuracy of the algorithm and the reputation of the platform ecosystem. A well-designed filtering capability will attract more actors, and therefore enable positive network effects.

The Platform Canvas is a strategic tool through which quality and continuity are secured by means of governance principles, boundary resources, network effects, and filtering features. In IoT-enabled ecosystems, standardized technologies should be constant for a longer period of time to ensure uninterrupted ubiquitous interaction for data collection and analysis.

The EVB, on the other hand, can, and probably should, be revised more often, dynamically and regularly to a) identify new value expectations and b) evaluate the need to expand the ecosystem.

While this process seems simple on paper, in real life it is much more complicated. Based on the cases studied in this research, despite the existing body of knowledge of the importance of the core interaction (Choudary, 2015; Evans and Schmalensee, 2016; Korhonen et al., 2017; Parker et al., 2016), starting to design an ecosystem from an ecosystem-level value proposition seems to be counterintuitive (see Publications I and VI). Either the orchestrator focuses on its own value capture, or the ecosystem is built as a compilation of development projects, which are often primarily focused on technological solutions. In the cases of this research, neither of these approaches demonstrated success in creating positive network effects quickly, in fact quite the reverse. The smart cities had been developing their ecosystem for over eight years, yet the ecosystems were still mainly just a fragmented set of pilots. Furthermore, whereas in 2016 the industry cases (Publication I) were presenting their platform ecosystems on their public web pages, in 2022 they were no longer doing so; instead, they were emphasizing their participation in other ecosystems. It would require more research to understand why they decided to do this. However, it seems they are not actively searching for new actors in their ecosystems. One of the case companies has already decided to close their platform (Publication III).

A summary of the aims of the individual publications and their results in relation to the research questions of this thesis is presented in Table 8.

**Table 8.** Aims and findings of the publications in relation to the research questions

| RESEARCH QUESTION | AIMS OF THE PUBLICATIONS | FINDINGS OF THE PUBLICATIONS |
|---|---|---|
| WHAT CHARACTERISTICS OF BMI SHOULD ORGANIZATIONS CONSIDER WHEN INNOVATING IOT-ENABLED PLATFORM ECOSYSTEM BUSINESS MODELS? | Publication I<br>To formulate the most important criteria of BMI in an easy-to-use format for platform ecosystems | Identified nine characteristics, namely: value, user, producer, network effects, capture, governance, resilience, boundary resources, filtering.<br>Further identified that it would be more beneficial to start the BMI from defining the value proposition. |
| | Publication VI<br>To identify critical characteristics of an IoT-enabled ecosystem | Identified 10 characteristics, namely: interaction, virtual thing, services, physical object, standardized technologies, information, data, ubiquitous, user, and uniqueness.<br>Further, identified that it would be more beneficial to start the system design from defining the value proposition. |

| | | |
|---|---|---|
| ***HOW DO ORGANIZATIONS INNOVATE IOT-ENABLED ECOSYSTEM BUSINESS MODELS?*** | Publication II<br>To elaborate on the differences in business model development between traditional and IoT-driven businesses | The study identified six shortcomings in current BMI frameworks:<br>(1) disregarding the multilateralism of value co-creation,<br>(2) focusing only on financial and functional value and omitting other value dimensions,<br>(3) disregarding the fairness of value distribution,<br>(4) describing the BM components but not the dynamics between them,<br>(5) considering the BMI to be a one-time "exercise", and<br>(6) overlooking the technological requirements. |
| | Publication III<br>To classify ecosystem-level value proposition dimensions through identifying how value propositions have recently been described in academic literature and compare the theoretical findings of the value propositions to eight case ecosystems | The study identified five dimensions of value, namely: emotional, epistemic, financial, functional, and social value.<br>The case analysis shows that currently value propositions focus on financial and functional value. For value co-creation purposes more emphasis is required on the emotional and social dimensions. |
| **HOW SHOULD IOT-ENABLED ECOSYSTEM BUSINESS MODELS BE INNOVATED?** | Publication I<br>To formulate an easy-to-use tool for BMI in the ecosystem context | Platform Canvas framework with guiding questions for practitioners was constructed. |
| | Publication III<br>To elaborate the important aspects related to collaboration and value | Five value dimensions were identified. For value co-creation and trust-building purposes, more emphasis is required on the emotional and social dimensions. |

| | | |
|---|---|---|
| | Publication IV<br>To construct a framework, with which the distribution of value in an ecosystem by different dimensions and actors can be visualized | An Ecosystem Value Balance (EVB) framework is offered for BMI. |
| | Publication VI<br>To verify the applicability of the EVB through two case studies | The focus groups found the framework beneficial as it offered a tool to communicate value expectations and propositions. |

The findings and implications of the three research questions contribute to solving the research problem:

*The ecosystem-level BMI in IoT-enabled ecosystems suffer from insufficient and fragmented scientific knowledge as well as inadequate capabilities in organizations.*

Digital transformation directly affects the value creation of companies (Hess et al., 2020, p. 6). Moreover, successful digital transformation requires a digital strategy to guide the management of organizations to facilitate the innovation of new digital technology enabled value propositions (Sebastian et al., 2020). These are major changes that require agility on the part of an organization's business models, collaboration activities, and culture (Warner and Wäger, 2019). Although cultural change in organizations is important, the focus in this research was on elaborating the enablers to increase agility in business model innovation and emphasize the importance of co-operation and co-creation of value.

This research proposes a novel agile EVB model at the core of the Platform Canvas to be implemented on ecosystem level. This model was developed for innovating an ecosystem-level co-created value proposition and assuring the motivation and retention of ecosystem actors by balancing the value sacrifices and capture throughout the ecosystem. The model emphasizes the importance of considering the expectations and capabilities of all ecosystem actors – or at least representatives of each actor type. This way, it enhances the "cross-pollination" of ideas and solutions.

In addition to tactical purposes, the same model can be used as a strategic tool to enhance the sustainability and resilience of the ecosystem. Furthermore, it specifies in which areas the IoT-related aspects should be evaluated. Thus, it can be integrated into the digital strategy management process.

# 6 CONCLUSIONS

The academic and management contribution of this dissertation research is presented in this section. After explicating the contribution, this section includes an assessment of this research and avenues for future research.

## 6.1 Academic Contribution

The academic contribution includes enhancements to the BMI in IoT-enabled platform ecosystems and value theories as well as a novel methodological approach to extract the content of ambiguous concepts.

### 6.1.1 Contribution to IoT-enabled Business Model Innovation

While digital transformation is affecting nearly all areas of our lives, IoT specifically is creating vast novel business opportunities. However, until now, the concept of IoT has been unclear, like have been the effects of it to the BMI. This research points out the new level of complexity IoT brings to the ecosystem level BMI. First, this research acknowledges the importance of concept clarity, hence elaborates the IoT specific characteristics. Furthermore, as presented in Table 7 (p.61), this research brings forward, how IoT needs to be considered in relation to multiple platform ecosystem BMI characteristics and points out how many of the IoT characteristics are related to more than one platform ecosystem BMI characteristics. This research offers a model to overcome the barriers of success of IoT-enabled business.

First, the research elaborated the definitions of two key concepts: BMI in a platform ecosystem and IoT. Due to the presence of inconsistent definitions, the research commenced with multiple literature reviews to ensure the consistency of the key concepts. The reviews showed that the business model, platform ecosystem, and IoT as concepts have value, producer, and customer (i.e., actors or market sides) in common (see Publications I, II, and V). Understanding these three concepts are the core of designing a prosperous IoT-enabled ecosystems.

The research also established that the current BMI frameworks, especially in IoT-enabled platform ecosystems, have six shortcomings:

(1) They disregard the multilateralism of value co-creation (Cheah and Wang, 2017; Hartmann et al., 2016; Kiel et al., 2017; Markfort et al., 2022; Zhang and Wen, 2017)

(2) They are focused on financial and functional value, omitting other value dimensions (Cheah and Wang, 2017; Keränen, 2017; See-To and Ho, 2014)

(3) They disregard the fairness of value distribution (Benitez et al., 2020; Jeong and Oh, 2017)

(4) They focus on describing the BM components but not the dynamics between them (Westerlund et al., 2014)

(5) They tend to consider BMI as a one-time "exercise" (Markfort et al., 2022; Zott and Amit, 2007)

(6) They overlook the technological requirements (Aagaard et al., 2018)

The results of this research address all the above-mentioned deficiencies. First, the proposed model emphasizes the importance of understanding the expectations of all ecosystem actors and creating and developing the value proposition together to ensure the expectations can be met. Second, the model, through the EVB, reminds the ecosystem actors to consider all types of value. Employing the EVB also highlights the value distribution. The fourth point regarding the dynamics between the BMI components is addressed by describing which components should be considered simultaneously (see Table 7 on p. 61). Last of all, this research suggests that the BMI model to be employed regularly. In particular, utilizing the EVB as a "tactical tool" for ecosystem development is recommended.

Digital transformation changes the business environment and consequently, the value expectations of the actors involved. Therefore, this research emphasizes the importance of an iterative approach to BMI, where the value proposition and expectations are regularly evaluated. Hence, this research proposes a novel iterative model for IoT-enabled platform ecosystem BMI (see Figure 12 on page 66).

### 6.1.2 Contribution to Value Theory

Sheth et al. (1991) proposed a taxonomy of five types of value: conditional, emotional, epistemic, functional, and social values. However, Pura (2005) considered that functional and emotional values formed a single category known as convenience value, and added monetary value to the dimensions. While Sheth et al. and Pura conceptualized social value in terms of "belonging to a group", recent discussion on sustainability, such as in Hiteva and Foxon (2021), has expanded social value to encompass social responsibility in the sustainability context. Although sustainability is regarded as a key value in smart cities, for example, this research found that it received only minor attention in the focus groups, despite its expected significance in the EVBs of the cases.

Notably, this research found no evidence of conditional value in the research articles, nor in the cases. Based on these findings, this research proposes that the key value dimensions in the platform ecosystem context consist of emotional, epistemic, financial, functional, and social, where the social value includes the above-mentioned broader perspectives.

### 6.1.3 Methodological Contribution

Researching nascent domains can be challenging when there are no commonly agreed definitions of the concepts being studied. In Publication V, a novel method for accumulating understanding of earlier concept definitions was created. The method is based on snowballing (Jalali and Wohlin, 2012; Wohlin, 2014), utilizing the Porter stemming algorithm (Mustafee, 2003) and thematic analysis (Boyatzis, 1998). It includes four phases: (1) identifying the descriptions, (2) identifying the terms and phrases, (3) identifying the categories, and (4) finalizing the framework.

First, the descriptions of the concept are identified through backward and forward snowballing. This method is especially efficient when studying under-defined concepts since snowballing reduces the noise caused by non-applicable articles (Wohlin, 2014). The critical phase in snowballing is the definition of the start set, thus balancing between an overwhelming amount of false positives and sufficient comprehensiveness (Wohlin et al., 2012). This requires a judgement call from the researchers.

In the second phase, the frequency of each word is calculated. In this case, all collected descriptions were put into a web-based reading and analytics environment (the Voyant tool was used). When the analytics environment is not able to differentiate between inflected endings, a Visual Basic implementation of the Porter Stemming Algorithm (PSA) (Mustafee, 2003) is used. First, the PSA removes all inflected endings from the morphological base term. Then the words are grouped by the base terms. The phase also includes a manual analysis, where the most relevant term is assigned to describe each group of words.

In phase three, the most frequent stems are grouped together by meaning to identify the most important descriptive categories. Finally, a complete description of each category (and examples) is written to elaborate the meaning of the category. For further information, see Publication V.

This method enables a large amount of data to be structured with minor manual effort. Thus, it minimizes the risk of human error while allowing a large data set to increase the credibility and confirmability of the analysis.

## 6.2 Managerial Contributions

Currently, IoT has not met the high expectations placed on its potential to transform society and create new avenues for revenue generation (Chui et al., 2021; Ians, 2022).

This research elaborated a process and the key characteristics required for creating an IoT-enabled platform ecosystem. It can be used in creating a platform ecosystem in a similar manner to the Business Model Canvas (Osterwalder, 2004) enabling business model innovation in business networks. However, the model introduced in this research rectifies the deficiencies of the earlier BMI models.

Furthermore, while this model has been created to be used in BMI of IoT-enabled platform ecosystem, it can be used for other purposes, too. For example, the EVB can be used in creating the joint value proposition of innovation ecosystems (cases in Publication VI) or circular economy ecosystems (case in Publication IV) as the value balance is a key enabler of a successful ecosystem in general. In cases of non-digital ecosystems, the technological characteristics can be omitted.

This research expounds on the complexity of IoT-enabled platform ecosystems. While the technologies are available, their standardization is still vague and to a large extent non-existent. A platform will also need to balance the benefits and risks of openness (Parker and Van Alstyne, 2018). The orchestrator should gather a core team of actors to ensure that the governance rules and technologies support the positive network effects, but this should not be the primary driver of the ecosystem – the most important issue is to understand why the platform is needed, i.e., the value proposition.

It should be noted that the Platform Canvas and the EVB framework – like many other frameworks – give a snapshot of the current platform ecosystem. Ecosystems are, however, dynamic, and continuously evolving systems. Therefore, the model proposed in this research can be used as a basis for strategic planning but should be repeated regularly, keeping in mind the different challenges of each of the ecosystem life-cycle phases (Trischler et al., 2021).

There is no silver bullet for any of the stages. Quite often actors do not know, let alone are able to describe, what kind of value they expect. In cases of new innovations, it is especially difficult for customers to even know that they are missing something. A well-known example of this is the story that tells how Henry Ford asked people how they would solve the problem of slow transportation. For many, the solution would have been a faster horse. The orchestrator of a platform-to-be should have a clear vision of the overall problem that the platform will solve. With this vision, they can inspire the key actors and refine the strategy as a team.

It is worth noting that the answers by the proposed tools inevitably contain in-built biases. Utilizing the EVB and Platform Canvas may lead to different results depending on the roles of the users, their seniority level, and perhaps even other less evident factors (such as the news they have seen recently may affect their views). Therefore, it is important to involve a rather large variety of actors in the BMI process. Additionally, the model presented here is not capable of fixing the whole IoT business diffusion problem, so a cultural change is required. Traditionally, in a pipeline business, there has been one company which has managed the supply chain and aimed to capture most of the value. In the platform ecosystem context, the orchestrator should understand the ecosystem-specific requirements of offering value to all actors and ensuring that all actors participate in value co-creation (Publication IV). Furthermore, a similar cultural change is required from all actors. Everyone should focus on maximizing the overall ecosystem-level value capture, not sub-optimizing the capture for themselves (Thomas et al., 2022; Turber et al., 2014; Westerlund et al., 2014). More often than not, the company culture within a single company is seen as a hurdle in digital transformation (Hess, 2022, p. 129) – it is likely to be an even bigger obstacle in the context of ecosystems, where multiple actors should simultaneously make changes in the same direction.

## 6.3 Assessment of the Study

This research was conducted under the pragmatist paradigm as it aims to find a practical solution to a problem in a man-made subjective, but rational world – i.e., how to capitalize on the business opportunities offered by IoT. The research included comprehensive literature reviews analyzed through meta-synthesis, and thematically analyzed case studies. All methods used were qualitative, therefore, the evaluation of the research is conducted against the quality criteria of qualitative research.

### 6.3.1 Introduction of the evaluation criteria

During the past couple of decades, the evaluation of qualitative research has been developing in multiple streams (Cho and Trent, 2014). Unlike in quantitative research, where the criteria (internal validity, external validity, reliability, and objectivity) have been established for a long time, in qualitative research each research tradition has developed criteria of its own, complemented by attempts to create a set of criteria that would be applicable more generally (ibid.). The criteria in qualitative research have been more difficult to agree on as the nature of qualitative research is to stress exploration, creativity, interpretation, and flexibility (Seale, 1999). Indeed, there has been critique against having criteria in the first place, as it has been seen as unhelpful and frivolous (Tracy, 2010). However, in cases like dissertations, where the researcher is still acquiring skills, instructions such as evaluation criteria are required (Dreyfus et al., 1986; Dreyfus, 2004). Therefore, in this research, a set of evaluation criteria has been used.

Lincoln and Guba (1985, p. 300) identified four criteria of trustworthiness: credibility, transferability, dependability, and objectivity. They explained the criteria as follows:

*Credibility* of research is established through activities that aim to increase the probability of producing credible findings. These activities are (1) prolonged engagement with the research subjects by investing enough time to create trust, (2) triangulation through sources, methods, investigators, and theories, and (3) persistent observation to ensure the most relevant characteristics are studied in detail. Another way to increase credibility is (4) peer-debriefing, which means that researcher bias is reduced by testing the working hypothesis through presenting it to a peer. The fifth way to improve credibility is to conduct a (5) "negative case analysis", through which the working hypothesis is refined to widen its applicability. The sixth way to increase credibility is (6) "referential adequacy" where, for example the data is recorded and analyzed later by the researcher or anyone who wants to verify the reliability of the analysis. The seventh, and last, way to improve credibility is (7) member checking. This means that data, analysis, and conclusions are evaluated with the research subjects or at least in their organizations. In this way the researcher can validate whether the subjects meant what the researcher thought they meant and correct any misunderstandings promptly.

*Transferability* is partly similar to the external validity of quantitative research. It is impossible to make a statement as to whether the results are applicable in another context or during a different time, but the researcher should provide enough data so it can be applied by others to be able to make a justifiable judgement of transferability.

*Dependability* refers to the reliability and consistency of the research. This requires the process of inquiry, data, findings, interpretations, and recommendations to be transparent and properly documented in such a manner that it can be audited and even criticized by another researcher.

*Confirmability* means that the methodologies are appropriate, findings are grounded in the data, and negative evidence is considered. (Lincoln and Guba, 1985)

Later Lincoln and Guba recognized the temporal aspects included in the relativism of truth in qualitative research and added *authenticity* to their criteria (Seale, 1999). This means that the researcher should aim for fairness by conducting the research in different realities, and appreciate the viewpoints of others, for example (ibid.).

Tracy (2010) introduced eight “Big-Tent” criteria for evaluating qualitative research. While the terminology differs from the Lincoln and Guba criteria, most of them are the same. However, Tracy includes two criteria that are not covered in the seminal list. The research should have a worthy topic and be conducted in an ethical manner. In present times, when mis- and dis-information is being continuously spread and technologies are developing faster than ever, it seems important to include these two additional criteria in the evaluation of this research. Therefore, the evaluation of the study begins by addressing these two currently critical criteria, followed by the traditional criteria by Lincoln and Guba.

### 6.3.2 Worthy Topic

The topic of this research is very significant. As demonstrated earlier, the platform business, ecosystem management, and IoT are all topical – even when considered separately (Carayannis et al., 2018; Gubbi et al., 2013; Liu et al., 2021; Mäkinen et al., 2014; Ruutu et al., 2017). The topic is particularly relevant, as putting the three above-mentioned sub-topics together may enable enormous business opportunities and changes to our everyday life (Cavanillas et al., 2016; Hanelt et al., 2021; Ju et al., 2016), so this research has both scientific and managerial implications. Whether the future changes are positive or negative depends strongly on the ecosystem actors and their ability to make the cultural changes required to split the value capture equitably (Li et al., 2019). This research has aimed to demonstrate the need for cultural changes as well as the means to describe the current state of each ecosystem and its shortcomings.

Further, the combination of these three sub-topics has received relatively little attention thus far (Leminen et al., 2018). All three sub-topics are nascent (Omerovic et al., 2020; Tsujimoto et al., 2018) and require clearer conceptualization, definitions, and “user instructions” for the business world to be able to gain best value from them.

Finally, the research approach of studying IoT from the business and value offering point of view is required to transform the technologies into innovations and lucrative business (Leminen et al., 2018).

### 6.3.3 Ethics

For any research to be ethical, it should consider procedural, situational and culturally specific, relational, and exiting ethics (Tracy, 2010).

Procedural ethics refers to the instructions encompassed by the Institutional Review Board, e.g., avoiding deception, and ensuring privacy and confidentiality. In this research, all subjects participated voluntarily, and they were anonymized before analysis. A double-blind review was conducted for all six publications.

Situational ethics requires continuous reflection and questioning the ethical decisions. In this research, little attention was paid to this as the research focused on external topics, not individuals personally. The research was conducted in Finland and all participants were Finnish. While this may cause a limitation to transferability of the results, it did reduce the risk of cultural misunderstanding.

Relational ethics is related to the self-awareness of the researcher and how the reciprocity of subjects is ensured. This was considered thoroughly when selecting the participants in the focus groups. A power imbalance was prevented by selecting participants from a similar organizational level. Additionally, a moderator was present in the workshop sub-groups to ensure all participants were heard, and the tone of the discussion remained respectful.

Finally, exiting ethics was ensured by sharing the results with the participants before they were used in the publications. Furthermore, the results were reported in an objective and constructive voice to minimize the risk of misuse.

### 6.3.4 Credibility

The credibility improvement activities are, as mentioned above, prolonged engagement, triangulation, persistent observation, peer-debriefing, negative case analysis, referential adequacy, and member checking.

The first two literature reviews (Publications I and II) were conducted mainly by one researcher, which is a clear limitation of the credibility. However, the method used was a meta-synthesis, which is interpretive, eclectic, and hermeneutic, and focused on finding similarities and differences in the data (Sandelowski et al., 1997; Tranfield et al., 2003), hence it offers methodological triangulation through iteration in data collection and analysis. Publication I collected the data from Web of Science, and Publications III and IV from Scopus, which limited the number of publishers. However, changing the search platform to Google Scholar (in Publications II and V) provided source triangulation as the publications included all publishers. While the data collection was conducted through snowballing, whose credibility relies strongly on the quality of the start set, emphasis was placed on creating the start set in all of the publications. Publication I combined seven search words and iteratively searched sixteen original, seminal publications. This was possible as, at the time of the literature review, the number of publications on digital platforms was still relatively small. In Publication II, the start set was created through two broad searches and then combining them into one set of twenty-five publications from different publishers, geographical areas, years, and authors. According to Wohlin (2014), this could be considered sufficient. The final literature review (Publication V) was conducted in an even more credible manner as it was conducted by three researchers. The start set was collected twice, 30 months apart, and combined to maximize the source triangulation. The start set was deliberately large with 29 full papers and included articles from different research domains, countries, publishers, years, and authors. The snowballing led to 216 articles. The analysis was conducted using the Porter stemming algorithm (Mustafee, 2003).

The first multiple case study included orchestrators of Finnish platform ecosystems. While the data was collected from a single company, the responses do not necessarily reflect the views of all actors. However, the objective of the study was to verify the Platform Canvas framework, i.e., whether all characteristics identified in the literature were recognized by practitioners, too, hence the case selection could be considered applicable. The interviews were recorded, which allows the original data to be returned to when necessary and the summaries of the interviews (i.e., completed Platform Canvases) were shared with and approved by the interviewees. Therefore, credibility can be considered to be sufficient.

The second multiple case study (Publication III) was conducted using secondary data. This was not optimal but was considered to be sufficient as the cases were the same as in Publication I. Hence, the researcher knew the companies and their platform strategies in advance. The third, a single case study (Publication IV), was conducted based on data collected for another study (i.e. Harala, 2021). The data was collected through interviews and publicly available data. The interviews were recorded in this case study to enable returning to the raw material when required. Also, in this study, the researcher who gathered the original data was part of the research team. In the latter multiple case study (Publication VI), the case representatives were included in the planning of the data collection workshop. The data was collected in focus group workshops, both in video recordings and in writing. The focus group workshops were video-recorded to enable the researcher to return to the material when needed, and also to analyze the attitudes of the participants and the atmosphere during the workshop. After the data analysis, the city and platform representatives had the opportunity to discuss the findings and clarify potential misunderstandings. Also, the members of the workshops were selected so that they represented a similar organizational level to minimize the effect of power disparity.

Each of the studies leading to an article included peer-debriefing. The dissertation supervisor reviewed all research ideas, chosen methods, and article drafts in advance. In addition, all articles were written in a team, offering regular opportunities for peer-debriefing.

### 6.3.5 Transferability

Transferability refers to the extent to which the research results can be transferred to another context or setting (Cho and Trent, 2014). In order to enable good transferability, the researcher should rigorously describe the participants, research process etc., to provide enough information for other researchers or, for example, industry representatives to judge whether the results are applicable in their context or at a different time. In quantitative research, numbers can be used to describe generalizability but in qualitative research the judgement of transferability is left to the reader because they are the only ones who know the differences between the settings well enough (Lincoln and Guba, 1985, p. 316).

In the literature reviews conducted in this research, the process was documented carefully in the articles, including methods, search strings, databases, and results. Literature reviews as such are not especially context sensitive, thus there may be contexts where the same process is applicable. The case studies were also documented thoroughly, including case selection criteria, participants, industries / domains, interview questions, workshop flow, etc. However, for ethical reasons, the respondents and workshop participants were anonymized. Their roles in their respective organizations have, however, been described in as much detail as anonymization allowed.

### 6.3.6 Dependability

Dependability means that another researcher can replicate the research and excogitate to the same results as long as they have similar participants and conditions (Cope, 2014).

To enhance dependability, all methodologies and case selection criteria were documented thoroughly in the articles to create a clear audit trail. Additionally, all data is stored on the servers of Tampere University. Likewise, all analysis and the thinking behind the interpretations have been documented with Microsoft programs (excluding the coding of the last case study, which was also documented using Atlas.ti, a qualitative data analysis and research system), providing comprehensive compatibility. Even the Porter stemming algorithm used in Publication V is readily available as open source (Mustafee, 2003). However, the learning journey during this dissertation can be seen. The data and analysis of the first three articles are less properly documented than the latter three. It is also worth noting that, as the research was conducted under a pragmatic paradigm, which requires data to be interpreted, the background, personal experience, and pre-understanding of the researcher is bound to affect the interpretations made in this research. The documentation was done based on the understanding of the expectations of rigor at the time of collecting, analyzing, and reporting on each research study. Also, it is good to acknowledge that each research subject (i.e., interviewee or focus group participant) has their own views and interpretations, which will have an inevitable effect on the results.

Another way to improve dependability is to use overlapping methodologies. Each of the publications relies on one main method (except Publication III, which combines a literature review and a case study). However, as a whole, this research can be considered as a "cobblestone road". Each of the publications can be seen as a cobblestone supporting one another and leading towards the final destination. Consequently, this means that the methods selected for each of the publications support the path towards the conclusions.

### 6.3.7 Confirmability

Confirmability describes the neutrality of the research (Lincoln and Guba, 1985, p. 300, pp. 318–327), i.e., how the subjects or the researcher affect the results. The research should be conducted in a manner that minimizes the effects of bias, motivations, and interests of the subject and researcher. In pragmatic research relying on interpretivist assumptions, there is no absolute truth, but the research aims at a sufficient level of confirmability. Demonstrating confirmability requires an audit trail, where establishing the interpretations and conclusions is shown (Cope, 2014).

Halpern's classification of audit trail categories is summarized in Lincoln and Guba (1985, pp. 382–384). These six categories of audit trail that should be considered when evaluating the confirmability of research are: (1) raw data, (2) data reduction and analysis, (3) data reconstruction and synthesis, (4) process notes, (5) intentions and disposition, and (6) instrument development.

The empirical raw data of this research included public documents, interview records, and electronically recorded materials. The interviews and focus groups were made up of actors from multiple organizations throughout the ecosystems so as to acquire data from multiple perspectives. The final focus group workshops were video recorded, so that even the level of interactions and participant feelings could be analyzed. All literature review search strings and databases used were recorded; all of the search results are stored on the servers of Tampere University. The start sets of snowballing were included in the articles. Furthermore, in Publication V the complete data set was included as supplementary material.

The data reduction and analysis in the empirical part included interview notes, transcripts, and concise Excel sheets. The final focus group material was coded using Atlas.ti qualitative data analysis and research software to enable co-occurrence and cross-tabulation analysis. The data from the literature reviews was encapsulated in Excel sheets. In Publication V, an openly available Porter Stemming Algorithm and a free Voyant tool were used for analysis.

The data reconstruction and synthesis were endorsed by authoring all articles in co-operation with other researchers to improve objectivity. Furthermore, the results were reported as concise tables in Publications II to VI and supplemented with pictures of the created concepts in Publications II and V.

The process of each research was documented by storing the discussions between researchers in e-mail, chat, and as comments in the drafts of the articles. The methodological decisions were always made in co-operation with the co-writers.

The intentions and disposition were documented in each of the publications. All of them included justifications of method selection, a summary of the relevant literature, and evaluation of the implications and limitations of the study.

The instrument development was documented in all three frameworks as pictures and Excel sheets. All frameworks required multiple drafts (Platform Canvas 3, IoT characteristics 3, and Ecosystem Value Balance 5). All drafts are stored on the servers of Tampere University.

As a summary, the confirmability of this research can be considered to be sufficient, but not perfect. The documentation improved throughout the research process as the knowledge and expertise of the researcher improved.

### 6.3.8 Authenticity

Demonstrating authenticity requires that the researcher has aimed for fairness. This can be done, for example, by encouraging subjects to understand that others may have a different stance or ideas, empowering, and stimulating action. Authenticity is more relevant in the empirical studies included in this research (Publications I, IV, and VI) as the interviews did not support increasing authenticity. However, as the interviews were semi-structured, it allowed the interviewee to reflect on their answers, which could improve authenticity. Furthermore, the focus group workshops were particularly good in improving authenticity. The participants were selected to be on relatively the same organizational level, the discussions were held in small (3-5 person) teams, and results were shared with the whole focus group after each discussion. Each small group had a moderator to facilitate the discussion. At the end of the workshop the participants agreed on the next activities that needed to be conducted for improving the ecosystem.

In the literature reviews, the authenticity was improved through discussions between the researchers.

## 6.4 Limitations of the Study

This research, like any other, has its limitations. The limitations specific to each of the publications are reported in each publication. In this chapter, the focus is on the limitations of the research as a whole.

As reported above, it is evident that the trustworthiness of the research improved over time. The earlier publications have more and larger methodological limitations than the later ones, which becomes clear when comparing the literature reviews in Publications I, II, and V. The further the research proceeded, the more thorough the reviews became, leading to more credible and dependable results. There are two reasons for this. For one, the skills of the researcher improved and second, the general academic knowledge on these nascent research topics increased as more academic articles were published.

Another limitation related to the novelty of the research area is the obscurity of the concepts. The literature review in Publication I was conducted in 2016, when the literature on platform ecosystems was still immature. Already at that time, literature was spread over information systems, innovation management, and economics, all of which had their own priorities regarding which characteristics were the most important. As the whole research took nearly six years, the meanings of words describing the concepts may have evolved. Although this is a limitation, it is mitigated by being an article-based compilation type of thesis, as each publication included a review of recent literature. Furthermore, the research was framed thoroughly based on multiple literature reviews to minimize this limitation.

The knowledge on the scope of business model innovation increased during the research, causing the scope of Publication I to become too narrow. While the same characteristics are valid today, the process of how the canvas should be used has become somewhat obsolete as Publication I proposes the canvas be used by the orchestrator company, which may limit the scope and emphasize the views and expectations of the orchestrator. However, the eight characteristics identified in the study are still valid.

The literature reviews were conducted according to the snowballing method (Wohlin, 2014). The quality of the results relies heavily on the quality of the start set and the selected database. It is difficult to assess how much the decisions made in each of the literature reviews affected the results. However, Badampudi (2015) has demonstrated that the method is accurate when the start set is sufficiently defined. In the literature reviews of this research, the analysis was made by creating meta-syntheses, which integrates the findings through an interpretive, hermeneutic, and eclectic process to create next-level understanding because interpretive synthesis is bigger than the sum of its parts (O'Gorman and MacIntosh, 2015;

Sandelowski and Barroso, 2007; Tranfield et al., 2003). This should reduce the level of the limitation.

The research would have benefited from longer term cases and a larger number of cases in the final empirical study. However, the original cases had a strategy of designing the business model from the orchestrator perspective, hence, the cases needed to be changed. On the other hand, the smart cities as focus groups were eager to be cases, as both of the ecosystems had faced challenges in moving to the next phase of the ecosystem life cycle. These cases were purposely selected through intensity sampling (Suri, 2011), as the goal was to create a thorough understanding of participant value expectations in ecosystems that hope to reach the expansion phase of the life cycle.

This leads us to the final limitation. The research aimed at understanding ecosystem-level value propositions. However, value is subjective, temporal, and it can be extrinsic or intrinsic. It is also usually attributive. Therefore, measuring value is difficult. In this research, the value perceived was the opinion of a research subject. Hence, another person may see it differently. To minimize this limitation, significant effort was put into selecting the focus groups. The people were familiar with the expectations of their organization but also aware of the practicalities, hence middle management was invited. Also, many of the participants knew each other in advance, and trusted each other, which helped to have an open discussion. Thus, the discussions in the workshop were lively. Nevertheless, the evaluations remained opinions.

## 6.5 Proposals for Future Research

The limitations lead to proposals for future research. The scarcity of research in this area offers a wide variety of avenues for future research.

First, the frameworks and the iterative BMI process proposed in this research should be validated with more and longer-term cases. While the cases in this research found that the EVB and Platform Canvas were useful, they were not validated together, or in longitudinal research. Based on theory, this model is expected to enhance the BMI in IoT-enabled platform ecosystems, and perhaps also other types of platform ecosystems. Also, a cross-industry study could be conducted to explore the potential similarities and differences in the challenges and opportunities of IoT platform ecosystems across different industries. For example, what, if any, are the differences in the BMI of the Industrial Internet of Things ecosystems compared to smart city ecosystems?

Second, more understanding is needed on the effects of value balance (or imbalance) on ecosystem success during different phases of ecosystem life cycle. The research should include multiple industries, ecosystem types, and even longitudinal research to understand how the balance evolves over time and from one life cycle stage to another. The cases in this research were in the birth and leadership phases (Moore, 1993). A difference in value balance and especially in value potential was apparent in these cases but what does the balance look like in the expansion or self-renewal phases? Can the change to the next phase be predicted based on the EVB? Predictability would be important as the ecosystem faces different challenges in different life cycle phases. Also, further research could explore whether there are synergies or trade-offs in how different value dimensions are leveraged to create sustainable business models.

Third, while ecosystems are dynamic and affected by external market conditions, further research is needed to understand how often the EVB and Platform Canvas should be revisited. The frequency may alternate between different types of ecosystems and industries.

Furthermore, since BMI is a co-creative process it is affected by the characteristics of the team innovating the BM. Different people have different views based on their seniority, expertise, experience, and even their character. Further research could strive to define the properties required from an optimal BMI team to maximize the reproducibility of a "great" BMI.

In general, an orchestrator is needed (Thomas et al., 2022), but there are indications that the role of the orchestrator may need to be transferred from one actor to another during ecosystem evolution (Dedehayir and Seppänen, 2015). How, when, and how often this happens – or should happen – in IoT-enabled ecosystems, where the platform owner may be a different actor than the "process owner" (i.e., city organization in the cases of smart cities) requires attention. Additionally, the role of governance in relation to shaping the value proposition and the role of the orchestrator could be investigated.

Moreover, measuring the level of value requires a measurement regime to enable the comparison of different business models, ecosystem strategies, and their success. For the epistemic, financial, and functional value it is probably relatively simple to create measurement "scales", but for the emotional and social dimensions, it may require inter-disciplinary research before sufficient understanding on experiencing value can be obtained. A balanced scorecard (Kaplan and Norton, 1996) type of solution might be worth exploring as an option. Understanding the relative importance of value dimensions in different types of platform ecosystems could offer insights on influencing consumer behavior and decision-making.

This research took the less common perspective in ecosystem research of social exchange, thus striving to elaborate the actor relationships in relation to the ecosystem structure and especially to minimize the risk of power misuse, leading to reduced continuance intention. However, it could be beneficial to further examine whether network economics theories (such as effects of compatibility decisions of different actors, effects of price, quality and governance on the perceived value, effects of information imbalance) could enhance the model proposed in this research.

While digital transformation – and especially operating in ecosystems – requires a cultural change in companies, it is difficult to estimate whether companies are ready to accept the type of thinking that applying this model will require. Companies have been focusing on maximizing profits for themselves instead of focusing on maximizing the overall value for the whole ecosystem. Therefore, research supporting cultural change is required, too.

Additionally, while DT includes continuously developing emerging technologies (such as blockchain, artificial intelligence, and machine learning), future research could also explore the role of these novel technologies in shaping the value proposition and value creation processes in IoT platform ecosystems. For example, will AI have a role – and if yes, what kind of role – in BMI or in differentiating the value propositions?

Finally, the research began by identifying a gap between the IoT expansion estimates and the actualized numbers. This research assumes that a significant contributor to that gap is the lack of feasible business models. However, there may be other major contributors, too. Hence, research toward identifying those impediments could be worthwhile.

To conclude, this research has opened up avenues for researching value proposition evaluation in IoT-enabled ecosystems. The business opportunities built upon these ecosystem interactions require more attention before they can be realized.

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# ORIGINAL PUBLICATIONS

# PUBLICATION I

**Business Model Innovation with Platform Canvas**

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# Business Model Innovation with Platform Canvas

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## Abstract

**Purpose:** This paper offers a literature review and explores a business model innovation for platform business. It also suggests a practical tool, Platform Canvas, to support implementation activities.

**Design/Methodology/Approach:** A literature review was conducted in fall 2016 that resulted in the tentative canvas approach, which was evaluated in seven real company cases.

**Findings:** The study identified the eight most important characteristics of a platform business model innovation. To support the innovation and development of successful business models in a platform ecosystem, the Platform Canvas tool was created. With guiding questions, Platform Canvas allows for an ecosystemic approach to business model innovation: it helps to understand the value creation and capture for multiple actors.

**Originality/Value:** The unique result is a practical tool, Platform Canvas, which facilitates business model creation in platform ecosystems.

Keywords: Platform, ecosystem, business model, Platform Canvas, literature review

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## Introduction

Google, Facebook, Amazon, and Apple—these and many other platforms are disrupting traditional businesses as they transform the existing value creation processes and customer behavior (e.g., Miguel & Casado, 2016; Simon, 2013). By doing so, they are transforming the structure of major industries and forcing traditional incumbent companies to re-evaluate their current business models, simultaneously allowing opportunities for new entrants. Participating in platform ecosystems is becoming an important way for companies to gain more revenues and profits, as platforms with their inherent network effects enable exponential growth. Platforms, especially digital platforms, are used as a business model; examples are Alibaba and General Electric's Predix.

The success of platforms is explained by sustainable and repeatable interactions (Choudary, 2015) that breed the growth or emergence of an ecosystem. Our emphasis on the platform ecosystem uses a novel theoretical framework by Jacobides *et al.* (2018), which argues that ecosystem emergence is enabled by modularity and complementarities. As they emphasize, *"allow a set of distinct yet interdependent organizations to coordinate without full hierarchical fiat"*, hence seeing the ecosystem as "*a set of actors with varying degrees of multi-lateral, non-generic complementarities that are not fully hierarchically controlled*" (Jacobides et al., 2018, p.2264). According to them, the core of ecosystems lies in combinations of modular complementarities and similarity of shared rules of operation.

Digital technology expands reach, convenience, speed, and efficiency tremendously compared with the traditional way (Parker *et al.*, 2016). Although we are concentrating on digital platforms, the platform ecosystem is considered from the business perspective rather than as a technical issue (Iivari *et al.*, 2016). Hence, for the purposes of the use of technology, we agree with Chesbrough (2010, p. 354): "*Technology by itself has no single objective value. The economic value of a technology remains latent until it is commercialized in some way via a business model.*"

In this study, we explore business model innovation with the overall objective of value creation and/or capture (Wirtz and Daiser, 2017; Clauss, 2016) in the context of platform ecosystems. Accordingly, we employ the old but still valid definition by Weill & Vitale (2001) , which says that a business model is "a description of the roles and relationships among a firm's consumers, customers, allies, and suppliers that identifies the major flows of product, information, and money, and the major benefits to participants." With this ecosystemic approach, we proceeded to develop a tool – Platform Canvas—and a supporting set of questions to help management and scholars to innovate their business models in platform ecosystems.

The paper is structured as follows: first, we present the main characteristics of a platform ecosystem. Second, we introduce the research design and data. Third, we represent the results and the developed tool, Platform Canvas. Finally, we discuss the challenges of the platform creation process and how the Platform Canvas tool can help facilitate this process, and conclude by summarizing avenues for further research.

## Platform Ecosystems for Novel Value

Business model innovation considers the business model rather than products or processes as the subject of innovation (Baden-Fuller & Haefliger, 2013). In more detail, business model innovation can cover various aspects: (1) a value creation innovation, like new capabilities, new technology/equipment, new partnerships, new processes – or (2) a new proposition innovation, consisting of a new offering, new customers and markets, new channels, and new customer relationships – or (3) a value capture innovation, that could include new revenue models and value cost structures (Clauss, 2016).

### Platforms with modularity and complementarity

Platforms give companies new opportunities by changing the traditional business rules and how companies interact with each other (Vazquez, 2016). Their purpose is to facilitate the multi-party exchange of products, which can be goods, services, or even social currency, creating novel value and at the same time allowing value capture. Platforms can also be considered matchmakers that bring members of different groups together. They sell access to the target group(s)

(Evans and Schmalensee, 2016). In one way or another, platforms provide more value for customers by helping companies to create new integrated services (Ju, Kim and Ahn, 2016).

Digital platforms are "*software-based external platforms consisting of the extensible codebase of a software-based system that provides core functionality shared by the modules that interoperate with it and the interfaces through which they interoperate*" (Ghazawneh and Henfridsson, 2015, p.199). The digital platform can, therefore, be described as the technical infrastructure to which the ecosystem participants integrate (Iivari *et al.*, 2016).

A platform ecosystem can be seen as a collection of firms interacting with a contribution to the complements (de Reuver *et al.,* 2016). An interactive platform ecosystem is created using technology to connect ecosystem members, such as people, organizations, and their resources. Hence, the platform ecosystem is oftentimes seen as a two- or multisided marketplace where value is created for all members of the network (Parker *et al.*, 2016)

To succeed in digital platforms and the larger entity of the platform economy, participants need to recognize their roles in the platform ecosystem. Platforms leverage the ability to create and scale value outside the organization in an ecosystem (Choudary, 2015). Platform ecosystems are clearly business ecosystems. According to Rong *et al.* (2015), an ecosystem can be considered to be an established value network where the roles are fixedly interconnected and where the interconnected stakeholders have a shared faith and in which they co-evolve. Therefore, companies need to understand that they cannot provide the value alone and that their actions have an impact on the overall ecosystem in which they operate. Thus, for the ecosystem members to co-evolve, their capabilities need to be linked with the actions of the other participants (Moore, 1996).

### Platform as a business model innovation

The platform has been presented as a business model innovation that enables external producers and consumers to create value together by interacting with each other (Choudary, 2015). Its ecosystem comprises the platform's sponsor plus providers of complements that make the platform more valuable for the customers, considering how the actors—including users—are organized around a platform (Jacobides *et al.,* 2018).

What is the new business model innovation when technical modularity allows all these independent components of a system to be produced by different producers (Jacobides *et al.,* 2018)? The opportunity for a platform often arises when there is too much friction in the market, which hinders the different user groups from dealing with each other (Evans and Schmalensee, 2016). The aim of the platform is then to reduce barriers to participation—that is, to reduce friction in order to get new participants to join both sides of the market. By doing so, the platform enables sustainable and repeatable interactions by balancing their quality and quantity (Choudary, 2015). Platforms provide opportunities to tackle the innovation management challenge of allowing value co-creation with users (or consumers). They allow for innovation to take place beyond the province of in-house experts and research and development laboratories; when customers start to engage and be more interactive, new forms of value appear (Parker *et al.*, 2016). In other words, a platform as a business model innovation requires ecosystem level considerations in order to explore value co-creation and capture innovations (Clauss, 2016).

## Research Design

There is a demand for research into the transformative and disruptive impact of digital platforms on organizations and their business models (Parker *et al.,* 2016), for more research exploring digital platform innovation (de Reuver *et al.,* 2017) as well as for research on ecosystem value creation/capture (Jacobides *et al.,* 2018). The purpose of our study is to solve this need for supporting business model innovation in the context of platform ecosystems. An extensive literature review allowed us to break down and identify the critical characteristics of platform ecosystems. We then proceeded to formulate the most important criteria in an easy-to-use format with a construct of Platform Canvas.

### Literature Review

We first identified the relevant characteristics, frameworks, and models in the extant platform literature to obtain a pre-understanding of the field, following a similar procedure to that of Wirtz and Daiser (2017). This was done with a comprehensive literature review, conducted in fall 2016, combining the keywords "digital," "platform," "characteristic," "ecosystem," "element," "disruption," and "value." The review process included an iterative search of references and citations available in research papers in the Web of Science database. This snowballing methodology complemented the search results by identifying original books and articles (Wohlin, 2014).

During the comprehensive literature review, 16 sources—journal articles and books—were identified as original sources. The original sources were published between 2002 and 2016. From these original sources, we identified and grouped the characteristics that were presented as essential to the meaning described in the source. This grouping resulted in 18 critical characteristics for establishing a platform ecosystem (see Table 1). The descriptive names of these were derived and synthesized from the terms used in the original sources with broad synonyms.

### Crafting the Platform Canvas tool

As the Business Model Canvas (Osterwalder and Pigneur, 2010), complemented by the book *Value Proposition Design* (evaluated in the recent study by Kyhnau and Nielsen, 2015), has become the de facto diagnostic tool for understanding the value creation potential of businesses, our goal was to develop a similar construct that is easy to use and emphasizes the special characteristics of platform ecosystems. We are aware of multiple other constructs that attempt to do this (for example, digital platform canvas[1]; the platform design canvas[2]; and Platform Canvas[3]. However, they are not research-based.

The previously described literature search offered 18 critical characteristics. For a more manageable number of characteristics to be included in the canvas, these were then arranged according to their prevalence in the sources. In the first list of characteristics, the prevalence varied between 3 and 15; the mean was 6.8 and the median was 5. The second list was compiled based on the three most cited sources and the characteristics emphasized by these sources. The first six characteristics were the same in both lists. The seventh was different, and by accepting both of these, we ended up with the eight most essential characteristics.

Accordingly, we created a first version of the template, which was Microsoft Excel-based and had a cell for each of the eight characteristics. Each of the cells also included a couple of questions to clarify the meaning of the terms used.

The first version was tested by using it as a supporting tool for interviewing companies about their platform ecosystem activities and business model innovation. The canvas template was first separately filled by representatives of seven Finnish manufacturing companies with their in-house knowledge and by a researcher using publicly available data. Then, the researcher interviewed the company representatives for 1-2 hours. At the end of each interview, the company representatives were asked to give feedback on the canvas itself.

During this initial use, it became clear that the platform participants have to have a deep and detailed knowledge of the market in which they are participating before they can benefit from Platform Canvas. It should be noted that all of the companies had created the platform based on their own needs. Only one company mentioned that they had been obliged to re-visit their platform strategy since they had noticed the platform did not respond to the needs of the presumed participants.

These eight characteristics seemed to bring structure to the interviews, for both the interviewer as well as the interviewees. With this validation of the canvas content, the eight characteristics were developed into the Platform Canvas tool. However, as some of the terms needed clarification in order for the company representatives to be able to answer, those changes were incorporated into the Platform Canvas. The visual elements and their positions were also added based on insights from the research. For example, an image of a group was placed to highlight the fact that platforms are about groups of people; both a heart and a dollar sign were added to emphasize different types of value.

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[1] http://icsb.nl/artikelen/new-business-model-canvas-for-digital-platforms/
[2] https://platformdesigntoolkit.com/toolkit/
[3] https://www.slideshare.net/YearOfTheGoat/the-platform-canvas-learn-how-to-build-platform-business-models-in-45min);

| PLATFORM KEY CHARACTERISTICS | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Core interaction | Simplicity | Maintainability | Tools for consumption | Metrics | Filtering | Facilitate | Creation Tools | Traction | Cost of multihoming | Matching | Monetizing | Change tolerance | Value | Producers | Consumers | Governance | Network effects | |
| 3 | 3 | 3 | 2 | 3 | 4 | 4 | 4 | 5 | 5 | 6 | 7 | 9 | 11 | 12 | 12 | 13 | 15 | Source reference |
| x | | | | x | x | x | | x | | x | x | x | x | x | x | x | x | Bonchek M., Choudary, S. P. (2013) Three elements of a Successful Platform Strategy |
| | | | | | | x | | | x | x | x | x | x | x | x | x | x | Moazed, A. (2016) What is a Platform? |
| | | | x | | | | x | x | | x | x | | x | x | x | x | x | Simon, P. (2011) The Age of the Platform |
| | x | x | | x | | | | | x | | | x | | x | x | x | x | Abeysinghe A. (2016) Building a digital enterprise- learning from experience |
| | | | | | | | | x | | x | x | x | x | x | x | x | x | Boudreau, K. J., Jeppesen, L. B. (2014) Unpaid crowd complementors: The platform network effect mirage |
| | x | | | | x | x | | x | | | x | x | x | | | x | x | Choudary, S.P. (2015) Platform Scale |
| | | x | | x | | x | x | x | | x | | x | x | | | | x | Cusumano, M. A., Gawer, A. (2002) The Elements of Platform Leadership |
| | | x | x | | x | | x | | | | | | x | x | x | x | | Westhead, M. (2014) Platforms - Two/multi-sided markets |
| | | | | | | | | | x | | x | | x | x | x | x | x | Edelman, B. (2015) How to Launch Your Digital Platform |
| | | | | | | | | | x | | | x | x | x | x | x | x | Abeysinghe A. (2015) Platform for digital transformation |
| x | | | | | | | | | x | | x | | | x | x | | x | Hyatt, M. (2016) Why you need a platform to succeed |
| x | | | | | x | | x | | | | | | x | | | x | x | Tiwana, A. (2013) Platform ecosystems |
| | x | | | | | | | | | | | x | | | x | x | x | Evans, D., S., Schmalensee R. (2016) Matchmakers |
| | | | | | | | | | | x | | | | x | x | x | x | Evans, D., S., Hagiu, A., Schmalensee R. (2006) Invisible Engines- How Software Platforms Drive Innovation and Transform Industries |
| | | | | | | | | | | | | x | | x | | x | x | Parker,G et al (2016) Platform Revolution |
| | | | | | | | | | | | | | x | x | x | | x | Kouris, I., Kleer, R. (2012) Business models in two-sided markets: an assessment of strategies for app platforms |

**Table 1: Summary of key platform elements identified in the literature review**

## Platform Canvas

Platform Canvas operationalizes the eight key characteristics of business model innovation for a platform ecosystem identified by the literature review. These characteristics are presented here to understand the main issues that companies need to consider when planning their activities in the platform ecosystem. Hence, the presentation order does not reflect the popularity of the characteristic in the literature. In addition, the questions developed to guide the use of Platform Canvas are explained.

### Eight key characteristics

The core interaction of the platform, which refers to the exchange of value, is the single most important type of activity in the platform ecosystem (Parker *et al.*, 2016) and is accordingly central in the canvas. First, it brings forth the characteristics of **(1) value**, describing the value creation potential of the platform, and **(2) monetizing,** as capturing the value. The literature refers to this for example by creating feasible pricing models that maintain or even increase the traction toward the platform (Parker *et al.*, 2016, pp. 106–110).

The core interaction also introduces the two sides of the platform: **(3) producers** and **(4) users**. This emphasis on at least two sides has also been addressed by the term "bilateral market power of the platform" (Kouris and Kleer, 2012); although with added participants the term "multi-sided markets" is also used (Evans and Schmalensee, 2016). Different scholars refer to the *producer* of the value using different terms such as "*complementors*" and "market side 1"; some even combine all sides and refer to them only as participants. Researchers often refer to the value *user* side as consumers, customers, and end users. All of these terms are also used in traditional pipeline businesses, although the roles do not mix in such businesses as they do in platform ecosystems.

**(5) Filtering** *(including matching)* allows for making the value exchange efficient, simultaneously allowing the platform to attract participants (Parket *et al.,* 2016, pp. 296-297), and is considered crucial for all participants in the platform ecosystem. It describes the algorithm's ability to filter a massive amount of data in a way that enables the quick and precise matching of the value producer and the value user. Hence, these software-based tools enable the exchange of value between the right producers and appropriate consumers. Accordingly, the platform owner aims to build and maintain an ecosystem where the platform will continue to attract participants; this is partly ensured by providing the desired match easily.

"The platform rules" for all participants are addressed with **(6) governance**. The literature describes governance with several terms such as control, rules, access control, and trust. With an elaborate governance system of laws, enforcement, and penalties (Evans and Schmalensee, 2016), the platform can facilitate value co-creation and match the most compatible users with each other.

**Resilience (7)** (including change tolerance and maintainability) describes the platform's ability to adapt to a changing environment. It has also been referred to as modular, evolvable, durable, and plug-n-play. All of these emphasize the importance of being adaptive to change. However, a company which is highly adaptive to change can even cause market turbulence for its own benefit (Simon, 2013). Maintainability of the system can also be considered to be part of resilience. It includes three perspectives: a) maintaining compatibility with future complementary products (i.e., platform integrity) when new technologies arise, b) developing the platform while maintaining compatibility with past complements, and c) maintaining platform leadership despite changes (Cusumano and Gawer, 2002). With this goal, aspects of boundary resources (both technical and co-operative) need to be addressed.

The final and most crucial characteristic of a platform is the **(8) network effect.** This refers to the ability to increase the scale of business significantly with minimal investment (Choudary, 2015, pp. 74–75). Utilizing the network effects is essential for the platform ecosystem to exploit its full potential.

**Process with guiding questions**

As with the business model canvas, a list of questions to explore the main characteristics (called "blocks" in Osterwalder and Pigneur, 2010) was developed. The questions are intended to help companies to innovate and evaluate their platform business models from different perspectives, thus addressing the ecosystemic nature of platforms. Each characteristic can be defined by answering the facilitative questions (see Table 2). We propose that these questions may also help platform ecosystem participants consider their positions and prospects in the platform: they may find these beneficial due to the differences in platform thinking versus traditional business thinking. We further propose that Platform Canvas and the guiding questions can lead the participants through the whole innovation process, or can be used to explore certain aspects of the platform.

To address the core interaction, both the value for producer and value for users need to be described in detail and understood thoroughly. It is also important to understand that the role of the user may vary in different interactions. Hence, with regard to *value,* it is not enough to think which friction the platform reduces;

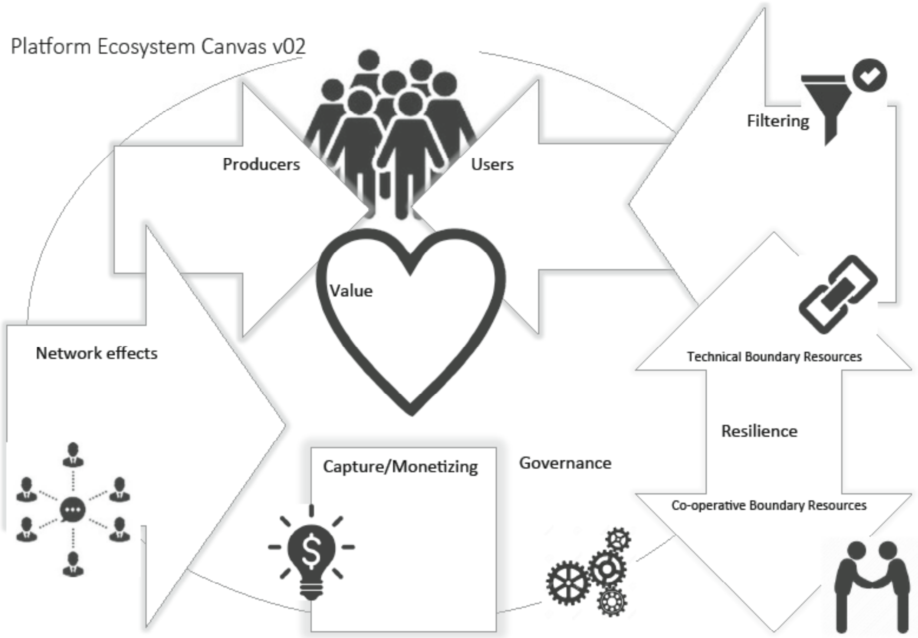


**Figure 1: Platform Canvas**

it is equally important to identify all the different values created by the interaction and how the platform attracts users on all sides. It should be remembered that the value may be monetary, but in many cases, it is something completely different (like information).

Second, the opportunities related to the network effects must be understood. Whether the effects are direct, indirect, or both, and what kinds of scalability requirements the platform faces because of this, must be addressed. The platform owner must have an idea of how the tools

| Characteristics | Questions |
|---|---|
| Value producers | Who are the value producers and what motivates them to create the value? Through which channels do they produce the value? |
| Value users | Who are the value users, and what motivates them to consume the value? Through which channels do they consume the value? |
| Value | What are the different values that are created? How does the platform attract participants? How is the chicken-and-egg problem solved? Which friction does the platform reduce? |
| Filters | What data are acquired to match producer and user? Which filters does the platform need to serve the relevant content to consumers and connect them to the relevant value producer? |
| Network effects | Which types of network effects are achieved? |
| Value capture | What currency does the user provide to the producer in exchange for value? How does the platform capture some portion of this currency? |
| Governance | What are the tools for lowering the barriers to entering the platform? Which creation/curation/ customization/ consumption tools does the platform provide? |
| Resilience | To what extent are the boundary resources defined? |

**Table 2: Guiding questions**

and services in the platform solve the chicken-and-egg problem (attracting participants on all sides of the market to the platform) and how the platform keeps the interest of the users. This affects the requirements for the filtering abilities of the platform.

After these aspects have been reviewed and planned, the system side of the canvas can be completed. The management first needs to define the governance and curation aspects. The final phase of the design is to ensure the resilience of the platform. This is done by opening up both the technical and co-operative boundary resources. The platform owner should have a clear picture of how the tools and services provided help facilitate the interactions, value creation, and value exchange, which can then guide the finding of appropriate technology partners for the platform.

## Discussion and Conclusions

Platform Canvas is intended to guide the platform ecosystem participants—platform sponsors or owners, platform complementors, and other service providers—in their business model innovation. One could describe Platform Canvas as a "*poka-yoke type*" (Shingo, 1986) error-proofing tool for organizations planning their activities in a platform ecosystem. As poka-yoke aims to eliminate the possibilities of causing a defect to a product or process by offering a method for involving members of the production or process, for example, the canvas aims to offer a method to explore business model innovation in a platform ecosystem by offering a template for involving ecosystem participants. Overall, we propose that with its eight key characteristics it can be used to support innovation in a similar manner to the Business Model Canvas when establishing a platform ecosystem or evaluating possible needs in re-thinking the ecosystem (Osterwalder and Pigneur, 2010).

### The contribution of the canvas

The canvas helps challenge the platform participants to open up their thinking. It provides the possibility to see the big picture and simultaneously drill down to a more detailed level. Hence, the canvas provides an understanding of the complexity related to platform ecosystems. Platform participants need to understand the dual role of individuals (one can represent both value producer and value user—i.e., one can be a value prosumer). Especially in cases where participants are seeking to understand the impacts and possibilities of business model innovation in an ecosystem, Platform Canvas can help them find new perspectives for understanding the possibilities of the platform ecosystem (for API economy, see e.g., Huhtamäki *et al.*, 2016). The initial use of the eight characteristics in the manufacturing industry validated this (Sorri, 2016). As the emphasis was on re-evaluating business models, the importance of prior market knowledge was noted.

The canvas has also been used to study the expectations that startups have in relation to their platform-based business models and their abilities to support the core interaction and capture value from it (Korhonen *et al.,* 2017). This study showed that many startups see themselves as connectors of users and producers, and hence confirmed the importance of ecosystem thinking in a platform-based business (Parker *et al.,* 2016).

From the business model perspective, according to Chesbrough (2010), the most important functions that a platform ecosystem should fulfill are to articulate the value proposition, detail the revenue mechanism, and describe the value network. These have been included in Platform Canvas, which also addresses the ecosystemic nature of platforms—the fact that in ecosystems there are multiple business models in play that need to be considered. Furthermore, we claim that the canvas contributes to the business model literature with the inclusion of network effects, which are presented as necessary and specific to platform ecosystems. For example, a comprehensive literature review on business models by Zott *et al.* (2011) listed the components of e-business models found in the existing research at that time, and none of the scholars considered the network effects to be important.

### Limitations of the canvas

The eight critical characteristics of a platform ecosystem were identified through an inclusive literature review and based on how they often they appeared in the literature. As digital platforms are becoming increasingly complex research objects (Evans and Basole, 2016), their research is also becoming complex and takes place within information systems, innovation management, and economics (de Reuver *et al.,* 2017). Accordingly, there is also a great deal of variation within the sources regarding which characteristics are considered important when developing successful digital platforms. This stems for example from the bias towards successful cases, which are studied ex-post (de Reuver *et al.,* 2017).

The canvas has been mostly used internally, which alleviates the challenges with disclosure issues between various organizations. However, for an even better grasp of the complexities related to the platform and also for a better in-depth analysis of the possibilities of novel value creation, additional research on canvas utilization at the ecosystem level could increase, for example, understanding of the emergence and resilience of an ecosystem.

The cases of this research are all from the manufacturing industry as well as from startups. Our assumption was that the utilization of the canvas is not limited by the domain. However, more research needs to be conducted to examine this in more detail. While the aim of Platform Canvas is to help business managers, managers must still familiarize themselves with the basic theories and fundamental differences of the platform business model compared with the traditional ones.

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# BUSINESS MODEL FRAMEWORKS IN IOT CONTEXT – A LITERATURE REVIEW

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**Abstract**

*Employing the Internet of Things (IoT) in business changes the way in which value is offered to customers. To enable and ensure effective value exchange, proper business models are required. In this literature review study (n=56), business model frameworks created for the IoT context were evaluated. The results show that although most of the frameworks emphasize the ecosystemic nature of IoT, even they still largely do not describe the connections, dynamics, and causality between the business model components. While IoT as such does not necessarily need a specific business model, the ecosystemic nature of IoT is bound to influence the business model, thus making IoT business models more integrative, inter-relational, and complex. The results also suggest that the ecosystem-level co-creation of business models needs to be emphasized and studied further.*

**Keywords**: Internet of Things; IoT; Business Model; Literature review; Case study

## 1. Introduction

The "Internet of Things" (IoT) is expected to have a significant effect on businesses. Based on the amount of public discussion around the subject, it can be assumed there is also a strong market interest in IoT (see e.g. https://www.iotone.com/). IoT is becoming the backbone of value provision for customers (Vermesan and Friess, 2014). The only requirement to enable the prosperity of IoT businesses is proper business models. This study seeks to create an understanding of how business model development in the IoT context differs from the traditional ways to conduct business, since the technology to enable IoT-driven business already exists.

The IoT creates opportunities for new types of business, new services, and pressure to increase collaboration across industries and to enhance openness (Ju et al., 2016). This complicates the current firm-level business models since it creates a need for an ecosystem-level business model. Simultaneously, it should be kept in mind that disruptive technologies, such as IoT might be, affect our social structure and create new social and even political opportunities (Benkler, 2006). In the past, business models were linked in two integrated streams – the money stream and the product stream (Glova et al., 2014). Today, this is no longer the case. There is an infinite number of different ways to connect customers, physical or virtual "things," and businesses together (Westerlund et al., 2014). However, the IoT may help to align the physical product stream, the information stream, and the money stream by enhancing and improving visibility and control (Glova et al., 2014).

The IoT has been studied since the early 2000s (see Mejtoft, 2011); yet little research has been carried out that focuses on IoT-related business models (Whitmore et al., 2015). Before a technology can succeed, three factors have to be present: the technology itself has to be available, there has to be a strong market demand, and business models have to be established to link the supply and demand (Palattella et al., 2016).

The digital transformation enabled by IoT will fundamentally change business models towards as-a-service concepts, increasing customer involvement as well as turning data into value, thus finally converting traditional modes of cooperation into complex ecosystems (Pflaum and Gölzer, 2018).

This literature study provides the reader with the opportunity to understand how IoT-enabled business model development differs from traditional business model development, and how IoT business model development is linked with the actual development process in practice. We start by reviewing the current definitions of IoT and the business model, and continue by describing the research method in more detail. After these theoretical sections, we analyse the findings and conclude with a discussion, envisioning paths for future research.

## 2. Current definitions and their shortcomings

The terms 'business model' and 'IoT' have several different definitions, none of which seem to be widely accepted by the academic community. The inadequate consensus on the definitions impedes scholars attempting to describe the phenomena and their attributes (Podsakoff et al., 2016). In the next paragraphs, we illustrate the conceptual development and define the key terms for this literature study. The IoT and business model may not be "wicked problems" (Rittel and Webber, 1984) as they can be defined; until now the lack of consensus on a definition has made it challenging to measure the success of different business models in a certain context and create cumulative knowledge (Foss and Saebi, 2018). The same applies to developing IoT solutions. It can be stated that this vagueness hinders the development of a feasible and comprehensive IoT-enabled business.

### 2.1. Business model

Understanding the purpose of a business model is an increasing trend in research (Westerlund et al., 2014). Traditionally, business models have been described by defining the value proposition, value creation, and value capture (Burmeister et al., 2016); hence, this study examines whether the same principles also apply in the IoT context. It is fair to say there is no common consensus on the definition of a business model (Laudien and Pesch, 2018). We agree with Foss and Saebi (2018) that the heterogeneity of definitions and the lack of construct clarity of the business model causes deficiencies in the cumulativeness of the business model theory, which in turn complicates empirical testing. In this study, we compared 13 different frameworks for defining a business model (see Appendix 1).

In the early days of business model research, the future views of electronic markets were included in the business model definition: "A business model depicts the content, structure, and governance of transactions designed so as to create value through the exploitation of business opportunities" (Amit and Zott, 2001, p. 511). Nearly ten years later, Teece (2010, p. 173) posited that a business model "articulates the logic and provides data and other evidence that demonstrate how a business creates and delivers value to customers. It also outlines the architecture of revenues, costs, and profits associated with the business enterprise delivering that value." Both of the definitions emphasize, however, that the business model is a firm-centric concept. In 2012, Leminen et al. (2012) recognized a research gap related to IoT business models. At that time, IoT applications were context-specific. Leminen et al. perceived the connection between the development of domains (such as consumer electronics or factory automation) and market expansion, leading to the embracing of the term ecosystems. Thus, they argued that there was a need to define business models at the ecosystem level. One of the shortest definitions of a business model has been presented by Muegge (2012). He claimed that the business model is the story of how a business works. This is a concise, easy to remember definition, but does not give any particular details on what to include when creating a business model. In 2013, Li and Xu (2013) proposed that "the business model should be a bridge between technology and economy, which can guarantee the sustainable development of the industry."

For the purposes of this study, we chose a relatively old definition by Weil and Vitale (2001), which has stood the test of time well. It defines a business model to be *"a description of the roles and relationships among a firm's consumers, customers, allies, and suppliers that identifies the major flows of product, information, and money, and the major benefits to participants"* (Weill and Vitale, 2001, p. 34). It includes the ecosystemic paradigm, unlike many later definitions. In addition to what a business model is, it also describes what the business model is for, i.e. what can be accomplished with it. Although the definition can be seen as firm-centric, it can also be interpreted as referring to "allies," which thus broadens the definition to cover the ecosystem. The benefits from IoT are based on co-creation of value (D'Souza et al., 2015; Ikävalko and Turkama, 2018; Ju et al., 2016); thus the business model definition should include the ecosystem paradigm.

### 2.2. The Internet of Things

The definition of IoT is at least as diverse as was the case for business models in the previous section. In our study, we have identified 40 different definitions (will be provided upon request). In 2005, the International Telecommunications Union implied that connectivity for anyone, at any time, and in any place would be supplemented with connectivity for anything (Itu, 2005). In 2009, the Cluster of European Research

Projects on the Internet of Things (CERP-IoT) published the following definition of IoT: *“a dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols where physical and virtual “things” have identities, physical attributes, and virtual personalities and use intelligent interfaces, and are seamlessly integrated into the information network.*” (Vermesan et al., 2009, p. 6). Notably, their definition also included the definition of a “thing”, which is “a real/physical or digital/virtual entity that exists and moves in space and time and is capable of being identified.” The IoT definition of CERP-IoT emphasizes the infrastructure. Minerva et al. (2015, p. 74) created what they called an all-inclusive definition: *“Internet of Things envisions a self-configuring, adaptive, complex network that interconnects ’things’ to the Internet through the use of standard communication protocols. The interconnected things have physical or virtual representation in the digital world, sensing/actuation capability, a programmability feature and are uniquely identifiable. The representation contains information including the thing’s identity, status, location or any other business, social or privately relevant information. The things offer services, with or without human intervention, through the exploitation of unique identification, data capture and communication, and actuation capability. The service is exploited through the use of intelligent interfaces and is made available anywhere, anytime, and for anything taking security into consideration.”* Based on these definitions, the IoT includes ten elements: physical objects, virtual things, uniqueness, standardized technologies, global availability, interconnection and interaction, information, services and applications, and security. Thus there is no commonly accepted definition of IoT (Dorsemaine et al., 2016). It is worth noting that, based on the definitions above, the IoT itself does not include a business element. Hence, the IoT is considered only as an enabler of business.

## 3. Research Method

As mentioned in the introduction, there is plenty of variation in the definitions of both “IoT” and “business model” and the analysis of secondary information is conducted by synthesizing the existing literature. Consequently, a meta-synthesis type of literature review (O’Gorman and MacIntosh, 2015) through backward snowballing (Wohlin, 2014) was chosen as the research method. Meta-synthesis differs from the more popular systematic literature review by aiming to attain the next level of understanding and to develop conceptual understanding further. This is done by combining interpretive, eclectic, and hermenutic processes together (Tranfield et al., 2003). It aims to identify all important similarities and differencies in the data (Sandelowski et al., 1997). Integrating interpretive qualitative findings leads to the interpretive synthesis of data where the result is more than the sum of the parts (Sandelowski and Barroso, 2007). Hence, meta-synthesis can be considered as a suitable method to study such concepts as IoT and business model, since there is no consensus on definitions.

Backward snowballing is done by exploring publications that are referenced in the starting set of publications (Jalali and Wohlin, 2012). In the starting set, each publication is processed individually. First, all titles of the references are reviewed; the abstract is reviewed unless the title clearly excludes the reference. In cases where the abstract includes potential (referring to frameworks, business models or IoT), the full paper is read and analysed. After this, the references of the references are analysed in a similar manner. This drilling to the next level is continued until nothing new emerges, which in this case was until IoT was no longer included in the references. Google Scholar was selected as the search engine as the aspiration was to achieve as unbiased a starting set as possible and not to rely only on a single publisher or geographical area (Wohlin, 2014). While this study covers IoT – often covered in ICT publications – and business models – typically included in management literature – we had to conduct a search from the widest possible database. Google Scholar (GS) was selected as the search engine since its coverage is considered sufficiently wide (165 million documents according to Orduna-Malea et al., 2015, see also Brophy & Bawden, 2005). However, using GS's relevance search returns appropriate results (Hariri, 2011) thus the literature starting set was created by making two broad searches (IoT "business model" and IoT AND "business model"). Citations and patents were excluded, because the focus was on scientific research results. The top 20 most relevant publications according to Google Scholar from each search were included in the tentative starting set. GS ranks publications from full text weighted by publisher, writer, and recent citations to academic literature. Most of the publications were the same in both queries, resulting in 25 publications for the initial starting set. The initial starting set included publications from different publishers, geographical areas, years and authors, thus the diversity was considered sufficient (Wohlin, 2014). Two of the publications contained no references; hence they were excluded from the literature review. After snowballing backward to where IoT was included in the title or abstract of the source, 56 full text sources were identified and analysed. This resulted in the identification of 13 different IoT-related business model development frameworks for analysis.

## 4. Findings

While the IoT business models require interdisciplinary delineations, full usefulness can be achieved only after a convergence of three paradigms has been realized (Atzori et al., 2010), referring to middleware (that is, internet-oriented), sensors (NFC, RFID etc.; things-oriented) and knowledge (reasoning over data and semantic execution environments; semantics-oriented). These orientations lead to two types of IoT business models: the paid data model and the smart property model, both of which have operating and transaction modes (Zhang and Wen, 2017).

Hui (2014) stated, "Filling out well-known frameworks and streamlining established business models won't be enough." With this remark, he was referring to the cloud-based opportunities created by the IoT and the fundamental implications this has for business model innovation in every line of business. Westerlund et al. (2014) support this view. According to their concept, the major deficits in the existing component-based frameworks (such as the Business Model Canvas (Osterwalder and Pigneur, 2010)) neglect to describe the connections and dynamics between the different business model components but focus merely on the model architecture. Sun et al. (2012) support this view by stating that the component-based frameworks do not describe the linkages between cause and effect. Nevertheless, based on the reviewed publications, the Business Model Canvas (BMC) appears to be almost the standard procedure for defining a business model among practitioners.

Since the value proposition, value creation and value capture remain the key elements in any business model (Cheah and Wang, 2017; Sorescu, 2017), we next summarize the key findings of the literature review in terms of these elements. More details are provided in Appendix 2.

### 4.1. Value Proposition

Notably, Burmeister et al. (2016) emphasize that the value proposition focuses on Business to Business to Consumer (B2B2C), in other words, the complete value chain. Baden-Fuller et al. (2013) state that the value proposition is part of customer engagement. They see the customer as playing a major role in creating content, thus increasing the value of the offering in the form of product extensions. This co-creation of value indicates that current and future business models consist of different types of value and require a system perspective (Romero and Molina, 2011). Westerlund et al. (2014) use the term "value drivers" in their framework to describe the motivations of often diverse participants to enable an ecosystem to be formed. They see value drivers as a means of promoting value generation, innovation realization and creating a non-biased win-win ecosystem. Two papers approach business model innovation and value proposition design with the question "Why?" (Turber et al., 2014; Turber and Smiela, 2014). While this seems to be a very generic question, it offers a straightforward way to understand the meaning of a value proposition. The value proposition is created to answer the question why anyone should join an ecosystem – including the company offering some value, as the reward it receives as value capture is the answer to the question "Why?".

### 4.2. Value creation

A commonly acknowledged fact is that data are key ingredients of an IoT-enabled business model. According to Hartman et al. (2016), the five data-related key activities vital for what they call DDBMs (Data Driven Business Models) are the following: 1) selection of the data set, 2) processing and cleaning data, 3) data reduction (or reducing the number of variables by data transformation), 4) data mining to identify data patterns, and 5) data interpretation and visualization of the discovered patterns. Sun et al. (2012) underline the importance of considering all types of data – internal, external, structured and semi-structured – as well as all five types of data sources (operational, dark, commercial, social and public data). Thus, data plays an important role in IoT-enabled business; however, it is hardly the only principal element. Ju et al. (2016) include product development, partner management and platform integration in key activities, and Sun et al. (2012) transportation, among other things.

Westerlund et al. (2014) take an ecosystemic approach to value creation. From their perspective, key activities form a value exchange, which occurs in value networks where tangible and intangible values flow. The value exchange strives to explain "how the engine works," i.e. how different parts of the value network or ecosystem work together to transfer the resources to add value to its members. Turber et al. (2014) describe value creation with a single word: "What?" and they also answer the question. They proposed that the IoT architectural stack is the source of value creation and value capture among partners. The stack they refer to includes four layers: device, network, service and content layers, based on the research by Yoo et al. (2010). According to Turber et al. (2014), the device layer includes logical capabilities, such as an operating system, which connects the actual physical device to the other layers of the stack. Next, the network layer includes physical transportation and logical transmission (i.e. from transmitters to network standards). Finally, the service layer enables the creation and consumption of the content, which is stored in and shared from the content layer.

Value creation also requires different types of resources. Ju et al. (2016) define the key resources as including sensors, cloud services, an IoT-dedicated network and the capability for business analytics. They also emphasize that changing technologies change the business environment, and hence traditional business models are no longer adequate. Zhang and Wen (2017) propose that the key resources are entities, which in the case of a DAC (Distributed Autonomous Corporation) are the DAC itself and human beings. These resources provide the IoT commodity and are automatically able to search for and purchase IoT products according to certain rules. Westerlund et al. (2014) call key resources value nodes. These nodes include different actors and activities or even automated processes. They may be individuals, commercial or non-profit organizations or groups, networks of organizations, or even networks of networks. In short, the nodes are the entities that create value by being connected to each other and in IoT ecosystems, and there is significant heterogeneity in their nature. Turber et al. (2014) define key resources by asking "Where?" They use this question to spotlight the four-layer architecture – more specifically the layers of the device, connectivity, services and content, where each layer represents a source of opportunities for value creation.

Approximately half of the scholars in our sample emphasize the need to focus on ecosystem-level value creation and capture as well as grasping the integrated value driver (e.g. Ju et al., 2016; Turber and Smiela, 2014; Westerlund et al., 2014). The value chain linkages introduced by Baden-Fuller et al. (2013) highlight the linkages between identifying customer groups and sensing their needs and monetizing the value. These linkages may go far beyond traditional value chains, as IoT tends to have a multi-sided business model (Keskin and Kennedy, 2015).

When comparing the frameworks for instance with the Business Model Canvas type of approaches, it becomes clear that there is no cost structure element. This can be understood since IoT boosts business process modularization as it strives for high scalability and system performance (Balandin, Andreev & Koucheryavy, 2013, p. 18). However, it is essential to remember business viability: the full potential of IoT applications can be reached only if the cost of deploying the solution is low enough (Tarkoma and Ailisto, 2013).

None of the frameworks directly addressed the challenge of balancing openness and autonomy in business ecosystems. Moore wrote about collective destiny in ecosystems. His view was that a completely new kind of competitive advantage can be achieved within and through business ecosystems, leading eventually to profitability and financial success for the participants (Moore, 1998, p. 58).

### 4.3. Value capture

Many of the frameworks consider value capture to be almost a synonym for capturing money. Dijkman et al. (2015) and Kiel et al. (2017) use the term “revenue flows” – probably due to the fact that they were reviewing cases using the Business Model Canvas framework. At its simplest, value capture answers the question of how the value is monetized (in other words, where the money comes from and where it ends up). The movement of money is also referred to as the “revenue model” (Kiel et al., 2017), “transaction modes” (Zhang and Wen, 2017) and “monetization” (Baden-Fuller and Haefliger, 2013). All these include timing and the effectiveness of fundamental unit pricing. Baden-Fuller also notes that monetization can be leveraged by appropriate complementary assets. While many of the writers have taken a clear monetary perspective, Burmeister et al. (2016) have a wider view of the term. Value capture also includes the capturing of non-monetary value. Turber and Smiela (2014) approach revenue flows by asking “Why?”, but the same question could also include other values than monetary capture. Like the value proposition, revenue flow, value capture, or whatever one wants to call it, is also the reason behind why someone wants to join an ecosystem or participate in a value chain.

Another aspect of value proposition is that it can also help in identifying customers. Hartmann et al. (2016) prefer the term “customer segment” over “client segment”. For example, questions like “What communication channels should we use to engage our customers?” or “What type of customers do we have – multinational corporations, small or medium-sized companies, or individual consumers?” can help in this identification (Sun et al., 2012). These questions help to define the required tools and activities. Baden-Fuller et al. (2013) emphasize that in addition to identifying the customers and customer groups, it is equally important to understand whether the users are willing to pay for the value proposition or not – and if not, is there another group of customers that would be willing to pay for it? When identified correctly, some customer groups can acquire subsidized goods and services and the whole ecosystem gains value from the network effect (Keskin et al., 2016). As Gassmann et al. (2014) point out: failure to understand who the customers are is a key factor in failing ventures.

## 5. Discussion and conclusions

We agree with Smedlund et al. (2018) who argue that IoT-enabled business ecosystems are complex and adaptive systems founded on data and connectivity. Therefore, they require diverse strategies. The IoT creates new business model opportunities, but especially, it creates new rules for business, as it requires business models to acknowledge the different business culture in ecosystems. Ecosystems survive when all members find a sufficient reason to participate and contribute.

It can be stated that business ecosystems should be examples of purposeful multidimensional systems that are value-guided and whose participants coexist, interact and form complementary relationships with each other (Gharajedaghi and Jamshid, 2011).

Seven of the 13 identified frameworks emphasize the importance of the ecosystemic approach. However, most of the frameworks for IoT business model creation are based on BMC-type frameworks, which do not describe the linkages or causality in the parts of the system although planning should focus on the ecosystem level. Even the frameworks that do emphasize the ecosystem approach tend to address the phenomena in an overly simplified manner, lacking a clear model or instructions on how to reach the optimal solution. The remaining six frameworks omit the ecosystem aspect, apart from Dijkman et al. (2015), who mention the importance of considering the whole ecosystem in a single sentence in their paper.

Oftentimes, the goal seems to have been to develop models where the pricing offers a low entry barrier and the models are otherwise attractive. In a shared value model, industry- or domain-specific partners usually co-create value. This is used typically in cases where members of the ecosystem can offer some kind of solution development to customers (Chen et al., 2011).

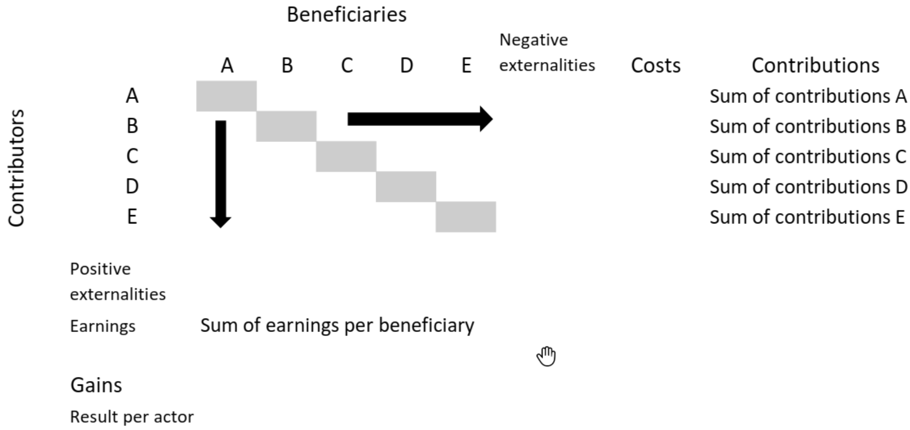
Chan (2015) has created a framework on top of the IoT architecture stack. He proposes that the business model is designed around the "IoT strategy category and value chain". Table 1 illustrates the structure. Each of the members of the value chain is evaluated separately. For example, in the input column all data input sources are itemized – be it a device or a mobile phone, for example. Likewise, in the benefits column, all monetary and non-monetary values are listed (Chan, 2015).

**Table 1. IoT Business model framework adapted from Chan** (2015, p. 562)**.**

| Company | Collaborator | Inputs | Network | Service / processing / packaging | Content / information product | Benefits | Strategy | Tactics |
|---|---|---|---|---|---|---|---|---|
| | A1 | | | | | | | |
| Company A | A2 | | | | | | | |
| | A3 | | | | | | | |
| | B1 | | | | | | | |
| Company B | B2 | | | | | | | |

Chan has chosen a structural model where the forms (or even ecosystems) of business procedures need to be described and implemented in an optimal way (Glova et al., 2014). When Chan's model is compared to the EBM model of Bahari et al. (2015) illustrated in Table 2, it is clear that the two models have prominent similarities. Nonetheless, they answer different questions.

**Table 2: Simplified illustration of the EBM model** (Bahari et al., 2015, p. 13)**.**




While Chan's model assumes that benefit is created linearly in one direction, the EBM model acknowledges multi-directional value creation and value capture prospects. On the other hand, the EBM model measures value in money and Chan's model also recognizes other types of value exchange.

This study has limitations. The decision to choose Google Scholar as the main and sole source of literature has some limitations (see e.g. Haddaway et al., 2015). Secondly, snowball sampling has biases that are hard to assess due to the inherent randomness of the selection. Naturally, the sample used could have been larger; however, based on our search from these databases, the sample is extensive. Thirdly, the analysis process was mainly done by one researcher, thus there may be biases in reading and analysing the data set. Finally, the conceptual blurriness in IoT literature makes it difficult to clearly define the boundaries of the literature and therefore define the boundaries of this contribution. Nevertheless, we hope that this paper adequately describes the details of the research process, thus ensuring future replicability.

However, as this literature review demonstrates, the IoT as such does not necessarily require new frameworks for business model creation. The ecosystemic nature of IoT compels participants to use models other than traditional single company focused models. This is bound to influence the business model development process to become more integrative, interrelational and probably also complex. A single company should no longer create its business model in a void. It should identify the ecosystem members and co-create an ecosystem-level model, where all members gain more value than the effort they spend in contributing value to others. Interrelating with different parties also facilitates the emergence of an ecosystem. We consider the development of business model frameworks for the ecosystem context to be of the utmost importance and propose that this be covered in future studies. We believe creating these models will require system philosophical thinking to ensure that the model is comprehensive but concise.

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# APPENDIX 1 Comparison of business model frameworks

| Writer(s) | Title | Year | Value proposition | Value Creation | Value Capture | Ecosystemic | Notes |
|---|---|---|---|---|---|---|---|
| Sun, Yan, Lu, Bie, Thomas | A holistic approach to visualizing business models for the internet of things | 2012 | Aspirations (Why): Value proposition, 6R and timely feedback | Needs (What) include channels, customer relationships, customer segments Design (How) Key partners, Key resources, Key activities, costs | Aspirations (Why):Revenue, cost | No | DNA-model, missing BMs might be reason to slow progress. The A or Aspirations- block deals with results and responds to the question of "Why?" The A-block which deals with offer or value consists of three elements: Value Proposition, Revenue and Cost. Kuvaa kuten BMC, mutta syy-seuraus-suhteita korosten. |
| Westerlund, Leminen, Rajahonka | Designing business models for the internet of things | 2014 | Value drivers | Value nodes, value exchange | Value extract | Yes | Value drivers describe the motivation to join the ecosystem, Value nodes describe the actors and activities (why activities?),Value exchange refers to actions to create and capture value. Value extract shows which of the created values can be monetized.<br>Lähestyy oletuksella IoT on ekosysteemi (vai onko IoT ekosysteemin mahdollistaja - luulisin näin) "An ecosystem busi- ness model is a business model composed of value pillars anchored in ecosystems and fo- cuses on both the firm's method of creating and capturing value as well as any part of the ecosystem's method of creating and capturing |
| Turber, Vom Brocke, Gassmann | Designing business models in the era of internet of things | 2014 | Why | Who, Where | | Yes | Who refers to all participants of the ecosystem. Where describes the four-layered modular architecture (device, connectivity, services and contents). Why describes the reason to participate for each collaborator. Let that be monetary of or non-monetary |
| Turber, Smiela | A business model type for the internet of things | 2014 | Why | Who, What | | Yes | Dimension 1 "WHO" encompasses all participants involved in the ecosystem. This includes partners, suppliers and customers alike, which we refer to as "collaborators" in a wider sense. Rational: 1) a firms external ecosystem is "operant resource" (Vargo & Lusch, 2007), we therefore suggest to explicate all collaborators 2) Value is co-created by all members of the ecosystem, and so by customers. A differentiation between partners and customers is redundant in this context. Dimension 2 "WHAT" incorporates the four-layered architecture of digitized products (2.1), with each layer as contributing source of value creation and capturing among collaboration partners. Rational: We strongly suggest that these four layers need to be made explicit in an IoT business model as its specifics and value networks trace back to this architecture. Dimension 3 "WHY" outlines each collaborator's "reason" to participate in the ecosystem and meant to outline the benefits of different nature according to (Lusch et al., 2007). Rational: 1) With the external ecosystem as operant resource, we suggest to apply Adner's "the wide lens" and consider all ecosystem partners surplus of participation and the ecosystem's overall stability 2) Benefits can be monetary, yet, through collaboration, non-monetary incentives come into play, [illegible] |
| Dijkman, Sprenkels, Peeters | Business models for the Internet of things | 2015 | Value proposition | Key partners, Key activities, Key resources, Customer relationships, Channels, Customer segments, Cost structure | Revenue streams | No, but mentions it in the discussion | Based on Osterwalder BMC, does not emphasize non-monetary value |
| Ju, Kim, Ahn | Prototyping business models for IoT service | 2016 | Value proposition | Key partners, Key resources, Key activities | | Yes | Based on Osterwalder BMC but misses the capture. |
| Burmeister, Lüttgens, Piller | Business Model Innovation for **Industrie 4.0**: Why the "Industrial Internet" Mandates a New Perspective on Innovation | 2016 | Value proposition | Value creation | Value capture | No | Value proposition focus on B2B2C, comprehensive service business, Value creation includes value chain integration and connected information flows. Value capture appropriates from digital structures and supports price / cost variabilization<br>"The value proposition describes the drivers of customer value as well as the unique features of the firm's offering. The value creation layer includes the re- sources, capabilities and processes required to deliver the offering – starting from partner/ supplier relationships to sales channels. Value capture comprises the underlying cost struc- ture and revenue formula, which decide on profitability and economic sustainability" |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Montanus | Business models for **Industry 4.0** - Developing a Framework to Determine and Assess Impacts on Business Models in the Dutch Oil and Gas Industry | 2016 | Value proposition | Value creation | Value capture | Yes | |
| Zhang, Wen | The IoT electric business model: using blockchain technology for the internet of things | 2017 | | | | No | the IoT E-business model from entity, commodity and transaction process, in which we study on the 4 stages of the traditional E-business (i.e. they are Pre-transaction preparation stage, Negotiation stage, Contract signing stage and Contract fulfillment stage.) |
| Kiel, Arnold, Voigt | The influence of **the Industrial Internet of Things** on business models of established manufacturing companies – A business level perspective | 2017 | Value proposition | Key partners, Key activities, Key resources, Customer relationships, Channels, Customer segments, Cost structure | Revenue streams | No | Based on Osterwalder BMC, does not emphasize non-monetary value |
| Hartmann, Zaki, Feldman, Neely | Capturing value from big data – a taxonomy of data-driven business models used by start-up firms | 2016 | Value proposition | Key resources, Key activities, Customer segment, cost structure | Revenue model | No | 6 dimensions, 35 variables and a taxonomy |
| Bouwman, De Vos, Haaker | Mobile service innovation and business models | 2008 | Value proposition | Service domain, Organization domain, technology domain | Finance domain | No | STOF-model |
| Chan | Internet of things business models | 2015 | Benefits | Company, collaborator, inputs, network, service/processing/packaging, content/Information product, strategy, tactic | | Yes | |

# APPENDIX 2 Comparison of business models

| Definition | Emphasis | Scope | Authors&Year | Title |
|---|---|---|---|---|
| An architecture for the product, service and information flows, including a description of the various business actors and their roles and a description of the potential benefits for the various business actors and a description of the sources of revenues. | value proposition, value capture | Network centric / ecosystemic | Timmers, 1998 | Business Models for Electronic Markets |
| A business model decipcts the content, structure and governance of transactions designed so as to create value through the exploitation of business oppportunities | Value creation | Company centric | Amit & Zott, 2001, p.511 | Value creation in e-business |
| The method by which a firm builds and uses its resources to offer its customers better value than its competitors and to make money doing so. It details how a firm makes money now and how it plans to do so in the long term. The model is what enables a firm to have a sustainable competitive advantage, to perform better than its rivals in the long term. A business model can be conceptualized as a system that is made up of components, linkages between the components, and dynamics. | Value proposition, value capture | Company centric | Afuah & Tucci, 2001, p. 3 | Internet Business Models and Strategies |
| A description of the roles and relationships among a firm's consumers, customers, allies and suppliers that identifies the major flows of product, information, and money, and the major benefits to participants | Value creation, value capture | Value network /ecosystemic | Weil & Vitale, 2001, p.34 | Place to Space: Migrating to eBusiness Models |
| A construct that mediates the value creation process. It translates between the technical and the social domains, selecting and filtering technologies, packaging them into particular configurations to be offered to the market | Value creation, value propositionAct of innovation, architecture of revenue | Company centric but includes value network positioning | Chesbrough & Rosenbloom, 2002 | The role of the business model in capturing value from innovation : evidence from Xerox Corporation ' s technology spin-off companies |
| A good business model answers Peter Drucker's age-old questions: Who is the customer? And what does the customer value? It also answers the fundamental questions every manager must ask: How do we make money in this business? What is the underlying economic logic that explains how we can deliver value to customers at an appropriate cost? includes all the activities associated with making and selling something | Iterative, value proposition, value capture, value delivery | company centric | Magretta, 2002, p.4 | Why Business Models Matter |
| A business model elucidates how an organization is llinked to external stakeholders, and how it engages in economic exchanges with them too create value for all exchange partners | Company centric, value creation and value exchange | company centric | Zott & Amit, 2007, p.181 | Business Model Design and the Performance of Entrepreneurial Firms |
| The business model is like a blueprint for a strategy to be implemented through organizational structures, processes and systems | Strategy implementation tool | Value network acknowledged but company centric | Osterwalder & Pigneur, 2010, p.15 | Business model generation : a handbook for visionaries, game changers, and challengers |
| A business model articulates the logic, the data, and other evidence that support a value proposition for the customer, and a viable structure of revenues and costs for the enterprise delivering that value | Value proposition, value capture | Company centric | Teece, 2010, p. 179 | Business Models, Business Strategy and Innovation |
| Business Model refers to the logic of the firm, the way it operates and how it creates value for its stakeholders. Strategy refers to the choice of business model through which the firm will compete in the marketplace | Value creation, value capture | company centric | Casadesus-Masanell & Ricart, 2010, p.196 | From strategy to business models and onto tactics |
| Articulates the value proposition, identifies a market segment and specify the revenue generation mechanism, defines the structure of the value chain required to create and distribute the offering and complementary assets needed to support position in the chain, details the revenue mechanism(s) by which the firm will be paid for the offering, estimates the cost structure and profit potential, describes the position of the firm within the value network linking suppliers and customers, formulates the competitive strategy by which the innovating firm will gain and hold advantage over rivals | Value proposition, value capture | Supply chain acknowledged but company centric | Chesbrough, 2010, p. 355 | Business model innovation: Opportunities and barriers |
| An abstraction of the complexity of a company by reducing it to its core elements and their interrelations | | Value network / ecosystemic | Bucherer & Uckelmann, 2011, p. 256 | Business Models for the Internet of Things |
| A business model defines who your customers are, what you are selling, how you produce your offering, and why your business is proftable | Value proposition | Company centric | Gassman et al, 2014, p. 7 | The Business Model Navigator:That Will Revolutionise Your Business |

# PUBLICATION III

**Co-creation of ecosystem-level value propositions**

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# Co-creation of Ecosystem-level Value Propositions

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**Abstract:** A joint value proposition has been claimed to be a fundamental part of ecosystems' success. The propositions have been either end-customer or ecosystem leader-centric and focusing on functional and financial value. However, according to social exchange theory, the ecosystem actors are likely to expect to be equally rewarded from their value creation efforts and thus the value propositions should be evaluated on ecosystem-level. Secondly, the value denotes much more than just functional and financial value. This study proposes that also emotional, and social value propositions should be included when designing an ecosystem. The study was conducted in two phases. First, the ecosystem value proposition literature was reviewed to define the required value dimensions. After that, the dimensions were applied in a multiple case study. The results show that emotional, epistemic, and social dimensions, as well as ecosystem-level value propositions, require more scholarly attention.

**Keywords:** Value co-creation; Value proposition; Ecosystem; Value types; Ecosystem-level

## 1 Introduction

Ecosystem as a concept has gained continuously increasing attention among both scholars and practitioners in the fields of technology, innovation, and business. Based on the public discussion, the ecosystems have (incorrectly) been seen as "silver bullets" that solve all challenges. Regardless, the successful stories remain scarce. One of the reasons can be that currently, the literature focuses on the joint ecosystem value propositions from either the end-customer or ecosystem leader perspective. The value capture possibilities for all individual actors on the ecosystem level have remained under-explored. Only a few articles have studied the ecosystems value proposition from an ecosystem-wide perspective considering the value capture possibilities of all ecosystem actors

However, when combining the current ecosystem theories with the social exchange theory (SET), it can be proposed that value propositions should be evaluated at the ecosystemic level to guarantee appropriate propositions to all ecosystem actors – current and future ones. The actors should find the distribution of value equitable and the value each captures sufficient compared to the effort required in value creation.

To create a holistic understanding of the ecosystem-level value propositions, an increased understanding of value proposition dimensions is required. The current literature focuses mainly on functional and financial value propositions (see e.g. (Keränen, 2017)). However, the Service-Dominant Logic proposes that the exchanged value does not necessarily require a financial transaction but rather an exchange of user-experienced value not only dyadic but also multilaterally (Thomas et al., 2014).

This study presents a classification of ecosystem-level value proposition dimensions. These dimensions can be either dyadic, multilateral, or both. The identified dimensions enable ecosystem actors to evaluate the comprehensiveness of the value proposition of the ecosystem and thus, improve its probabilities to become attractive and successful. A value proposition can, at its best, fit many dimensions. In those cases, the proposition may have more impact than those that affect through only one dimension. This supports the importance of co-creation and other joint activities within an ecosystem as reciprocity supports building trust and thus, leads to social stability.

The study is based on a literature review and a multiple-case study. First, it identifies how value propositions have recently been described in academic literature. The propositions are classified by value dimensions established in value theories. The latter part of the study compares the theoretical findings of the value propositions to eight case ecosystems. The study shows how these dimensions were earlier communicated in the case ecosystems and how the situation has evolved during the past few years.

This study contributes to the ecosystem theory building by presenting the variety of value dimensions required to be considered when designing an ecosystem. It also opens new perspectives to the practitioners in designing a successful ecosystem.

## 2 Previous works and developing the research framework

Ecosystems are complex systems open to their environments, thus it is difficult to predict, or even understand, how they function (Skyttner, 2006; Tsujimoto et al., 2018). An ecosystem consists of multilateral and mutually consistent actors (Adner, 2017), who are only loosely connected (Iansiti and Levien, 2004), thus ecosystems' structure is flexible (Hein et al., 2019) and can therefore be constantly changing.

The core of an ecosystem is the co-created final value proposition (Den Ouden, 2012; Polizzotto and Molella, 2019). The value proposition in ecosystems consists of super-modular, and non-generic, complementaries offered by the actors. (Jacobides et al., 2018). While co-creating the value, the actors co-operate and collaborate, but also compete within the ecosystem (Bogers et al., 2019) as business models of the actors may overlap (Langley et al., 2021). This may cause friction in value co-creation.

While creating value together, actors of an ecosystem should aim to maximize the value for the whole ecosystem, not just maximize the value capture of the leader firm (Li et al., 2019). This requires coordination and alignment of the roles and capabilities of all actors, and a mutually shared vision (Jacobides et al., 2018; Moore, 1996, p. 53). Maximizing the value capture for all actors also means that understanding the real-time and future needs of the actors is an ecosystem-wide challenge to be solved to be able to innovate co-created unique and sustainable value propositions for lucrative business models (Matthyssens, 2019; See-To and Ho, 2014). Value co-creation can be considered to be a collaborative process between ecosystem actors, facilitated by technology where also social changes are required before the society accepts it (Mejtoft, 2011).

To clarify the complexity of value co-creation, Bharti et al. (2015) created a conceptual framework of the "pillars of value co-creation" by synthesizing academic literature. The framework includes five pillars, which all have to be in place for value co-creation to happen. These pillars are interactive environment, resources, co-production, perceived benefits, and management structure. The perceived benefits include e.g. customer learning, expected benefits, and value. The benefits can be personal or social integrative, learning or emotional, but the major motivators to participate in value co-creation are emotional and utilitarian values ie. to the ecosystem actors, value denotes much more than just pure monetary value.

According to Service-Dominant Logic (SD-L) "The customer is always a co-creator of value" (Vargo et al., 2008) as value stems from use rather than exchange (ibid). This means that the customers' expectations and previous experiences should be considered when designing the value proposition. This is likely to be difficult as both 'value' and 'expectation' as concepts are ambiguous, especially, when value can include other than monetary transactions, and simultaneously, the value exchange can be multilateral (Autio and Thomas, 2020).

There are several ways to classify different types of value. For one, types of value can be divided into two types: utilitarian and experiential hedonic value (Hirschman and Holbrook, 1982). On the other hand, Sheth et al. (1991) considered the value consisting of five different types: conditional, emotional, epistemic, functional, and social value. The conditional value means that the customer perception of the value depends on the circumstances or situation (e.g. seasonal products or services). The emotional value includes utilities that cause feelings like achievement or trust. The epistemic value consists of a sense of novelty and knowledge-related aspects like data, information, and learning. For example, collaborative filtering can offer epistemic value.

**Table 1** Examples of value propositions per value dimension

| Value Dimension | Examples |
|---|---|
| Emotional | Risk reduction, trust, stability, sensory appeal, loyalty, motivation, wellness, nostalgia, aesthetics, fun/entertainment, self-actualization, badge value, cultural fit (e.g. ethics), responsiveness, achievement, attention, fame trust |
| Epistemic | Novelty, data, information, knowledge, transparency, learning, insight, innovativeness, interesting |
| Financial | Reduce cost, make money, increase brand value, gain investors |
| Functional | Time savings, customization, availability, simplicity, usability, convenience (reduce effort, avoid the hassle), quality, integration, security (e.g. data security), accessibility, scalability, meeting specifications, flexibility, durability |
| Social | Group identification, network expansion, social responsibility, reference, interaction, sense of belonging, engagement, status, reputation |

Functional values include perceptions of the product or service, which affect e.g. usability, quality, durability, scalability, or availability of a service. Social value aspects like group identification, network expansion, reputation, and social responsibility (Almquist et al., 2018, 2016; Parker et al., 2017; Sheth et al., 1991). Pura (2005) adds one more type: financial value including making money, saving costs, increase in brand value, etc. These different dimensions of values affect behavioural intentions and commitment to those. It is very difficult, if not impossible, to explicitly allocate different value propositions to the dimensions. Table 1 summarizes some examples used in the above-mentioned literature to elaborate the variety within each dimension.

A traditional way to analyse networked business has been to use Transaction cost economics theory (TCE), which focuses on the costs of making an economic exchange. However, that doesn't cover the complexity of ecosystems (Jacobides et al., 2018), as TCE assumes the exchange is made based on a contract (Williamson, 1979). The dynamic and coevolving nature of ecosystems would benefit more from using the Social exchange theory (SET) instead of TCE in analysing the interdependences and co-creation of value (Benitez et al., 2020). SET was introduced in 1958 to understand the relationship of actors in exchanging goods – let those be material or non-material (Homans, 1958). The core of the theory is, as Homans presented it, that ”persons that give much to others try to get much from them, and persons that get much from others are under pressure to give much to them. This process of influence tends to work out at equilibrium to a balance in the exchanges.” (Homans, 1958, p. 606) This means that the behaviour of actors changes based on the actions and expectations of others. SET also emphasizes the importance of non-material goods. Those can be e.g. services but also rewards like prestige or admiration. One of Homans's other findings was that the exchange propositions can lead to a generation of a group structure. Reciprocal relationships evolve through continuous evaluations and SET can be used in explaining trust, satisfaction and loyalty builds between the actors (Jeong and Oh, 2017), hence SET helps in explaining the motivations of value co-creation.

## 3 Data gathering and analysis process

The research was designed to have two phases; It began with a literature review to be complemented with a multiple case study. The literature review was started with a search string (ecosystem AND "value proposition") of title, abstract, and keywords in Scopus, which resulted in 199 articles between 1987 and January 2021. Figure 1 illustrates the yearly frequency of publications.

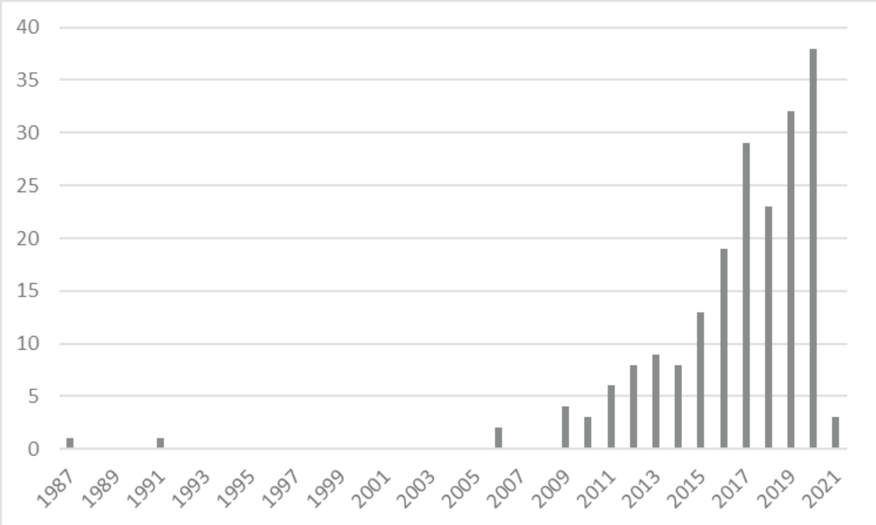


**Figure 1** Frequency of publications

Full-text reviews were conducted on 60 most recent, accessible articles. The subject has received global interest since the first author affiliations are scattered to 26 different countries in six continents (see Table 2). Most of the authors are, however, from Northern America and Western Europe.

**Table 2** Country of the Affiliation of the First Author

| Country | # of Pubs | Country | # of Pubs |
|---|---|---|---|
| Germany | 9 | Netherlands | 2 |
| USA | 8 | Spain | 2 |
| Finland | 5 | Austria | 1 |
| Switzerland | 3 | China | 1 |
| UK | 3 | Czech Republic | 1 |
| Australia | 2 | Greece | 1 |
| Belgium | 2 | Italy | 1 |
| Brazil | 2 | Portugal | 1 |
| Canada | 2 | Russia | 1 |
| France | 2 | Serbia | 1 |
| India | 2 | Singapore | 1 |
| Ireland | 2 | South Africa | 1 |
| Malaysia | 2 | Trinidad and Tobaco | 1 |
| | | (blank) | 1 |

The results have been scattered also widely in different conferences and journals. Fourteen articles were published in conference proceedings and 46 were journal articles. Table 3 shows the top ten publication outlets, the remaining 40 had one paper per outlet. Since the results have been published in diverse outlets, it can be concluded that the co-creation of value in ecosystem-context has not yet established a research domain.

**Table 3 Top 10 publication outlets**

| Publication | Number of Articles |
| --- | --- |
| Industrial Marketing Management | 2 |
| Managing Technology for Inclusive and Sustainable Growth | 2 |
| Lecture Notes in Business Information Processing | 2 |
| ACM International Conference Proceeding Series | 2 |
| Advances in Intelligent Systems and Computing | 2 |
| Long Range Planning | 2 |
| IEEE International Conference on Industrial Engineering and Engineering Management | 2 |
| Marketing Theory | 2 |
| Sustainability | 2 |
| Journal of Cleaner Production | 2 |
| Other | 40 |

In 58/60 articles, at least one description for value proposition was identified. The identified descriptions were classified into the six dimensions of our framework as follows: financial (n=42), functional (n=42), epistemic (n=37), social (n=30), and emotional (n=29) value dimensions. Conditional value in an ecosystem context was not mentioned.

The second part of the study was conducted as a multiple case study. We selected eight different ecosystems, each led by a Finnish company, to be interviewed. The cases are elaborated on in Table 4. The representative from the focal company in each ecosystem was interviewed in 2016. They were asked to describe the value propositions of their ecosystem.

**Table 4** Description of cases, interviewees, and exemplary value propositions

| Case ID | Industry | Interviewee position | Examples of a Value proposition |
|---|---|---|---|
| Alpha | Industry automation | Sales Manager | Efficiency, simulation, part library, institutional co-operation |
| Bravo | Cargo handling | VP, Service Business Development | Asset optimization, maintenance management, safety |
| Charlie | Metal industry | Software Product Manager and Director, Software Customer Operations | Productivity, qualification management, quality, data, instructions |
| Delta | Cargo handling | Product Manager, Remote Service | Efficiency improvement, continuous revenue, risk mitigation |
| Echo | Health industry | Product Manager and Vice President, Digital Imaging and Applications | Efficiency, multi-channel, part libraries, information |
| Foxtrot | Forestry | Technology and R&D Manager | Cost reduction, reporting |
| Golf | Health industry | Head of Strategy and Business Development | Ease of use, peer-to-peer co-operation |
| Hotel | Cargo handling | VP, Service Business Development | Single interface, data, maintenance management |

In January 2021, the value propositions of the same ecosystems were reviewed as a desktop search. The identified propositions were compared against the original propositions. Further, we evaluated the value propositions against theoretical dimensions in the framework. Table 5 elaborates on how the value propositions have been developing. A short line (-) means no proposition was offered in that particular dimension. One spot indicates that a particular dimension has been identified from the value proposition (e.g. the case Alpha, offered simulation, and APIs as a functional value in 2016). If the number of spots has increased, there has been a progression in this particular dimension in value proposition between 2016 and 2021 (e.g. the case Alpha offers also virtual commissioning, augmented reality, and virtual reality as functional values in 2021 or, in emotional value, when the case Alpha has not offered anything (-) in 2016, but in 2021 offers risk reduction (one spot)). If the number of spots has remained the same, the offer is the same.

**Table 5** Progress of Value Dimensions in each Case from 2016 to 2021

| Case | Financial | | Functional | | Emotional | | Epistemic | | Social | |
|---|---|---|---|---|---|---|---|---|---|---|
| Year | 2016 | 2021 | 2016 | 2021 | 2016 | 2021 | 2016 | 2021 | 2016 | 2021 |
| **Alpha** | ● | ● ● | ● | ● ● | - | ● | ● | ● | ● | ● ● |
| **Bravo** | ● | ● | ● | ● | ● | ● | - | - | ● | ● |
| **Charlie** | ● | ● ● | ● | ● ● | - | - | ● | ● ● | - | ● |
| **Delta** | ● | ● ● | ● | ● ● | - | ● | ● | ● ● | ● | ● |
| **Echo** | ● | ● | ● | ● ● | - | ● | ● | ● ● | ● | ● ● |
| **Foxtrot** | ● | ● ● | ● | ● ● | - | - | ● | ● | - | - |
| **Hotel** | ● | ● | ● | ● ● | ● | ● | ● | ● ● | - | - |

Case Golf is not included in the analysis, as it has decided to terminate its platform and continue with a single app to support the value creation to the users of its products.

## 4 Findings and discussion

The literature analysis supports the assumption that social and emotional value has had less attention in ecosystem literature. Typical financial values are cost savings, increased revenue or market share, constant revenue flow, increased profit, and correctly timed investments. Functional value is often described as convenience, scalability, access to resources (like technology or assets), individualization, improved maintenance scheduling, speed, and availability. The epistemic value includes e.g. data, information, knowledge, customer insight, novelty, and leveraging creativity and innovation. Social values include two streams 1) the social value as described earlier e.g. interaction, collaboration, common identity, and inclusion, but also 2) the societal values, which include e.g. community well-being, sustainability, and reduction of the digital divide. The latter stream of social value is emphasized typically in sustainability and circular economy-related articles. Emotional values identified from the literature include e.g. trust, safety, risk mitigation, well-being, interdependency, and reputation. Both trust and risk mitigation were mentioned in 11 articles. Considering that trust is a prerequisite of value co-creation, it has had relatively little attention as part of offering value to the ecosystem members.

In certain situations, an activity can offer multiple types of value. For example, co-design can offer social value (as experiencing belonging to a group) as well as epistemic value (creating something new) or even emotional value through being valued as a group member. Also, crowd-related activities, like crowdlending or crowdfunding, can offer both social value and financial value. The social aspects of value co-creation were not mentioned in the reviewed literature. However, when assigning the value propositions to classes, all values starting with "co-" were classified as social values. Had this not been done, the number of social value propositions would have reduced to 26/60.

Only 22/60 articles mention ecosystem-level value proposition and from those only five (typically a platform ecosystem-related article) recognize the importance of offering value to all ecosystem actors. In most cases, the focus is only on the joint value proposition towards the ecosystems' customer. Some articles emphasized the value created to the ecosystems' leader. According to the social exchange theory (SET), the actors who give much also expect to be much rewarded and actors capturing much value are expected to invest more into the value creation (Homans, 1958). The current literature on ecosystem value proposition fails to include the propositions to ecosystems' actors, hence explaining how to motivate them to invest in value co-creation.

When the value propositions in each case ecosystem were assessed by the above-mentioned dimensions, the order of prevalence is the same as found in the literature review. When a leader company communicates the ecosystem value proposition, all seven companies include financial and functional value. Four out of seven are describing the financial value in more detail now than in 2016. Also, the companies have long lists of different financial values from optimization, cost reduction, efficiency improvement, revenue growth to free service. In functional value, the increase is even bigger as six out of seven leader companies are elaborating the functional value more explicitly. All of the ecosystems have a long list of functionalities described in detail. The functional values include e.g. possibilities to make simulations, having a single interface, improve maintenance management, APIs, part libraries, and ease of use. In the past few years also mobile access and augmented and virtual reality have become part of value propositions.

The epistemic value was communicated in six of the ecosystems. Also, in this dimension, the value is currently described in a more versatile manner. Data is in a key role as is information and insight, too. The latest improvements include KPI reporting, prediction, guidance, and data aggregation. Only the case Bravo seems to have missed the communication of epistemic value. This was unexpected as Bravo utilizes IoT in their ecosystem and collecting and utilizing data is what IoT is designed to do.

Also, social value descriptions have increased, though the start level was lower (four cases) and they have increased less (three cases). Only one case mentions anything about co-creation of value, co-design, or other “co-“-terms. It makes co-operation with educational institutions to lock in new users already before graduation. Social value is mainly seen as brand value, openness, and transparency. In addition to those, peer-to-peer information sharing, and openness are seen as offerings of social value.

The biggest relative change has happened in emotional value. While in 2016, only two of the cases described any kind of emotional value, in 2021 the number has multiplied to five cases. However, the cases emphasize mainly only safety and risk mitigation. None of them mentions anything about trust or trustworthiness.

Conditional value was not included in value proposition theories in an ecosystem context, nor do the cases offer any conditional value. Therefore, there seems to be no reason to include a conditional value dimension in designing an ecosystem-level value proposition.

## 5 Conclusion and Further Research

There is a deficit of scholarly knowledge in understanding value proposition co-creation at the ecosystem level. To enhance ecosystem business, more profound knowledge about the value propositions and their distribution principles within ecosystems is required. This study proposes a classification of value proposition dimensions in business ecosystems. In an ecosystem context, dividing the propositions into five dimensions of value is appropriate (leaving conditional value out). These five dimensions are emotional, epistemic, financial, functional, and social value.

More scholarly attention should be devoted to social and emotional value propositions. Based on the results, we claim that ecosystem-level value propositions are defined too narrowly. The companies leading the ecosystems are focusing mostly on functional and financial value propositions. Putting more emphasis on epistemic, social, and especially emotional value propositions may help the ecosystem to thrive. Especially now, when the data-based business models are becoming more popular, it is important to understand, which kinds of epistemic value the ecosystem actors want and what they can offer. Social expectations are important as value co-creation can be done only through collaboration – co-design and co-innovation being good examples of necessary collaboration. Trust is an important emotional value. See-To and Ho (2014, p. 186) claim "trust is a prerequisite of value co-creation", hence ecosystems should put more emphasis on designing and communicating emotional value.

Value co-creation is a complex process. Emotional and functional values are the main motivators for the actors to join co-creation. However, emotional value has not attained scholarly interest in ecosystem-context. This may be one of the reasons many ecosystems fail to be able to sustain their competitive edge. Also, considering the commonly agreed notion of the joint faith and the importance of co-creation of value, the "co-" and "crowd"-terms are relatively scarce in the reviewed literature. Thus, we propose the social dimension of value co-creation, together with the emotional dimension, to be studied to elaborate their role in developing a sustainable and viable ecosystem.

While understanding the dimensions make a foundation, the practitioners would benefit from a framework supporting the designing of a co-created value proposition. The framework should scrutinize the value creation and capture the possibilities and potential of all ecosystem members.

For academics, this opens new avenues of research in developing an understanding of the effects of value co-creation and distribution of value within ecosystems. The value dimensions should be tested with more cases to verify e.g. the absence of conditional value. However, this study strove to denote the importance of versatile perspective in creating an understanding of the motivational factors of value co-creation.

The study could have benefitted from a more comprehensive literature review and a more in-depth analysis of the current status of the case ecosystems. However, to open a discussion on ecosystem-level value proposition evaluation the study meets the expectations of comprehensiveness.

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# PUBLICATION IV

**Conceptual Model of the Ecosystem Value Balance**

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# Conceptual Model of the Ecosystem Value Balance

**Abstract.** Despite the growing interest in ecosystems, research on ecosystem-level value distribution is still scant. Value creation and different value dimensions have a relatively wide knowledge base in the context of dyadic relationships and networks. However, the existing ecosystem literature does not recognize these dimensions at the ecosystem level but rather focuses merely on financial, and functional value. This article proposes a preliminary framework for assessing the value at the ecosystem level. The framework denotes not only the financial and functional value but also social, emotional, and epistemic dimensions of value. It illustrates the balance between required sacrifices in creating value and benefits gained in capturing value. The framework is built as a constructive process. The construction includes a theoretically founded iterative design phase followed by the first empirical test with one case ecosystem. The findings indicate the value balance exists in a stable and established ecosystem. The article also proposes the next steps to develop the framework further. These include e.g. testing the framework with ecosystems, which are in more volatile phases (i.e pioneering or renewal phase), creating a measurement regime for evaluating the importance of each value, and linking ecosystem value balance to ecosystem health.

**Keywords:** Ecosystem, Value, Value Co-creation, Value Balance, Ecosystem Health

## 1 Introduction

Ecosystems consist of interacting organizations sharing a common faith but are not fully hierarchically controlled [1]. The core of an ecosystem is the final value proposition, which can be co-created when all required complementary components are in place [2, 3]. During the past few years, scholars have been increasingly interested in value co-creation. However, this does not guarantee higher appropriation by the ecosystem members [4]. Value is defined by the customer [5], i.e. the members of the ecosystem the value is offered to. The way customer perceives the value offering depends on their needs, preferences, funds and even the situation they intend to use it [6].

Ecosystems, like any other complex systems, are difficult to design as they are open to the effects of their environments, and hence their behavior is difficult to understand and predict [7, 8]. The flows of resources, nor the value proposition, do not necessarily follow the intended design of the system when companies and people are interconnected, loosely controlled, and the business models of the companies may overlap [9]. During the ecosystem era, the competitive advantage relies on when and how to build ecosystems and how to keep the competitive edge through continuous improvement in the proposed value [10].

The ecosystems co-evolve and based on the perceived value, members may join or leave it [2]. For an ecosystem to be viable and sustainable its' members need to find the value sharing equitable and the effort they invest in value co-creation to be in balance with the value they can capture in the ecosystem [3]. The sustainability of the ecosystem also requires the value propositions to be resilient and the ecosystem to have jointly agreed governance and development principles [6]. Innovating new business models enabled by co-created value propositions is an ecosystem-wide challenge requiring an understanding of real-time, but also future needs, of the members of the ecosystem [5]. Thus far, ecosystems do not have the tools to evaluate the value balance.

When discussing value, it should be recognized that it is more than just money. It includes also functional, social, epistemic, and emotional dimensions [11, 12]. While value co-creation has been studied for at least over a decade (since the introduction of service-dominant logic [13]), ecosystem-level value proposition research is scant. Furthermore, current literature on value has focused on financial value, considering e.g. price as a primary driver of customer value (see e.g. [14]). Seems that thus far scholars have paid less attention to other value dimensions, like social and emotional value, particularly in ecosystem contexts.

Ecosystem-level analysis can describe the success factors of the ecosystem and help both scholars and practitioners to understand how to create and sustain a successful ecosystem [15]. This study addresses this gap and after answering the research question, proposes an initial framework for assessing an ecosystem level value balance. The proposed framework is built through a constructive process, including the first empirical test with one case ecosystem. The article also initiates a research agenda for the iterative development of the proposed framework. This first step is based on answering the research question:

RQ: What kind of construct describes the distribution of different value dimensions within an ecosystem?

The article begins by summarizing the theoretical background, followed by the description of the used research method. Next, it presents the proposed initial framework and a case example. It concludes with a discussion chapter and the concluded proposals for future research.

## 2 Theoretical Background

Designing the framework requires an understanding of ecosystems, the importance of value within the ecosystems, and the different dimensions of value. This section summarizes the theories of the aforementioned concepts.

*Ecosystem* as a concept was first introduced by Moore when he coined a metaphor from ecology in the business context in the mid-1990s [10, 16]. As in ecology, also in business, the members of the ecosystem share their faith and their success relies on co-evolution and winning their rivals together [10]. The key characteristics of an ecosystem include it is loosely interconnected [17], a multilateral and mutually consistent set of members [18], who offer non-generic or super-modular complementaries [1] and is structurally flexible [19] – a kind of "meta-organization", which is active in co-operation and collaboration [20]. Ecosystems can either emerge non-predictively or be decisively designed, but in both situations, the core of the ecosystem is a value proposition [21, 22].

The ecosystem life cycle can be divided into four stages: (1) pioneering when the new, more operant value proposition is designed and offered, (2) expansion when the ecosystem invites more participants to achieve a critical mass of offering and participants, (3) authority when the ecosystem leader encourages the participants to co-operate towards a compelling shared vision, and (4) a 'renewal or death'-stage when the ecosystem focuses on incorporating innovations to improve the ecosystem performance and innovate new value propositions [10]. While the value proposition is important in all phases, it is critical during the first and last stages. Without an attractive proposition the emergence of the ecosystem is impossible in the pioneering phase, nor will the ecosystem remain stable in the renewal stage [10]. To co-evolve and expand the ecosystem members have to have confidence that the ecosystem has the potential to expand and thus be able to offer the value the member expects to capture [17].

*Value co-creation* refers to a principle that the customer participates in the value creation process together with the supplier [24, 25]. The co-created value should be both sustainable and unique, and the co-creators should trust each other [26]. Value co-creation is sometimes facilitated by technology, which requires social changes for society to accept it [27].

In ecosystems, all its members should participate in the co-creation of the value aiming to maximize the value for the ecosystem as a whole [21]. Compared to networked firms the target also is to share the value with all members, not just maximize the value capture for the leader firm [21]. The members are interdependent, which enables more value to the customer than none of the members could offer alone [23]. However, if the coordination and alignment of their activities fail, the ecosystem as a whole fails [1]. Therefore, the alignment of the capabilities and roles of the participants is essential. When they share a vision the members align their investments and strive to find a role, which supports the ecosystems' value proposition and thus, succeeds [10].

Mutually shared value propositions have been found to be pivotal to the attractiveness of an ecosystem [28]. These value propositions are also the core elements of a successful business model [29], hence essential for the success of the ecosystem. For example, [30] have introduced an ecosystem business model design tool, for describing the distribution of monetary value. The model, however, omits the other value dimensions. Also, [31] has created a framework for the IoT ecosystems, where one of the categories used is 'benefits'. The deficiency in this model is, it assumes value creation to be a one-way process. Consequently, it omits the ecosystems' fundamental principle of co-creation and mutual value sharing.

*Value* is the benefit one gains, compared to the sacrifice one needs to invest in the process [3]. In a business context, value has traditionally been weighed based on economic benefits and costs [32]. However, value is much more than money. Valuation as such is a continuous process, not a single activity [33], hence, the ecosystem is never "safe". The values and preferences, along with financial resources and needs of the customer, perpetually affect their perception of the value [12], thus, it is essential to know and understand the customers and their expectations – and in ecosystems, the understanding needs to be on the ecosystem level. As 'being valuable' is a subjective and relative view measuring it scientifically accurately is difficult – if not impossible [2].

There are five *value dimensions*: functional, social, emotional, epistemic, and conditional value [11]. The functional value is a customers' valuation of the characteristics of the goods – including services. These perceptions include e.g. usability, scalability, and availability of the service or the durability, price, or quality of the good. Social value is addressed when the customer values to be identified into a group (or avert that). Being a part of a fan club is an example of social value. The emotional value actualizes when the customer experiences positive feelings like charity or achieving the next level in a game may cause. The epistemic value is based on the feeling of novelty, learning something new, or be of interest. Epistemic value includes all data, information, and knowledge-related aspects. For example, collaborative filtering offers an epistemic value. The conditional value describes the alternative, which often depends on the situation. Typical conditional values are offered e.g. with seasonal products or services related to a certain situation like fairs. [12] builds on [11] by adding monetary value to the dimensions.

## 3 Research Method

The study was conducted as qualitative constructive research using the seven-step procedure described in [35]. The constructive approach was selected due to an innovative novel solution for a practical problem was required in addition to theory development. The following phases were conducted:

1) Finding a relevant problem:
   Value co-creation and ecosystems have had growing interest among scholars during the past years, but an ecosystem-level understanding of value distribution is insufficient. This study on ecosystem-level evaluation of value balance benefits practitioners by providing a tool for assessing the viability and sustainability of their ecosystems.
2) Selecting the target organization
   The case ecosystem needed to have sustained its viability as the study aimed to demonstrate, how value is co-created and shared on the ecosystem level. The beverage package recycling ecosystem lead by Palpa (Suomen palautuspakkaus Oy) fulfilled the requirement.
3) Obtaining deep understanding
   First, a theoretical understanding of value and ecosystem theories was acquired through conducting a literature review on academic value proposition literature. The objective of the literature review was to identify, how value

propositions have been described in academic literature and thus, verify are all theoretical value dimensions relevant in an ecosystem context. The review was based on a Scopus literature search (ecosystem AND "value proposition"), which gave 199 articles between 1987 and January 2021. There is a significant increase in the number of articles in recent years. A full-text review was conducted from the most recent ones backward in six-month sets. This was done to be able to complete the review when new descriptions of the value propositions cease to emerge. In total, 57 articles were reviewed. The descriptions were classified into the dimensions identified from theories ie. into conditional, emotional, epistemic, functional, monetary, and social value [11, 12] There were no descriptions related to conditional value in the ecosystem context, hence it was not included in the framework.

4) Innovate a solution and develop a construction
   There were three major requirements the construct should describe: which are the values offered, which sacrifices those require, and how these distribute across the ecosystem. The framework should also be easy to use and preferably be visual. Creating the framework was an iterative process balancing the requirements. After five iteration rounds, the initial framework seemed to fulfill all requirements.
5) Implement and test the solution
   The framework was tested with the packaging recycling ecosystem lead by Palpa Oy. The value propositions and sacrifices were collected through interviews [36] and publicly available information like magazines and internet pages. The testing is described in more detail in chapter 4.1.

Steps 6) Pondering the scope of applicability, and 7) theoretical contribution are elaborated in the Discussion and conclusions chapter.

## 4 Proposed Framework

The framework presented in Figure 1, is a matrix including all member types participating in the ecosystem. Each member is supposed to be both a value creator and a value capturer. The sacrifice column presents all efforts the members need to make to create value. It might be money, people, knowledge, etc. assets required to create value. Next, all captured values, by the value dimensions, are collected to the framework. The last column represents the value expectations each member has. The expectations include both the types of value the members want at the moment but also communicates what kind of potential the members see the ecosystem to have.

The framework demonstrates, can all members be satisfied within the ecosystem. If a member is making major investments in the value creation but receives only minute value, it is inclined to search for a more satisfactory ecosystem to join. On the other hand, if a member captures value without a reasonable effort to value creation, it can be considered to be a "free-rider" and the ecosystem would not suffer from excluding it.

The expected value is important information for the whole ecosystem [5] but especially for the ecosystem leader, as it helps to identify potential new members to the ecosystem and, thus, improving the vitality and resilience of the ecosystem. After all, the ecosystems are changing constantly [34].

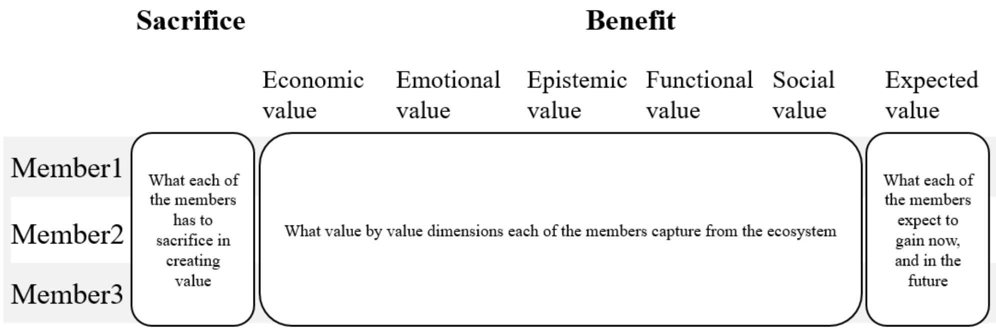


**Fig 1.** The value balance framework

Particularly, in the pioneering phase, the expectations help the ecosystem to find a viable value proposition. If the members are listing plenty of new expectations during the authority phase, the ecosystem leader can assume the ecosystem is approaching the final (ie. renewal or death) phase.

### 4.1 Case Example

The proposed framework was applied to the ecosystem formed for the beverage package recycling in Finland to evaluate the balance of value creation and capture within this established circular economy ecosystem. The ecosystem for the Finnish beverage package recycling consists of a wide variety of actors and organizations from multiple industries. Beverage package recycling in Finland dates back to the 1950s'. However, a central actor for the ecosystem, Suomen Palautuspakkaus Oy (Palpa), was established in 1996, which can be seen as the beginning of the pioneering phase of the ecosystem. Palpa administrates and coordinates the operations within the recycling ecosystem, and facilitates the collaboration between different actors, including multiple industries and competitors. Palpa is a non-profit company owned by major brewery and retail companies. Breweries produce the beverages and retailers sell the products and collect the deposit packages. According to Finnish regulation, the breweries are exempt from package taxes when joining a recycling system, and all retailers selling deposit packages are obliged to accept returns. RVM (Reverse vending machine) manufacturers, logistic providers, and material processors enable the recycling operations within the ecosystem. Consumers return the deposit packages to the returning locations and, thus, enable the high return rates of the Finnish beverage package recycling system. The proposed framework includes the actors of the ecosystem, which participate in the value creation and value capture within the ecosystem. Therefore, for example, media and reference systems are excluded from the analysis. The value balance framework of the case ecosystem considering the different value dimensions is presented in Table 1. For visuality purposes, all sacrifices have been written in red, and all benefits with green. The table categorizes, by value dimensions, the benefits each member of the ecosystem gains from participating in the ecosystem's activities.

***Table 1.*** The value balance of the Finnish beverage package recycling system

| **Member** | **Sacrifice** | **Benefit** | | | | | |
|---|---|---|---|---|---|---|---|
| | | **Economic** | **Emotional** | **Epistemic** | **Functional** | **Social** | **Expected value** |
| **Palpa** | Administration, deposit management, standardization, facilitation of collaboration | Non-profit organization | | Laws and regulations | Return container management, collecting and returning, developing and manufacturing the machines, logistics service, consumers returning the packages | Environmental impact, co-design | High return rates and efficient recycling operations |
| **Government** | Beverage packaging tax | | | | | Environmental impact, employment impact | Material efficiency enabled by a comprehensive recycling system |
| **Breweries** | Recycling fees and return package management | Beverage packaging tax exemption, cost reduction | | Standardization | Package returning and collecting | Environmental impact, brand | Cost-efficient package recycling and brand benefits |
| **Retailers** | RVM investments, management of the return location and its customer experience, co-creation of RVMs | Potentially more revenue enabled by well-managed return locations | The more negative impact, if not a member of the ecosystem | | RVM maintenance | The more negative impact, if not a member of the ecosystem, brand benefits of recycling | Convenience for customers and brand benefits |
| **RVM manufacturers** | Product development, manufacturing costs | Revenue | | Standardization | | Co-design | Business from recycling |
| **Logistic provider** | Logistic costs | Revenue | | Standardization | | | Business from recycling |
| **Material processor** | Process costs | Revenue | | | Raw material | | Business from recycling |
| **Consumer** | The effort of returning the deposit packages | Deposit | Charity, feeling of righteousness | | Convenience | | Convenience, environmental impact, deposit |

As an example, the breweries are one of the main building blocks of the ecosystem, as they produce the beverages requiring the packages. To participate in the recycling ecosystem, breweries sacrifice recycling fees for Palpa and allocate resources to the management of return packages. The economic value gained for breweries by joining the ecosystem is the exemption from beverage package taxes and cost reduction enabled by collaboration. The costs of being a member of the recycling system are kept lower than paying the beverage package taxes. Breweries gain epistemic value benefits through e.g. package standardization and the functional value benefits include the return and collection of the packages. The breweries benefit from social value gained through the positive environmental impact of recycling and brand benefits. The breweries expect to gain value from the cost-efficient package recycling and brand benefits. As is evident from the table, the expected values for each member meet the gained benefits to a large extent, which implies that the ecosystem is well-balanced regarding value creation and capture. The comprehensiveness, high return rates, and efficient operations of the recycling system further validate our findings, which imply that the value balance of the studied ecosystem is adequate to enable long-term success for the ecosystem's operations.

## 5 Discussion and Conclusions

The framework strives to offer a clear picture of what kind of value is created and captured in the ecosystem. The case was assumed to be in the authority-phase. This is supported by the balanced distribution of value. All members participate in value creation and also capture value. At the authority-phase, the expected value should correspond to the captured value. In Palpas case, the expected value corresponds to the value exchanged in the ecosystem reasonably well. These findings seem to confirm the original assumption.

The value proposition is more critical particularly on business ecosystems that are in pioneer and renewal phases in their life cycle [10]. In these life cycle phases, not only the current value but especially the potential value may have importance in attracting ecosystem members. Hence, ecosystems in these life cycle phases would particularly benefit from, in addition to a better understanding of the total value balance, also, the distribution of current needs and expectations of ecosystems' potential. The case in this study demonstrates, the ecosystems in more stable phases seem to emphasize the expectations for the current ecosystem members. Future research should evaluate, how the value potential is addressed in less stable phases of the ecosystems.

A limitation of the framework is that it fails to demonstrate, how valuable each of the value propositions is. When discussing, how valuable something is, there are no clear nor right answers as "beauty is in the eye of the beholder". Nonetheless, more research is required to delineate a measurement regime for the value balance framework to be accurate.

In an optimal situation when the framework is finalized, it should provide, in addition to the theoretical contribution, also a practical one. For it to be used by the practitioners as an ecosystem design tool without a researchers' support a questionnaire, workshop concept, or other kinds of means to facilitate the application, needs to be designed.

The importance of value dimensions is likely to vary in different ecosystems. The proposed framework, in its early phase, may not be valid for judging the value balance correspondingly across all kinds of ecosystems. However, the importance of different dimensions may be related to the ecosystem's mission. For example, in the Palpa ecosystem, different value dimensions are explicitly built in the ecosystem mission. Therefore, the importance of social value is assumably relatively high. Testing the proposed framework with more diverse cases is required in developing the model further. The above-mentioned limitations will be addressed as a part of finalizing the constructive process initiated during this study.

Ecosystem health is an emerging metaphor aiming to describe the longevity, performance, and success of an ecosystem [17, 37–41]. Ecosystem health is a crucial precondition to the ecosystem's capability to create value for its members: "If the ecosystem is healthy, individual participants will thrive; if the ecosystem is unhealthy, individual participants will suffer" [17]. Ecosystem health is considered to be a potential early indicator guiding and warning members, thus being an important avenue for further research [38, 39]. Hence, the value balance framework proposed in this article would benefit from linking it to ecosystem health in future research. [38] have already proposed a clear research agenda for strengthening the common base on ecosystem health. Also, we propose that particularly the connection between ecosystem health and value creation should be explored in further research, to understand what kind of health indicators are linked to value creation. Future research should also cover, how captured value could have positive feedback on ecosystem health.

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# PUBLICATION V

**Revisiting IoT Definitions: A Framework towards Comprehensive Use**

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# Revisiting IoT definitions: A framework towards comprehensive use

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ABSTRACT

New technologies constantly change the paradigm of how businesses will be run in the future. The Internet of Things (IoT) enables new business opportunities for data-driven transformation in organisations. The emergence of the IoT concept has resulted in numerous definitions, with earlier references primarily focussed on the technological aspects. This has hindered the broader diffusion of the term IoT as, arguably, the definitions do not integrate other non-technological elements of IoT and focus more on business and service provisions. To resolve this, our research identifies the most significant building blocks required in designing an IoT system. This is accomplished through a methodological review of 122 definitions and their consolidation into a novel definitional framework. The definitional framework unifies the traditional technology focus of the earlier definitions and integrates additional elements that are likely to increase the adoption of a comprehensive definition to support the development of future business applications. Furthermore, the framework serves as a reference set for scholarly societies and standards organisations who, in the future, can be tasked with formulating a definition of IoT, as has been the case with the NIST definition of Cloud Computing, which was preceded by several academic studies on defining the term.

## 1. Introduction

The Internet of Things (IoT) as a concept has been around for about two decades (Ashton, 2009; Brock, 2001). It is expected to radically influence our lives, the way we do business and even the global economy (Carayannis et al., 2018; Lu et al., 2018). As early as 2005, the International Telecommunications Union (ITU) published a widely read report on the IoT. The report declared that people would be in the minority in creating and receiving data once digital devices became ubiquitously connected to the Internet. The same report introduced a vision of a ubiquitous network – "anytime, anywhere, by anyone and anything" (ITU, 2005, p. 3). Since then, many scholars have created descriptions that elaborate on what this vision means in practice. According to Westerlund et al. (2014), the IoT will not only have effects on information processes but also business and even social processes, and by doing so, will provide numerous opportunities – even unexpected ones. It will change the way individuals interact with machines when machines become smart through self-aware 'things' (Vermesan et al., 2009). For example, the IoT will improve the efficiency of supply chains by enabling orders to guide themselves autonomously through the whole supply chain (Kiel et al., 2017), reduce energy consumption in properties (Vermesan et al., 2009), improve asset tracking (Dorsemaine et al., 2016), reduce healthcare costs by monitoring our health (Dijkman et al., 2015) and increase efficiency in education by introducing 'interactive high-definition lectures' (Byun et al., 2016). All of the above will be enabled by collecting data from processes with sensors and actuators and then using the analysed results for process control and development.

However, contrary to the IoT revolution that was expected in areas such as marketing (Bang and Simkin, 2017) and primary industries such as oil and gas (Geng, 2017), it can be argued that recent studies indicate that IoT is being adopted at a slower pace than earlier estimations. According to a Gartner study released in September 2018 (Pettey, 2018), the number of IoT sensors is estimated to exceed 10 billion units, and the annual growth rate is expected to be around 30%. Another study by IoT Analytics estimated the number of sensors to be only seven billion and the annual growth rate to be 18–20% (Lueth, 2018). Nevertheless, these studies confirm that the estimate by the *World Economic Forum (WEF) Global Agenda Council (GAC)* on the future of software and society made in 2015 was too optimistic when approximating the number of connected things at over 50 billion by 2020 (Global Agenda Council on the Future, of Software & Society, 2015). There are several reasons for this deceleration, for example, implementation challenges and issues with

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the IoT standardisation of platforms, connectivity, business models and killer applications (Banafa, 2016). Another reason for the slower uptake has been that research has primarily focussed on the technological aspects of IoT and has ignored research into business models and value creation. For example, the *National Institute of Standards and Technology (NIST)*, though being a part of the U.S. Department of Commerce, considers IoT to include five building blocks (i.e., primitives): sensor, aggregator, communication channel, external utility (eUtility) and decision trigger (Voas, 2016). While eUtility is stated to be "a software or hardware product or service", their main purpose is described to be feeding data. It neglects to describe why the data needs to be fed, i.e., what kind of (business) value the data enables. Similarly, nearly 40 ISO standards related to IoT exist that all focus solely on technological aspects (e.g. (International Organization for Standardization, 2019, 2020a, 2020b, 2021). These standards address issues such as requirements for data exchange, interoperability, reference architecture, and technical management process. While these are important to the technical implementation, they do not help in defining why an IoT system should be built. The vagueness of the definitions of what constitutes the IoT is also a contributory factor. This lack of clarity and consensus in definitions has thus hindered the level of understanding of IoT concepts, tools and technologies.

In this paper, we methodologically review existing definitions of IoT and, through a detailed analysis of the literature, identify the essential elements present within the current descriptions of IoT. Using these elements, we develop a comprehensive and overarching definition that includes the key IoT characteristics outlined in the existing definitions. We propose a definitional framework for IoT system design. Based on the findings of the analysis, this study aims to contribute to the cumulative and iterative building of a descriptive theory of IoT, as well as supporting practitioners in developing new, commercially successful IoT systems. Our work is the first step towards the development of a consensus definition for IoT. Similar to the development of the NIST definition of Cloud Computing (Mell and Grance, 2011), and which was preceded by several other examples of scholarly work all intending to define Cloud Computing (e.g., Vaquero et al., 2009; Wang et al., 2016; Madhavaiah et al., 2012), we hope that our work will help inform scholarly societies and standards organisations such as NIST and IEEE when developing a formal definition of IoT.

Following the introduction section, in Section 2 we argue the need for a synthesis of existing definitions of IoT. There have been several studies on investigating a common definition for emerging technologies like Big Data (De Mauro et al., 2016) and Business Intelligence (Ponelis and Britz, 2012); however, there are no existing studies that have focussed on a methodological approach towards the formulation of a standard definition for IoT. The methodological approach adopted for the review is described in Section 3, followed by Section 4, which outlines the different phases for the development of the framework. Section 5 is our discussion section. The paper concludes with Section 6 which highlights the key contributions of the work, articulates its limitations and draws pointers for future work.

## 2. Need for a common definition of IoT

Since being introduced, the IoT has attracted increasing interest amongst both academics and practitioners. Nonetheless, thus far, there is no universal consensus on the definition of IoT in academic or technical literature. Due to this imprecision and inadequacy in the clarity of the concept, it can be conceived as more complex than it might be (Gharajedaghi, 2011). Although a concept may not have an exact meaning, understanding its features helps to generate knowledge (Berenskoetter, 2016). Concerning the Internet of 'Things', Vermesan et al. (2009) point out that "things have identities". Atzori et al. (2010) complement this view by stating that things should operate through unique addressing protocols. Fleisch (2010) combines both perspectives in his white paper "What is the Internet of Things? An Economic Perspective", where he also states that IoT is an application of the Internet. On the other hand, Ju et al. (2016) see the IoT as a network infrastructure globally used by the information society, which is a combination of the Internet, near-field communications and networked sensors. Smedlund et al. (2018) emphasise the role of physical objects and the distributed nature of the network where devices exchange information. These examples describe the two approaches to IoT. Some consider it to be the sum of its parts, whereas others emphasise that it is an entity per se.

While most of the definitions focus on physical objects and virtual things – i.e., "non-living" sources, some consider that even individuals need to be seamlessly integrated into the IoT (Zhang and Wen, 2017). Keskin et al. (2016) take the idea a step further. In their view, the IoT will include "equipping all objects and people in the world with some form of identifying devices" (Keskin et al., 2016). Arguably, the two elements of the definition that most academics agree on are that the IoT includes "things" – either virtual, physical or both – and that there is some sort of interconnection or interaction between those things. This rather confusing assortment of definitions emphasises the need for clarification and especially a fundamental discussion amongst academics to create a shared understanding. Next, we present three reasons that articulate the need for a common definition of IoT.

*Reason 1 for the need for a common definition of IoT: It can be assumed that growth in both the volume of literature and diversification of the subject areas has led to vagueness and more variety as to what constitutes the IoT. Having a common definition will help us weave together the core concepts and technologies that should be seen as fundamental to the IoT.*

The volume of literature on the IoT has increased exponentially over the years (Fig. 1). For example, a Scopus search (conducted in August 2021) using the keyword "Internet-of-Things" in article titles, abstracts or keywords identified over 107,000 articles published in the period from 2003 to 2021 (note that we have excluded around 25 papers from this count that are pre-assigned to volume/issues that will appear in 2022): of these approx. 58% were conference papers, 34% were journal papers, and 2.3% were classified as review articles. The remaining 5,7% included books and book chapters, editorials, letters and short surveys. The earliest IoT publications date from 2003 (2 papers). The number of articles increased to double digits (15) in 2006 and to over 100 papers in 2010 (392). As illustrated in Fig. 1, there was a remarkable growth in the volume of publications between 2009 and 2019. In 2019, over 23,000 articles listed in Scopus included the keyword "Internet-of-Things", and by mid-August 2021, the number stood at approx. 13,400. The growth trend observed until 2019 seemed to have plateaued; however, this may be due to a possible delay in indexing articles in Scopus.

It is also interesting to note the breadth of publications concerning the different subject areas associated with the articles. While interpreting this data, the readers should bear in mind that an article can be categorised under multiple subjects in cases of inter-disciplinary and multi-disciplinary work for example, and thus the total count is over 107,000 articles. As can be seen in Fig. 2, Computer Science accounts for ~37% of papers (approx. 81,500 articles), followed by Engineering (~24%), Mathematics (~7%), Physics and Astronomy (~6%), Decision Sciences (~5.5%) and Social Sciences (~3.5%). Environmental Science with approx. 2600 papers were the last subject category that meets the Fig. 2 display threshold of 2500 or more articles.

*Reason 2 for the need for a common definition of IoT: Several synonyms or terms describing a similar concept have emerged during the past years. Without a commonly agreed definition, it is challenging to position emerging research and application areas such as Cyber-Physical-Systems (CPS), Industrial Internet of Things (IIoT), Industry 4.0 or the Internet of Things and Services related to the IoT (IoT&S).*

Concepts are linguistic tools for defining and understanding the world around us. Without a commonly agreed definition, it is challenging to delineate supporting, associated or contrasting concepts (Berenskoetter, 2016). Concepts should be defined parsimoniously but include all necessary and sufficient attributes (Brennan, 2017;

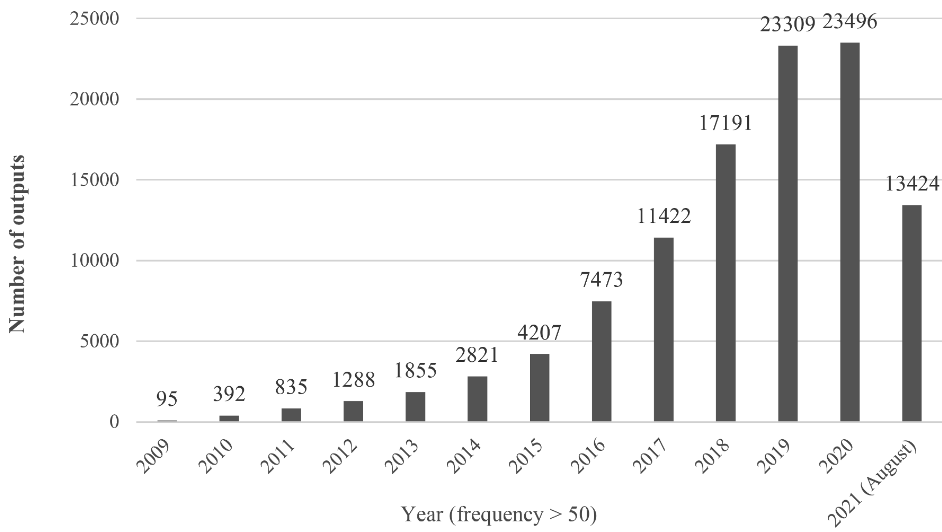


**Fig. 1.** The number of publications that include the keyword "Internet-of-Things" has increased rapidly between 2009 and 2021 (Scopus search - August 2021).

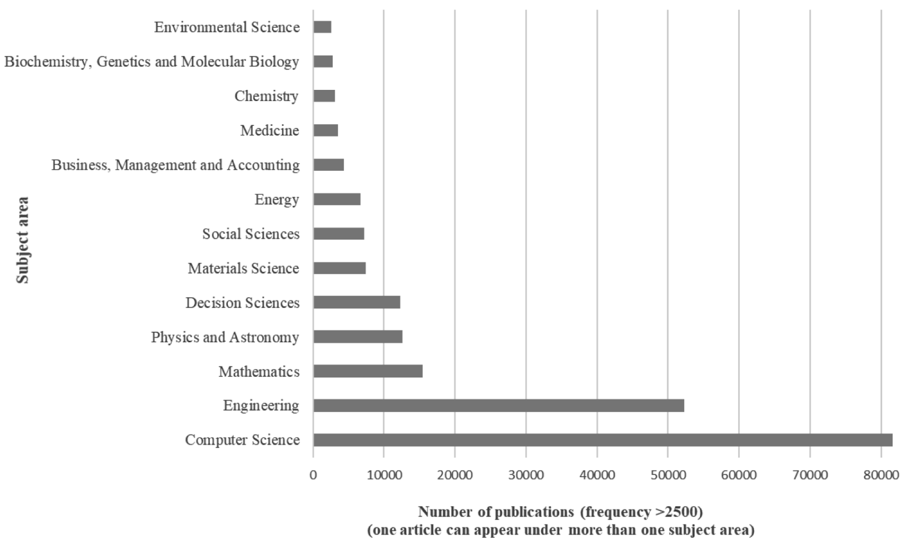


**Fig. 2.** IoT papers published in different subject areas (Scopus search - August 2021).

Podsakoff et al., 2016). Otherwise, confusion over definitions may limit the generalisability and comparability of research. For example, is the Internet of Things and Services (IOT&S) a superset of IoT or is it an extension of IoT with a business dimension? From the literature, the IOT&S can be understood either "to consist of business models, infrastructure for services, the services themselves and participants'' (Wang et al., 2016) or as a "seamless integration of physical objects such as sensors or home appliances (i.e., things) and services, which can be loosely defined as a network interface that exposes a piece of functionality" (De Leusse et al., 2009). Whilst the former definition prominently features business models, the latter's focus is restricted to technical artefacts (network interface). Thus, without an agreed definition of IOT&S, the term may be used as a synonym for IoT. Similarly, we consider a commonly accepted definition crucial for the future development of IoT. Hence, in this paper, we strive to bring clarity to the concept of IoT.

*Reason 3 for the need for a common definition of IoT: IoT utilisation seems to be expanding at a slower pace than earlier estimations, for example, by the World Economic Forum (WEF) Global Agenda Council (GAC) on the Future of Software and Society (Lueth, 2018).*

The utilisation of IoT seems to be expanding at a slower pace than earlier estimations have predicted. This is also contrary to the growth of academic literature related to IoT (Figs. 1 and 2). In 2015, the WEF Global Agenda Council (GAC) estimated the number of connected devices to be over 50 billion by 2020 (GAC, 2015). In contrast, three years later (in 2018), the prediction was reduced to just below 10 billion. As illustrated in Table 1 below, the number of active connections globally was expected to be 21.5 billion in 2025. This would correspond to the

**Table 1**
Number of active connections globally (in billions), actual and predictions (in grey).

| Report | Report's year | 2014 | | 2015 | | 2016 | | 2017 | | 2018 | | 2019 | | 2020 | | 2021 | | 2022 | | 2023 | | 2024 | | 2025 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cisco IBSG | 2011 | | 14 | | 25 | | | | | | | | | | 50 | | | | | | | | | | |
| IoT Market, Forecast at a glance* | 2014 | 11 | 14 | | | | | | | | | | | 32 | 50 | | | | | | | | | | |
| World Economic Forum | 2015 | | | | | | | | | | | | | | 50 | | | | | | | | | | 100 |
| Statista | 2016 | | | | 15.4 | | 17.7 | | 20.4 | | 23.1 | | 26.7 | | 30.7 | | 35.8 | | 42.6 | | 51.1 | | 62.1 | | 75.4 |
| State of the IoT 2018* | 2018 | | | 3.8 | 13.9 | 4.7 | 15 | 5.9 | 16.4 | 7 | 17.8 | 8.3 | 19.4 | 9.9 | 21.2 | 11.6 | 23.2 | 13.5 | 25.4 | 15.8 | 27.9 | 18.5 | 30.9 | 21.5 | 34.2 |
| State of the IoT 2020* | 2020 | 2.8 | 12.5 | 3.6 | 13.3 | 4.6 | 14.4 | 6.1 | 16 | 8 | 17.9 | 10 | 20 | 11.7 | 21.7 | 13.8 | 23.9 | 16.4 | 26.5 | 19.8 | 29.9 | 24.4 | 34.6 | 30.9 | 41.2 |
| State of IoT 2021* | 2021 | | | 3.6 | | 4.6 | | 6.1 | | 8 | | 10 | | 11.3 | | 12.3 | | 14.5 | | 17.3 | | 21.8 | | 27.1 | |

*IoT Analytics' report

**right-hand figure in per each year includes phones and tablets

*** grey figures are estimates in reporting year

total market being $1567 billion in 2025 (Lueth, 2018). Only one year after that report, Forbes Business Insights reduced their estimation of market size to $1102 billion (reduction of nearly 30%). The latest estimation (Lueth, 2018) is slightly more optimistic but still far less than the early projections. We can assume from Table 1 below and the market size figures that the speed of IoT diffusion is decelerating. According to Rogers (2003), diffusion depends on complexity, trialability, observability, compatibility and relative advantage. IoT systems are complex, and the required investment reduces the trialability of IoT. While IoT development has focussed on technology, it makes it complicated for potential adopters to understand the potential benefits of IoT systems, to perceive its consistency with their past experiences and the relative advantage that IoT may create. Consequently, the definition should emphasise the enhanced diffusion created by the value of IoT.

Arguably, the variety of definitions has led to multiple development projects that are in practice competing for the same resources, which may have delayed the implementation of IoT systems. The motivation for identifying a consensus definition also exists across other research fields. We carried out a benchmark study to select an appropriate method for formulating a common definition. The benchmarked existing work is presented in Table 2, which shows that the most typical types of the literature review were employed; however purposive sampling was also used in some cases. The typical number of papers considered in the reviews varied between 15 and 66. The analyses were typically made through content analysis, and a selection of the most representative definitions was also used.

## 3. Methodology for review

For this study, we were motivated by the literature review approach presented in "A break in the clouds: towards a cloud definition" by Vaquero et al. (2009). In this highly cited paper (as of March 2022, Google Scholar reports nearly 4700 citations), the authors described their literature selection process and then extracted the minimum definition of Cloud Computing from 22 previous definitions. The high citation count demonstrates the acceptance in the academic community of a literature review as an underlying approach for structuring technical definitions, which are expected to include constituent elements of numerous other definitions. Therefore, we decided to adopt a similar approach for this study. Furthermore, a temporal analysis of the development of the definition (Manikas and Hansen, 2013) is included to enhance understanding of the history of IoT.

Thematic analysis (Boyatzis, 1998) was chosen as the research method. The thematic analysis offers a flexible but systematic approach to analysing qualitative data (Saunders et al., 2019). This study applied a similar process to that of Estelles-Arolas et al. (2012) when they examined the definition of crowdsourcing. Thus, the study included four phases (Fig. 3). In the first phase, the existing definitions were identified through a literature review and analysed to identify common IoT descriptive thematic categories. The second phase analysed the text with the *Voyant* tool to identify the relevant descriptive words and phrases. In the third phase, a list of descriptive words was stemmed using the Porter Stemming Algorithm (Porter, 1980) and the destemmed descriptive words were assigned to descriptive thematic categories. Finally, the framework was refined in the fourth phase by selecting the most significant descriptive categories and delineating them with explanations and examples.

**Table 2**
Existing work on formulating a common definition.

| Application Domain | Description of the definition process | Reference |
|---|---|---|
| Cloud Computing | Gathered 22 definitions, summarised features to create an encompassing definition | Vaquero et al. (2009) |
| Big Data | Identified 15 definitions, classified into 4 groups, conjoint analysis to identify "the nucleus of the concept" | De Mauro et al. (2016) |
| Cyber Security | Systematic literature review, 29 definitions, exploratory text analysis with text mining, lexical overlap analysis, a correlation matrix for a sparse document-term matrix. The definition is based on the five most "representative" definitions | Schatz et al. (2017) |
| Business performance measurement system | Multi-database systematic literature review, 17 definitions, main features and content analysis of roles and processes, two teams, mutual agreement | Franco-Santos et al. (2007) |
| Crowdsourcing | Systematic multi-database literature review, 32 definitions, Tatarkiewicz's approach (to unite sentences referring to the intention of the term), integrated "differentia specifica" elements to the definition | Estellés-Arolas and González-Ladrón-de-Guevara (2012) |
| Innovation | Thorough literature review, 66 definitions, content analysis conducted by counting word frequencies | Baregheh et al. (2009) |
| Business intelligence | Purposive sampling, 27 definitions, content analysis to consider connotations, a priori coding | Ponelis and Britz (2012) |

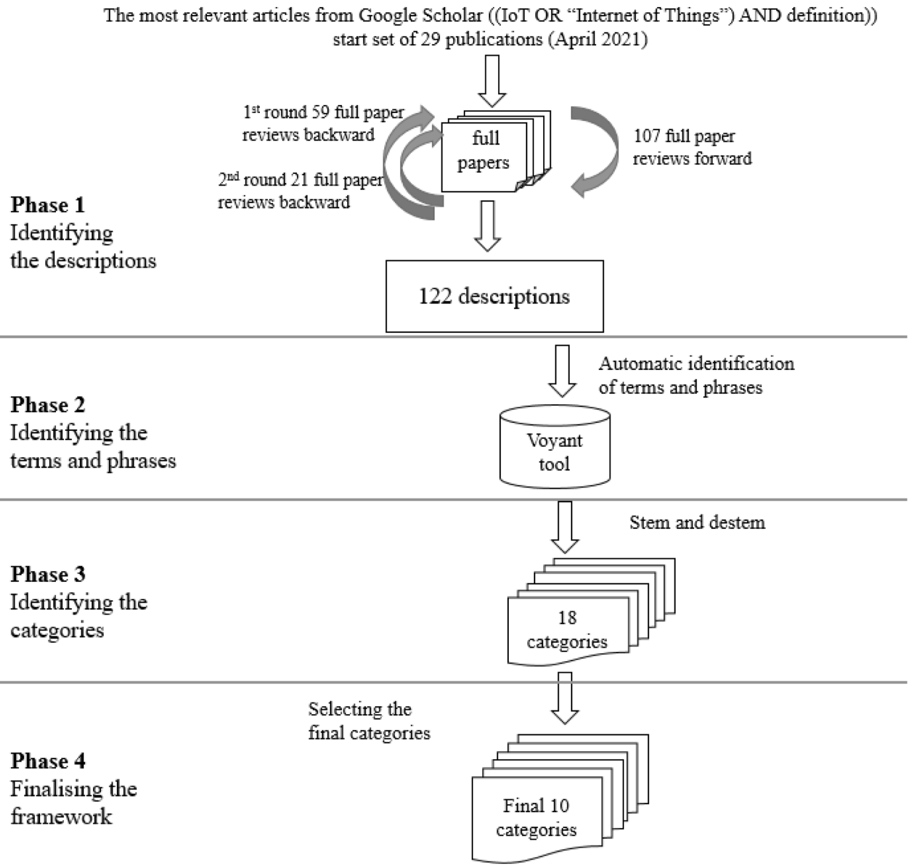


**Fig. 3.** Process of creating the framework. The names of the phases are shown in Fig. 3 (identifying the descriptions, terms and phrases, categories, framework finalisation). The following section on framework development uses the phase names and provides further details on the four phases.

## 4. The four phases of framework development

### 4.1. Phase 1 – identifying common descriptions

To identify relevant papers, in addition to our Scopus-based search with key terms, backward and forward snowballing were applied (Fig. 3). Especially in cases like an under-defined concept such as IoT, snowballing may reduce the noise caused by non-applicable manuscripts (Wohlin, 2014). Badampudi et al. (2015) have demonstrated that snowballing is as accurate as database searches when the start set is defined appropriately. The snowballing is done from the start set both forward (i.e., identifying publications that have used the start set articles as reference) and backward (exploring the reference lists of the start set publications) (Jalali and Wohlin, 2012). Since the aim was to have a non-biased start set, not limited to a single publisher, research methodology or geographical area, Google Scholar (GS) was selected as the search engine. As the focus was on scientific research results, citations and patents were excluded from the search. In ranking the publications, Google Scholar's search function uses full texts weighted by writer, publisher and recent citations in academic literature, emphasising the citation count (Beel and Gipp, 2009). Google Scholar was also selected as the search engine because it provides multi-disciplinary, publisher-independent access to a wide range of academic publications (Harzing and Alakangas, 2016; Hilbert et al., 2015).

When undertaking a literature review, the researchers need to make a judgment call related to identifying the initial set of papers for the review (hereafter, the start set). Identification of the start set requires balancing between comprehensiveness and "an overwhelming number of false positives" requiring manual exclusion and time (Wohlin et al., 2012, p.47). Our start set was created in April 2021 by conducting a search: (IoT OR "Internet of Things") AND (definition). The search results identified 29 most relevant papers (see Appendix 1). The papers were published between 2009 and 2019 and consists of 16 articles published in conference proceedings, ten journal papers, two book sections and one white paper. While most of the articles were from information technology and information system publications, there were also articles from the production management and management innovation domains. The affiliations of papers' lead authors were in four continents (Asia, Europe, Africa and North America), altogether 16 countries.

To understand the variety and complexity of descriptions, backwards and forward snowballing approaches were adopted to extend our start set, as suggested by Wohlin et al. (2012). The review was conducted by the whole research team (the three co-authors), and after each review phase, the selected descriptions were discussed to resolve the identified discrepancies. Backwards snowballing, also referred to as reference chasing, involved the full-text reading of the articles and identifying IoT definitions cited in the papers in our start set. A total of 59 definitions

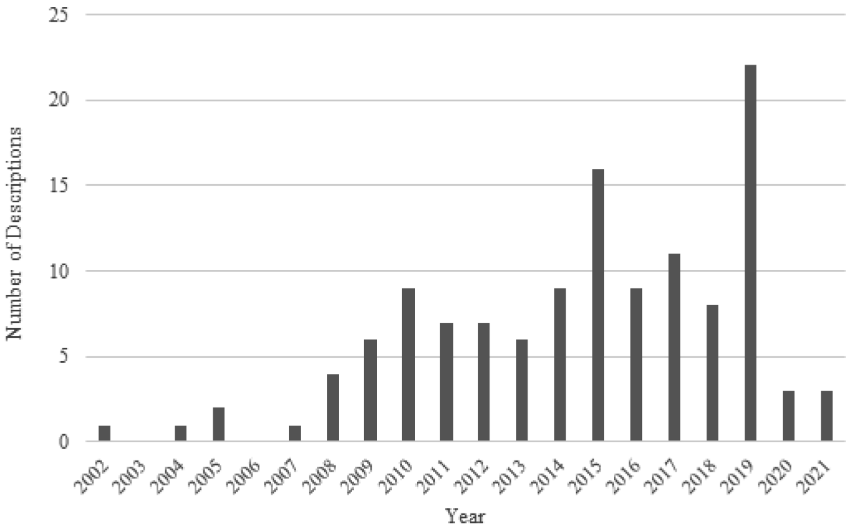


**Fig. 4.** The number of descriptions per year.

were retrieved through this process. Next, forward snowballing to identify relevant literature that cites the articles of the start set and complementing papers from the backwards snowballing. Google Scholar was employed for undertaking a structured approach also to forward snowballing. A Google Scholar search using the article title (verbatim) retrieves the link for full-text access and the list of citing articles. From the list of citing papers, we selected papers that included terms such as literature review, taxonomy, classification, frameworks, mapping study, survey, and definition. A total of 75 definitions were identified through the forward snowballing approach. The review was finalised by conducting a second backward snowballing, including the articles, where new definitions were identified. This resulted in additional eight definitions. As mentioned earlier, each author was responsible for a subset of cited articles resulting from the respective allocation from the start set. A master list of definitions enabled identification of the duplicate definitions. After reviewing 216 full papers identified by the backward and forward snowballing methods, 122 different descriptions of IoT were identified (the supplementary material can be downloaded from the publisher site). The number of descriptions is the highest in the year 2019 (Fig. 4) Some of the IoT sources, e.g., Atzori et al. (2010), were referred to more often than others. For this study, all descriptions were considered equally relevant.

After collecting the data, the descriptions were carefully read to identify initial themes for thematic analysis. These initial themes included network, physical object, virtual thing, data, protocols, and services. The themes were revisited in Phase 3.

### 4.2. Phase 2 – identifying the terms and phrases

The analysis began by inputting the descriptions into the Voyant tool, which is a web-based reading and analytics environment for digital texts. It is an effective way to identify the most important terms as an initial phase of the analysis as it calculates the frequency of each word and allows sorting those by frequency. When the volume of text is large, compared to manual analysis and frequency count, a Voyant-based analysis reduces the chance of missing meaningful words. The Voyant tool identified 1022 different words. Naturally, IoT was used very frequently in the descriptions, but, as the subject requiring definition, it was excluded. By analysing the most frequently used words, it became evident that many descriptive words had a similar meaning. However, Voyant considers the singular and plural forms of a word as two different words. In more technical terms, the words retrieved from the Voyant analysis contained inflexional endings (extra letters added to words in their different grammatical forms) and needed to be removed. Consequently, a second round of analysis was required.

We used the Porter Stemming Algorithm (PSA) for this analysis (Porter, 1980). More specifically, we used the Visual Basic implementation of PSA (Mustafee, 2003) to normalise the words through the process of stemming. In information retrieval, stemming refers to the removal of the inflexional endings to their morphological base term. We also refer to the base term as the PSA meta-data. The subsequent destemming process allows for the grouping of words that have the same PSA meta-data. Taking an example from our Voyant analysis, the words “network” (104), “networks” (20), “networking” (12) and “networked” (7) are four distinct words (frequencies reported by Voyant included in parenthesis). However, the PSA algorithm normalises these words to only one PSA meta-data called "network". Another example is "communication" (58), "communications" (10), "communicate" (26), "communicating" (5) being normalised to the PSA meta-data called "commun". In addition to automation (which included both stemming and destemming operations), this phase involved manual analysis of the results of the stemming algorithm and organising the words into groups. This enabled us to calculate the total occurrences of the words with inflexional endings, and which were assigned to a unique PSA meta-data. Furthermore, the manual analysis enabled us to assign the most relevant word to represent the group of words that were stemmed (for example, the PSA meta-data "commun" was re-labelled "communication"). For further information on the specifics of our implementation of the stemming and destemming process, please refer to Mustafee and Katsaliaki (2020).

### 4.3. Phase 3 – identifying the categories

The stemming led to 731 stems describing IoT. Each destemmed word is linked with a stem. Of these, stems used more than 20 times account for 50% of the total word count and 6.3% of the stems. This was sufficient to identify the most important descriptor categories. The destemmed words from the most frequent stems were grouped to themes by meaning. The descriptive words used in the descriptions were reviewed before being assigned to a group. This process led to 18 different categories . The ten most frequently mentioned categories are also the descriptive ones (see Table 3). The last eight include more general verbs or adjectives like based (used in 'based on'), which as such are not descriptive. Hence the top ten categories were chosen as the "obligatory building blocks of IoT".

### 4.4. Phase 4 – finalising the framework

In the final step of the study, a framework for creating an IoT system was developed. The diversity within each category was analysed, followed by explicating the meaning and content of each descriptive category. Finally, some examples were included in the framework for further elucidation.

**Table 3**
Descriptive categories identified through destemming.

| *Stems* | *Examples of destemmed words* | *Descriptor (group)* | *Frequency* |
|---|---|---|---|
| *network* | *networking, networked* | *Interaction* | *507* |
| *commun* | *communication, communicating, communities* | | |
| *internet* | *internet* | | |
| *connect* | *connected, connectivity, connections* | | |
| *interact* | *interaction, interactive, interacting* | | |
| *interconnect* | *interconnecting, interconnections, interconnectivity* | | |
| *integr* | *integrant, integrated, integration* | | |
| *thing* | *thing, things, thing's* | *Virtual Thing* | *361* |
| *devic* | *device, devices* | | |
| *virtual* | *virtual, virtually* | | |
| *sens* | *sensing, sense, sensed* | | |
| *sensor* | *sensor, sensors* | | |
| *actuat* | *actuator, actuators, actuating* | | |
| *digit* | *digital* | | |
| *servic* | *service, services* | *Services* | *241* |
| *applic* | *application, applications* | | |
| *comput* | *computing, computation* | | |
| *process* | *processing, processes* | | |
| *capabl* | *capabilities, capability, capable* | | |
| *object* | *object, objects* | *Physical object* | *229* |
| *physical* | *physical, physically* | | |
| *product* | *product, products* | | |
| *technolog* | *technologies, technology, technological* | *Standardised Technologies* | *179* |
| *protocol* | *protocol, protocols* | | |
| *standard* | *standard, standardisation, standardised, standardisation, standardised* | | |
| *infrastructur* | *infrastructure, infrastructural* | | |
| *interfac* | *interface, interfacing* | | |
| *software* | *software, softwares* | | |
| *Inform* | *information* | *Information* | *166* |
| *smart* | *smart, smartness* | | |
| *intellig* | *intelligence, intelligently* | | |
| *data* | *data* | *Data* | *82* |
| *world* | *worldwide* | *Ubiquitous* | *67* |
| *ubiquit* | *ubiquitous, ubiquitously* | | |
| *pervas* | *pervasive* | | |
| *ubiqu* | *ubiquity* | | |
| *worldwid* | *worldwide* | | |
| *human* | *human, humans* | *User* | *66* |
| *user* | *user, users* | | |
| *peopl* | *people* | | |
| *owner* | *owners* | | |
| *custom* | *customers* | | |
| *uniqu* | *uniquely, unique* | *Unique* | *65* |
| *identifi* | *identifiable, identifier, identify* | | |
| *identifi* | *identification* | | |
| *ident* | *identity, identities* | | |
| *us* | *use, using, used, useful* | | *48* |
| *entiti* | *entity, entities* | | *41* |
| *environ* | *environment, environments* | | *37* |
| *base* | *based* | | *33* |
| *enabl* | *enable, enables, enabling, enabled* | | 31 |
| *provid* | *provide, provided, provider* | | *31* |
| *includ* | *including, includes, include* | | *22* |
| *manag* | *management, manager, managing* | | 21 |

Although 122 different descriptions of IoT were identified in our study, notably, many scientific publications did not present any IoT description at all. The term is used fluently but in a rather inconsistent manner between publications. A similar inconsistency can be observed between the descriptions used. Two descriptions mention only one of the descriptive categories, while another two use all ten of them (see Fig. 5). Typically, a description employs four to five different categories.

After identifying the descriptive categories, the research team focused on the complete descriptions to comprehensively understand what should be included in each category.

The first group, *interaction*, includes terms like communication, interoperability, seamless integration and exchange of information. Although many terms are used, they are almost synonyms. The parts of IoT must communicate with each other to enable data utilisation.

The second group, *virtual thing,* was also described in different ways. It is referred to as a smart object, actuator, active participant, embedded electronics, microcomputer, sensing object, etc. It is inarguably an important term in the descriptions, although it is also the one that is most heterogeneously portrayed.

The third group, *services*, includes terms such as innovative applications, digital enhancement and decision making, amongst others. The value of this contribution comes from articulating the importance of acknowledging the IoT services as value-creating business enablers. Well-designed services can have pronounced implications for individuals and on a societal level. For example, utilising IoT in e-governance can promote government transparency and alleviate tax evasion (Brous 2015; Uyar et al., 2021). For example, The IoT also enables contactless services in healthcare diagnostics, treatment and even disease prevention, the importance of which has increased during the Covid-19 pandemic (Lee and Lee, 2021). Moreover, IoT services in the energy sector can have significant social, economic and environmental implications (Hiteva and Foxon, 2021). While the concept of the services group is likely to be important, it seems that the content is imprecise and lacks clarity. Considering the imbalance between the presumed importance and the vagueness, this group requires more attention.

Most of the descriptions emphasise the difference between a *physical object and a virtual thing* that makes the fourth group (*physical*). An object refers to the product to which things are attached or embedded. For example, a fridge may have a temperature sensor: the former being the object and the latter the thing. There seems to be a mutual understanding of differentiating these two items. Both are needed. The virtual thing enables a complimentary service for the user of the physical thing.

The fifth group is *standardised technologies*. The addressing scheme, agreed protocol, architecture, intelligent interfaces and enabling ICT are all related to standardised technologies. Standardisation is essential so that all things can connect to each other. Machines are not creative like humans; thus, the former know how to connect only when clear standardised instructions (like a TCP/IP protocol) have been given. Without a doubt, creating ubiquitous structure connectivity is necessary.

The sixth group is *information*, including terms like cloud computing, knowledge mining and data analytics. This group is closely related to the seventh group of terms, which is *data.*

The seventh group is data – whether it be big data, raw data, semantic level data or middleware level data. This is a significant group to include in this study. Data and information enable smart products, which are intended to add value significantly to IoT users and thus offer business opportunities. The difference between data and information is that data has not yet been processed or analysed. Both data and information can be considered to be new types of assets. They may be less observable and more malleable than a traditional physical asset, but have value, as they are not diminished when shared or used. One could even say the value of data and information increases when shared.

The eighth group is *ubiquitous*. It is described with terms such as information network, network infrastructure, real-time, pervasive and

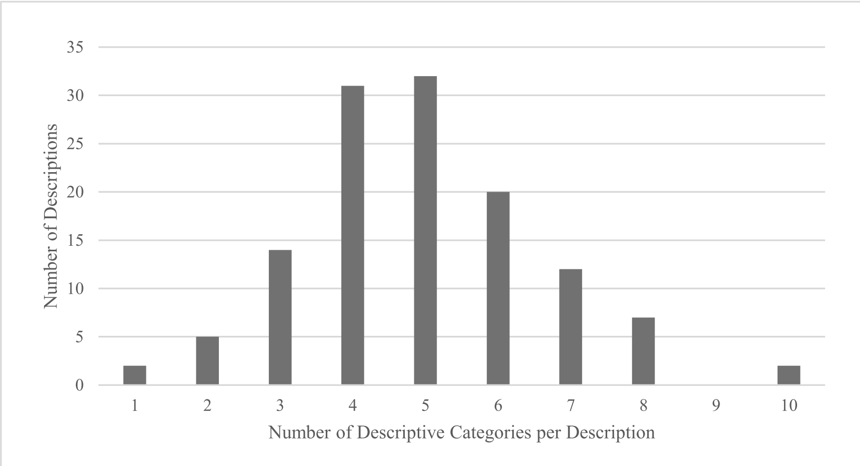


**Fig. 5.** The number of descriptive categories used in the descriptions.

ubiquity. All these indicate the same sentiment – anyone, anything, anywhere and anytime. While ubiquitous refers to availability anywhere, it is good to remember it does not mean that things and data must be available everywhere. The same applies to anytime in connectivity. Anytime is different from all the time. It is enough to have the ability to connect to the network; it is not necessary to be online all the time. In many cases, a continuous connection would be a waste of energy and money.

The ninth group is *user*. This group is important as it is the user who pays the bill and whose expectations should be met – or even exceeded. The user was also referred to as an owner or a human in the search. The user is closely linked to services. Consequently, the value offered to the users through services is the backbone of successful IoT system provenance, the importance of security issues can be expected to increase in the future.

The last group is *uniqueness*. Each physical or virtual thing in the IoT needs to be uniquely addressable (Glova et al., 2014). Other terms in the same group are also automatic identification, clearly identifiable and intelligent identifying.

While IoT technologies have developed substantially during the past decades, the system-level theories seem to have progressed less. This may be an indication that the concept is still unclear, and consequently, the academic community has not been able to build a commonly agreed descriptive – let alone normative – definition.

## 5. Discussion

Data, information and services constitute the core of transforming existing technology into business. These are the fundamental parts of creating value through the IoT. As Gupta (2016) stated: "Data is the new dollar". Through the IoT, a vast amount of data is created and shared effortlessly. This creates a new way for companies, networks or ecosystems to (co-)create and capture value, which can be turned into an asset with which business value can be created (Tiwana, 2014). This value can be either monetary or non-monetary – sometimes both. The key is that someone finds it valuable and thus is willing to trade the value.

Some of the descriptions include business aspects or business models for the basic structure of IoT (such as Leminen et al., 2012; Turber et al., 2014; Fleisch et al., 2015; Keskin and Kennedy, 2015; Serrano et al., 2015). Khan et al. (2012) even include business aspects in their model of an IoT stack. Moreover, the business can be considered to be built on the IoT: the Industrial Internet of Things, IIoT (Burmeister et al., 2016; Gierej, 2017; Iivari et al., 2016), which utilises data for developing new types of value for customers; or the Internet of Things and Services, IoT&S (De Leusse et al., 2009), where the IoT stack is combined with new valuable services for the customer. Although Xueqin et al. (2011) has a strong technology orientation in his description, he still recognises that IoT will not be able to become a part of our everyday life unless it has appropriate business models to utilise.

Examples of IoT devices include cameras (e.g., Nest Dropcam, Samsung SmartCam and Ring doorbell), switches and triggers (iHome, Belkin Wemo Switch), hubs (e.g., Amazon Echo), air quality sensors (e.g., Awair air quality monitor), electronics (e.g., Google Chromecast), healthcare devices (e.g., Withings Aura smart sleep sensor and Blipcare blood pressure meter) and light bulbs (e.g., Philips Hue and LiFX Smart Bulb) (Sivanathan et al., 2018). For this work, we have chosen Amazon Echo as an example, subsequently referred to as "Echo". Echo is an intelligent home assistant or "smart home" IoT hub, which takes voice commands from the users to control itself and other connected IoT devices/sensors, e.g., smart lights, smart kettles, smart locks, smart thermostats and smart doors (Li et al., 2019). The voice commands are interpreted and carried out by Amazon's cloud-based intelligent personal assistant service "Alexa", through which Echo carries out voice interaction, music playback, provides information like weather and traffic, and also controls other IoT devices (Jackson and Camp, 2018).

We have created a definitional framework to clarify the structure of IoT, especially for practitioners designing IoT systems. This framework describes each of the key categories identified in this study by presenting a short explanation and concrete examples (see Table 4).

Some of the descriptions emphasise ecosystemic thinking (Keskin and Kennedy, 2015; Leminen et al., 2015; Shin and Jin Park, 2017) when designing and implementing IoT. According to Westerlund et al. (2014), IoT systems and applications support businesses built on IoT only if value creation and capture are constructed with an ecosystem focus. Considering value co-creation at the ecosystem level, Mejtoft (2011) reminds us that, in addition to technological changes, society also needs to become more accepting of the newly advanced ecosystems, including 'things', which may be largely self-controlled by machines. For example, as Tiwana (2014) and Xuequin (2011) have demonstrated, applications are more likely to create business value than the technology itself. Metallo et al. (2018) have found that value proposition and key activities play a crucial role in IoT-enhanced business. The IoT offers significant business opportunities. One should remember, however, that

**Table 4**
Explanation of categories with examples in order of frequency in descriptions. The last column describes the categories with reference to Amazon Echo.

| Descriptor | Explanation | Examples | Amazon Echo |
|---|---|---|---|
| Interaction | Virtual things are connected to each other and can interact. | Wireless or wired connection. Able to request, send and receive data. | Echo is often connected to other IoT devices and sensors, e.g., smart lights, smart kettles, smart locks, smart thermostats and smart doors (Li et al., 2019). Multiple Echo devices can also be connected to each other, for example, to make a stereo pair ( Andersen, 2018). |
| Virtual Thing | The active participant that collects and possibly stores the data from the functioning of the physical object | Sensor, actuator, embedded electronics in general | Echo stores the interaction of the virtual agent Alexa in SQLite database and Web cache files (Li et al., 2019). |
| Services | The functionalities the system has to improve the process | Innovative applications, visualisation (like heat maps), decision making, optimisation, i. e. the value for the customer | Echo provides services such as music playback services, information services like weather and traffic reporting, and control services for other connected IoT devices like smart lights and smart thermostats (Jackson and Camp, 2018). |
| Physical Object | An object where the virtual thing will be embedded. Can also be an object whose performance needs to be controlled. | Fridge, car, welding machine | Echo is embedded with a conversational agent (Alexa) that can take voice commands from users and perform several tasks ( Gao et al., 2018). |
| Standardised Technologies | The means enabling data collection | A protocol like TCP/IP, a programming language like HTML, addressing schemes, architecture | Echo uses HTTP (port number 80), HTTPS (port number 443) and ICMP (port number 0) and accesses a number of domain names including *softwareupdates.amazon.com, devicemetrics-su.amazon.com, pindorama. amazon.com* and *pool.ntp.org* (Sivanathan et al., 2018). |
| Information | Information processing | Cloud computing, knowledge mining or data analytics | Echo receives voice commands ('ubiquitous listening') that are interpreted and carried out by Amazon's cloud-based intelligent personal assistant service "Alexa", and through which Echo carries out voice interaction, music playback, provider of information like weather and traffic, and also controls other IoT devices (Jackson and Camp, 2018). |
| Data | Actual bits and bytes. Raw data, big data | Temperature, friction, current, location, vibration | Some of the data stored in Alexa includes the user's history data, data on interactions with Alexa (e.g. user behaviour, user activity), account information, customer setting, Alexa-associated devices (Li et al., 2019). |
| Ubiquitous | The data needs to be available anywhere, but not necessarily everywhere. | Geographically, preferably real-time and openly | Echo has a complex cloud ecosystem that allows ubiquitous use of Alexa (Chung et al., 2017). It constantly scans for user voice commands to perform tasks. This is also referred to as 'ubiquitous listening' (Hui and Leong, 2017). |
| User | The human-to-machine interaction | The person(s) using Alexa's assistance | The user finds Alexa's assistance valuable, and thus is willing to buy one, create data by using it and trusts the system does not |
| Unique | All objects and things must be uniquely identified for data collection and analysis purposes. | An IP address | Amazon Echo has a unique IP address. |

the value companies and consumers see may be either monetary or non-monetary – in some cases, even both. Thus, when designing the IoT, different ways to create and capture value should be evaluated – not only from the designer point of view but considering the needs of all the different potential stakeholders.

All the identified categories should be included when designing IoT systems. However, as there are already many different technologies available, IoT developers should change their focus from technology to value offering. Thus, we propose a design process that is depicted in Fig. 6 and elaborated below.

While IoT is known to have implications for the individual and right up to the societal level, IoT system design should first start by defining the kind of value that is exchanged by describing the services offered. The second step is to analyse what kind of information is needed to create value and which physical object(s) can obtain it. This leads to the requirements for data. Third step focuses on the nature of the data: to define the risks related to that specific type of data and to plan data security accordingly. In the fourth and final step the technical

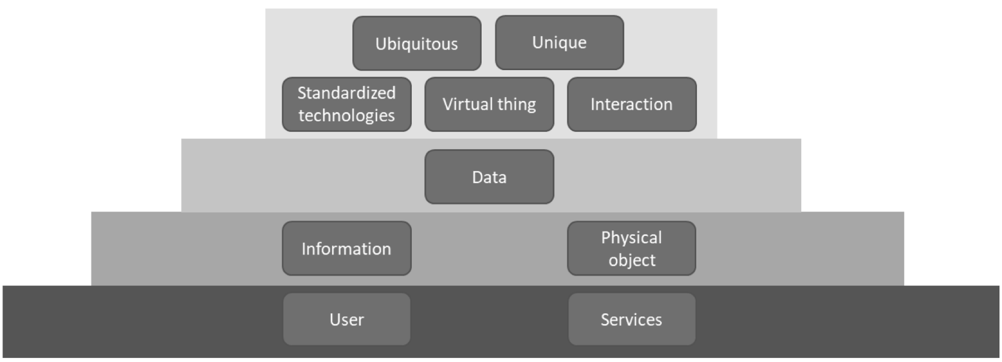


**Fig. 6.** Design flow for a value-based IoT system.

implementation is planned: which types of actuators, which protocols, etc.

Sometimes it is more intriguing to discover what is not included in descriptions. Relatively few of the publications emphasise the importance of safety and security. This refers to data security, privacy, and safety and control.

(1) Security: In these days of mis- and disinformation and other questions regarding data sovereignty and provenance, the importance of security issues can be expected to increase in the future. While the data in this study did not identify the importance of security and privacy, these aspects should be properly evaluated when designing the IoT. The magnitude of cyber risks is difficult to define, but nonetheless, without proper risk analysis, companies may face lethal attacks. Luckily, some risk assessment frameworks have already been developed, but impact evaluation models are still needed (Radanliev et al., 2018). Perhaps the first security risks that come to mind are cybersecurity attacks. A cyber-attack can affect operational continuity, control integrity, intellectual property, strategic information, identifiable business information, personally identifiable information or payments. According to Jacobs et al. (2016), income, assets, equity, growth, market share and liquidity are all jeopardised if a cyber attacker penetrates an IoT system.

(2) Privacy: Oriwoh et al. (2013) points out that there are four different privacy concerns: socio-ethnic, legislation/regulation, economic and technological – all of which need to be resolved. Hence, many parties (technology vendors, governments and the public) should be interested in resolving these challenges. Glova et al. (2014) draws attention to intellectual property rights and defining data ownership. They also raise concerns regarding data management, especially data privacy. While some data can – or even should – be open, some data (like health data) should be shared on a need-to-know basis. Data usage policies are needed to ensure data sovereignty and provenance, especially when data is stored and processed in clouds (Baracaldo et al., 2017; Biswas and Mukhopadhyay, 2018), as is often the case in IoT systems. Data provenance, integrity, correctness and privacy enforcement are important from the legal perspective and from an ethical perspective (Baldini et al., 2018).

(3) Safety (e.g., as in traffic safety): Now that autonomous vehicles are closer than ever, it is of utmost importance to ensure that the vehicles make correct decisions and are not attacked by cybercriminals, causing traffic accidents. Machines operated by the IoT or artificial intelligence need to be safe for use by the public (Chan, 2015).

While Haller et al. (2009) mention security and privacy issues in their description of the IoT, they fail to explain what they mean in detail. Vermesan et al. (2009), however, give a detailed description. They divide security, privacy and safety into four types: economic and market, social and ethical, technical, and legal and regulatory types. The economic and market issues include codes of conduct, privacy certifications and standards. Social and ethical issues cover consumer rights, public awareness and anonymity mechanisms. Legal and regulatory issues ensure safety and security by consent, use and collection limitations, openness, accountability and agreed data ownership principles. The largest group of security, safety and privacy issues are included in the technical section. These include technological safeguards, encryption, accessibility, data integrity and ID management. This presents the diversity in the meaning of security well, but it still omits the physical safety aspects in an environment where autonomous cars and robots are present.

## 6. Conclusions and future work

Jacobides et al. (2018) describe ecosystems as an economic community where interacting, interdependent participants commercialise innovation. While most of the definitions do not include business as a part of the IoT, we consider the IoT to be an entity and that it can be an ecosystem and thus a business enabler. Interaction, data and services are the means for achieving new types of shared and exchanged value. We also claim that the IoT is a system. It collects input (data with sensors), processes it (interaction, information) and delivers output (services) to "serve a common purpose", thus fulfilling the traditional definition of a system (Merriam-Webster, 2019)

Based on our study, we propose that all ten of the categories be included in the IoT framework. Consequently, the two most comprehensive existing descriptions (the CERP-IoT report by Vermesan et al. (2009) and a definition written by Minerva et al. (2015), which are shared by the IEEE IoT initiative) are both valid. Hence, as a conclusion, our framework in the form of a list of ten categories with explanations and examples is proposed for the development and implementation of new IoT systems. Everything starts from the value it adds and ends with the details of technical implementation.

There are some limitations to this study. First, the research design relies heavily on selected databases. Hence, to improve the credibility through data collection triangulation, this research employed several different data sources. An important design issue was the selection of Google Scholar as the first source of literature, "the seed" input. It is difficult to estimate how much the results might have changed if the seed source had been different. Second, the literature was collected by snowballing, where credibility relies strongly on the credibility of the start set. To minimise this potential risk to credibility, the source set for snowballing was taken twice, 30 months apart and then combined. The source set was deliberately relatively large and heterogeneous to increase the credibility. However, due to the enormous number of citations in some of the source articles, the research team may have missed some descriptions. Nonetheless, 122 descriptions are likely to give a reasonably valid result. Third, the credibility was also improved through scrutinizing the preliminary findings against the raw data. Furthermore, a conceptual study also relies a lot on the meaning of the concept, and the IoT is a typical "suitcase word" that carries many meanings. The thematic analysis mostly focussed on the descriptions. On the one hand, this ensured that the core of the sources' message was emphasised, but it also may have neglected the rest of the texts. This may have caused bias to the emphasis of the categories. To reduce the risk to credibility caused by this, the literature review was conducted by all three authors and the analysis phase by two researchers.

To increase the confirmability, the research process and used methods have been described in detail to enable repeatability of the research method. This will also improve the transferability of the research process to other underdefined concepts. Due to the rapid development of the IoT and IoT-related matters, the timing of the study may cause some unavoidable source of maturation bias. Thus, replicating studies to this review would be welcomed.

From the dependability point of view, there is a clear conflict in the sample used in this study on what to include in the IoT. Some scholars include a business model (e.g., Meyer et al., 2013), whereas others leave it out (e.g. Khan et al., 2012). Based on this study, many scholars consider business to be outside the IoT concept, hence the business is built *on* the IoT, not *in* the IoT. However, the value offering should be identified to understand what kinds of services are needed to enable business.

IoT applications already exist for environmental monitoring systems, smart energy grids and multiple industrial automation systems (Tarkoma and Katasonov, 2011). As we are on the verge of having autonomous cars and even autonomous ships, various safety and security issues also need to be considered (Gubbi et al., 2013; Stankovic, 2014). It is assumed that their importance will only increase. Therefore, the focus on designing the IoT should also be converted from "bits and pieces" towards system-level service and security issues.

The ITU vision of "anytime, anywhere, by anyone and anything" remains valid. To achieve this, an IoT business should be sustainable. Services, data and security are cornerstones in accelerating the expansion of IoT utilisation. Consequently, IoT development must be value-based. In the future, we propose more research be conducted on how IoT systems are currently created and what kinds of benefits if any, are offered by a value-based development process.

Our research has shown that there is considerable ambiguity in the definition of IoT. In this paper, we have reviewed existing definitions and have developed a unifying framework to support the development of a comprehensive definition. One direction for future research is the development of a classification scheme for IoT with a controlled indexing language. The IoT classification scheme could consist of an index of terms for the identification of the different categories defined in our framework (and indeed extending it to new categories and sub-categories). Such a scheme will limit the chances of ambiguity and help towards the development of a common language for IoT. This would be like other domain-specific classification schemes, for example, the 2012 *Association for Computer Machinery (ACM) Classification Scheme* (ACM, 2020). Other widely used and accepted, domain-specific classification schemes are the *American Institute of Physics' (AIP) Physics and Astronomy Classification Scheme* (AIP, 2020) and the *American Mathematical Society's 2000 Mathematics Subject Classification* (AMS, 2020). Barki et al. (1988, 1993) developed a classification scheme for Information Systems. Mustafee and Katsaliaki (2020) have also developed a classification scheme for Operations Research/Management Science (OR/MS), with the aim of recognising the considerable overlap of OR/MS tools and techniques with those used in disciplines like Industrial Engineering, Operations Management, Computer Science and Statistics.

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## Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.techfore.2022.121623.

## APPENDIX 1

List of articles included in the start set.

| Author | Title | Year |
|---|---|---|
| Alam et al. | IoT virtualisation: a survey of software definition & function virtualisation techniques for Internet of Things | 2019 |
| Asemani et al. | Understanding IoT platforms: towards a comprehensive definition and main characteristic description | 2019 |
| Atzori et al. | Siot: Giving a social structure to the Internet of Things | 2011 |
| Atzori et al. | Understanding the Internet of Things: definition, potentials, and societal role of a fast-evolving paradigm | 2017 |
| Ben-Daya et al. | Internet of things and supply chain management: a literature review | 2019 |
| Boyes et al. | The industrial Internet of Things (IIoT): An analysis framework | 2018 |
| De Leusse | Self-Managed Security Cell, a Security Model for the Internet of Things and Services | 2009 |
| Dorsemaine et al. | Internet of Things: a definition & taxonomy | 2015 |
| Duan et al. | A QoS architecture for IOT | 2011 |
| Fleisch | What is the Internet of Things? An Economic Perspective | 2010 |
| Floris & Atzori | Quality of Experience in the Multimedia Internet of Things: Definition and practical use-cases | 2015 |
| Jia et al. | IoT business models and extended technical requirements | 2011 |
| Ju et al. | Prototyping Business Models for IoT Service | 2016 |
| Kebane, Ray | A generic digital forensic investigation framework for Internet of Things (iot) | 2016 |
| Khan et al. | Future internet: The Internet of Things architecture, possible applications and key challenges | 2012 |
| Krco et al. | Designing IoT architecture(s): A European perspective | 2014 |
| Li & Xu | Research on business model of Internet of Things based on MOP | 2013 |
| Meddeb | Internet of Things standards: who stands out from the crowd? | 2016 |
| Mejtoft | Internet of Things and co-creation of value | 2011 |
| Meyer et al. | Internet of Things-aware process modelling: integrating IoT devices as business process resources | 2013 |
| Patel &Patel | Internet of Things-IOT: definition, characteristics, architecture, enabling technologies, application & future challenges | 2016 |
| Radanliev et al. | Definition of Internet of Things (IoT) Cyber Risk–Discussion on a Transformation Roadmap for Standardisation of Regulations, Risk Maturity, Strategy Design and Impact Assessment | 2019 |
| Rayes & Salam | Internet of Things (IoT) overview | 2019 |
| Stancovic | Research directions for the Internet of Things | 2014 |
| Thoma et al. | On iot-services: Survey, classification and enterprise integration | 2012 |
| Uckelman et al. | An architectural approach towards the future Internet of Things | 2011 |
| Weber & Boban | Security challenges of the Internet of Things | 2016 |
| Xu et al. | Ubiquitous data accessing method in IoT-based information system for emergency medical services | 2014 |
| Zhang et al. | IoT security: ongoing challenges and research opportunities | 2014 |

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# PUBLICATION VI

**Tale of two smart cities: Building value from an IoT ecosystem**

Sorri K., Yrjönkoski K., Seppänen M.

In review