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Business Model Frameworks in IoT Context -- A Literature Review

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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).

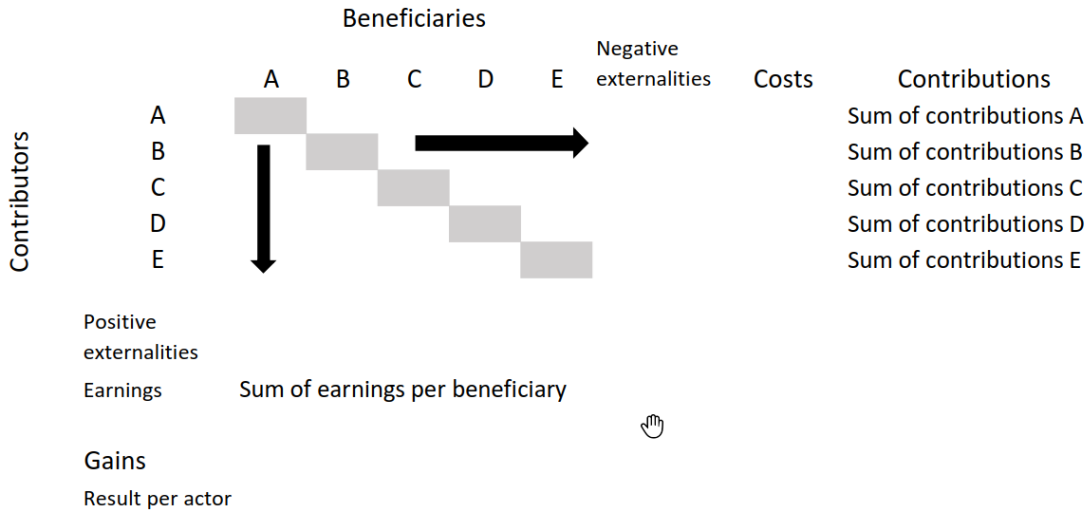
Chan (2015) has created a framework on top of the IoT architecture stack. He proposes that the business model is designed around the "IoT strategy category and value chain". Table 1 illustrates the structure. Each of the members of the value chain is evaluated separately. For example, in the input column 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. 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, such as control, expertise, (peer-) physical capital etc.
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 "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