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Business models for the Internet of Things

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ABSTRACT

The Internet of Things is the connection – via the internet – of objects from the physical world that are equipped with sensors, actuators and communication technology. This technology is looked at by a large variety of domains, such as manufacturing, healthcare and energy, to facilitate the development of new applications and the improvement of existing applications. To also enable the commercial exploitation of these applications, new types of business models must be developed. Frameworks exist to facilitate the development of business models. These frameworks define the building blocks that a business model address. This paper presents a business model framework specifically for Internet of Things applications. Through a literature survey, interviews and a survey among practitioners, it identifies the building blocks that are relevant in an Internet of Things business model, types of options that can be focused on within these building blocks and the relative importance of these building blocks and types. The framework can be used by developers as a starting point for creating business models for Internet of Things applications.

1. Introduction

The Internet of Things (IoT) refers to the interconnection of physical objects, by equipping them with sensors, actuators and a means to connect to the Internet. By technologically enabling this, the goal is to develop new applications and to improve existing applications. Famous examples of IoT applications include monitoring of personal health through wearables, washing machines that enable you to pay per load instead of for the machine, greenhouses that adapt their internal climate to the monitored properties of the crops that grow inside, and stables that adapt feeding and milking schedules to monitored properties of individual cows.

The IoT is currently going through a phase of rapid growth. The number of connected ‘things’ has increased threefold over the past five years (Digitimes, 2013) and is estimated to be 4.9 billion in 2015 (Gartner, 2014). As a consequence, organizations expect the IoT to become an important source of revenue. Cisco estimated that the global IoT market will generate $14 trillion in profit over the next decade (Bort, 2013) and Gartner (2013) predicts that the total global economic added value for the IoT market will be $1.9 trillion dollars in 2020.

The Economist Intelligence Unit (2013) stated that the biggest incentive for businesses to move ahead with the IoT are arguably the potential financial returns from its “productisation”. In other words, for the Internet of Things to be fully adopted by businesses, financial returns are key. Therefore, business models and ways to create value for IoT technology are needed. However, in spite of the thought that along with the introduction of the Internet of Things new revenue opportunities will rise and old business models will not be applicable to do so, the question what business models will be applicable remains (The Economist Intelligence Unit, 2013). Moreover, as our literature review in Section 2 of this paper will show, there currently exists little academic knowledge on how business models for IoT applications differ from business models for other application and how they should be constructed.

This paper aims to fill that gap, by presenting a framework for developing business models for IoT applications. The framework is created based on a literature survey into existing business model frameworks and subsequently adapting these frameworks based on interviews in 11 companies that develop IoT applications. Finally, the relative importance of the different parts of the framework for IoT applications are determined through a survey with 300 respondents resulting in 72 observations. By doing so, the contribution of this paper is a novel business model framework for IoT applications that is both grounded in literature and in interviews and a survey among IoT professionals.

Against this background the rest of this paper is structured as follows. Section 2 presents existing business models for IoT

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applications from literature. Section 3 presents our research method, Section 4 the data analysis, Section 5 the results, Section 6 a discussion of the results and Section 7 the conclusions.

2. Existing business models for the Internet of Things

A business model is an overview of the manner in which a company does its business. "*It is a description of the value a company offers to one or several segments of customers and of the architecture of the firm and its network of partners for creating, marketing, and delivering this value and relationship capital, to generate profitable and sustainable revenue streams*" (Osterwalder, Pigneur, & Tucci, 2005). Business models are usually split into various components (Chesbrough & Rosenbloom, 2002; Morris, Schindehutte, & Allen, 2005). The most widely used components in the business model literature are customer segments, value propositions, channels, customer relationships, revenue streams, key resources, key activities, key partnerships, and cost structure (Osterwalder et al., 2005).

A business model framework is a tool that helps a company to develop its business models, by providing an overview of these components. To develop a framework for business models for IoT applications, we initially searched for existing business models for IoT in literature with the aim of generalizing them into a framework. To conduct this search, we used the keywords "Internet of Things" AND "business model*"; searching the ACM Digital Library; IEEE Explore; Science Direct; Springer and Web of Science. With these search terms; we only found 20 papers. From these papers; we selected the ones that contained an actual business model; which led to only 5 papers. Two of these papers developed their business model; based on a business model framework called the Business Model Canvas (Osterwalder & Pigneur, 2010); which; in turn; is synthesized from a large number of similar frameworks (Osterwalder, 2004).

Table 1 shows the components that are covered by the various business models. These components are the partners, activities and resources that are key to produce and sell the product, the value that the product brings, the way in which the relation with the customer is built, the channel through which the product is sold, the types of customers that the product targets, the way in which costs are incurred and the way in which revenue is made. The table shows that the two models that are based on the Business Model Canvas cover all components of that framework. The models by Fan and Zhou (2011) and Liu and Jia (2010) cover a subset of these components. Li and Xu (2013) use different terminology to introduce their business model and primarily focus on the different stakeholders in developing an IoT platform and the activities that these stakeholders should perform. When developing the business model framework for IoT applications in this paper, we take the Business Model Canvas as a starting point, because two of the five business models for IoT applications that we found in the literature are based on the Business Model Canvas and because the Business Model Canvas itself is based on a meta-analysis of business model framework literature. We also apply the Business Model Canvas terminology by labelling the business model components 'building blocks'. A business model is constructed by choosing one or multiple specific 'types' for each building block. For example, 'Asset Sale' is a type of the building block 'Revenue Stream' that can be used to construct a business model.

3. Empirical research methodology

The overall goal of this research is to create a framework for developing business models for IoT applications and considering the literature survey described in the previous section shows that a business model framework has building blocks that are developed by specific building block types. Therefore, we use an empirical research methodology to identify the building blocks and building block types for business models for IoT applications. Subsequently, we determine which building blocks and specific types are considered significantly more important than others for developing business models for IoT applications.

The literature survey from the previous section shows that the research area of IoT business models is relatively unexplored; five IoT business models exist in literature and these have not been empirically validated. Therefore, we choose a sequential exploratory research design, based on the approach proposed by Teddlie and Tashakkori (2006), that is useful for exploring relationships when study variables are not known (Hanson, Creswell, Clark, Petska, & Creswell, 2005). In a sequential exploratory research approach qualitative data are collected and analyzed first, followed by collection and analysis of quantitative data. Afterwards, the inferences of both strands are integrated in one discussion. The sequential use of two different methods increases construct validity (Greene, Caracelli, & Graham, 1989), and ultimately leads to stronger conclusions (Teddlie & Tashakkori, 2006).

In particular, we continue as follows. First, we identify building blocks and specific building block types using literature and interviews with professionals who work on IoT business models. Subsequently, we determine the relative importance of the identified building blocks and types using the results of a survey contrasted with the results of the interviews.

4. Data and analysis

This section analyses the data that is collected to determine the building blocks and specific building block types for business models for IoT and to determine their relative importance.

4.1. Interviews

In line with the motivation for using the Business Model Canvas as a starting point for developing a framework for IoT business models, we develop an interview protocol based on the Business Model Canvas. The interview is semi-structured and aims to ask practitioners working on IoT business models about the completeness and correctness of the building blocks and types for IoT business models identified in the Business Model Canvas. The questions are based on the questionnaire developed by Osterwalder and Pigneur (2010, p. 19–42). Appendix A shows the complete interview protocol.

Participants were searched in the following ways:

A. Referrals from business network
B. Referrals from IoT specialists
C. Contact for IoT company found on the internet
D. Referrals from prior interviewees

As a result, 11 interviews were planned as shown in Table 2.

Table 3 shows the descriptive statistics of the interviews. It shows the sector in which the company of the interviewee operates, the size of the company, the type of clients of the company, whether the IoT offering that is considered in the interview (see Table 2) is primarily a product, a service, or both, and the number of years that the company is offering the product or service. The interviews were transcribed, sent back to the interviewees for verification, and coded. The interviews were used to complete and adapt the types of an IoT business model, by adding, removing, splitting or merging types, or by proposing an alternative classification for a type. Appendix B shows how these changes were made. It also

Table 1
Components covered in IoT business models.

	Sun, Yan, Lu, Bie, and Thomas (2012)	Bucherer and Uckelmann (2011)	Fan and Zhou (2011)	Liu and Jia (2010)	Li and Xu (2013)
Key partners	X	X	X	X	X
Key activities	X	X		X	X
Key resources	X	X			
Value propositions	X	X	X		
Customer relationships	X	X			X
Channels	X	X			
Customer segments	X	X	X	X	X
Cost structure	X	X			X
Revenue streams	X	X	X	X	X

Table 2
Interviews per company.

Interview number	Company	Sector	IoT application	Way of finding
1	Focus Cura	Healthcare/independent living	'ThuisMeetApp'	A
2	Dutch Domotics	Healthcare/independent living	'Zorgdomotica'	A
3	Hoogendoorn	Agriculture	iSii compact	C
4	Essent	Energy	e-Thermostat	A
5	Bundles	Smart home	Washbundles	D
6	Blinq Systems	Smart buildings	MapIQ	A
7	Ambient systems	Supply chain	Ambient supply chain	B
8	GSETrack	Transportation	GSETrack	C
9	Prometheus	Supply chain	Telematica	B
10	Philips	Smart home	Philips Hue	A
11	Mieloo & Alexander	Supply chain	ScanGreen	A

Table 3
Descriptive statistics interviews.

	Number of companies
Sector	
Agriculture	1
Energy	1
Healthcare	2
Smart home	2
Smart buildings	1
Supply chain	3
Transportation	1
Size	
Micro (<10 employees)	5
Small (10–50 employees)	2
Medium (50–250 employees)	2
Large (>250 employees)	2
Clients	
B2B	8
B2C	3
Product or service	
Product	4
Service	2
Both	5
Offering age	
<1 year	3
1–5 years	6
5–10 years	1
>10 years	1

shows how frequently a particular type was mentioned during the interviews.

4.2. Survey

A survey was used to ask the opinion of IoT professionals about the importance of each building block and each type. To this end, as suggested by Dillman (2000), we asked on a Likert scale whether respondents 'strongly disagree', 'disagree', were 'neutral' about the statement, 'agree', or 'strongly agree' that a selected building block or type should be incorporated into a business model.

In addition to that, we asked demographic questions and questions about an IoT initiative or project that the respondent had been involved in, if applicable. A pilot with six participants was performed. Apart from spelling errors, minor improvements for understandability and layout, no significant changes were made. The questionnaire is included in Appendix B.

An online survey was the most appropriate option to reach out to the target group. The survey was distributed online in various IoT focused groups on LinkedIn, Facebook and MeetUp. In addition, mailing lists, intranet posts, and e-mails in one of the authors' business network were used to distribute the survey. Ilieva, Baron and Healey (2002) present that the average response time in online surveys is 5.59 days. To take some slack into account, the survey was kept online for two weeks.

The survey resulted in 300 responses, of which 96 were completed. All partially completed cases in which all the core questions on the building blocks were completed were added, which resulted in a total of 103 cases.

We analyzed the data for various potential problems. First, a check on double IP addresses in the cases revealed no cases of respondents who intentionally took the survey twice. Second, the time spent to take the survey was checked for all cases. Since the tests on the survey pointed out that taking the survey appropriately took about 15 min, every case which was finished in under 10 min was not considered to be valid. Based on this criterion, 24 cases were deleted. Per building block, the standard deviations of the types were calculated (the question on the importance of each building block was also added). If a standard deviation is 0, this implies that the respondent filled out all factors within that building block with the exact same value. This could of course be honest and intentional. However, in 7 cases this happened multiple times, which raises the suspicion that respondents filled out the questions without the intention of giving appropriate answers. Deleting those cases left 72 observations for our analysis.

Because of the way in which we distributed our survey – by sending our survey to a large number of internet forums and e-mail lists – and the low response rate that we assume to be associated with this, we could have a non-response bias. Therefore, we check for differences between answers of early responders and late

Table 4
Descriptive statistics survey respondents.

Gender		
Male	63	88%
Female	6	8%
Not specified	3	4%
Age group		
18–24	1	1%
25–34	23	32%
35–54	36	50%
55+	10	14%
Not specified	2	3%
Education		
No degree	2	3%
High school	5	7%
Bachelor	6	8%
Master	48	67%
Doctorate	9	13%
Not specified	2	3%
Expertise		
Yes	49	68%
No	23	32%
Country of origin		
The Netherlands	32	44%
USA	13	18%
Germany	3	4%
India	3	4%
Austria	3	4%
Other (13) countries	18	25%

responders (Armstrong & Overton, 1977). Analyzing the skewness, kurtosis and normality on the differences and *t*-tests on the means of early responders (responded in first week) and late responders, we find no significant differences between the early and late responders. Therefore, we conclude that the risk of a non-response bias is low.

Table 4 shows the descriptive statistics of the respondents of the survey. 88% of the respondents of the survey is male (to compare, in 2012 in the USA the number of females enrolled in computer and information science Bachelor degree was 18% (National Center for Education Statistics, 2012)). Furthermore, respondents are relatively young and highly educated. Although respondents originate from various countries, The Netherlands and USA seem overrepresented. According to Hofstede (1980), the culture of The Netherlands and the USA are quite similar and both cultures are very different from other cultures such as Asian and South American culture. Therefore, we should be cautious with generalizing the conclusions of this paper to IoT business models developed around the world. To determine which building blocks and which building block types are considered more or most important, we use one sample *t*-tests (two tailed, $\alpha = 0.05$). Due to the likert scale answer format, our data is not normally distributed and also not homogenous in its variances. However, given our sample size, our sample is robust to these violations of normality (Bartlett, 1935).

5. Results

Based on the analysis described in the previous section, we first present a business model framework for IoT business models by showing the building blocks of such a business model and the identified types for the building blocks. Second, we present the relative importance of the building blocks and types.

5.1. Overall business model framework

Fig. 1 shows the business model framework for IoT applications that was derived from literature (see Section 2) and interviews with practitioners in the IoT domain (see Section 4.1). The building blocks that were identified in the first five interviews were used to adapt the types that were identified by Osterwalder and Pigneur (2010), by adding new types to the list, splitting up a type into multiple more detailed types, merging types into one more abstract type, or providing an alternative classification of types for a building block. The figure shows the building blocks that constitute an IoT business model (key partners, key activities, key resources, value propositions, customer relationships, channels, customer segments, cost structure, and revenue streams) and the possible types for each building block. A type that is marked with a gray background represents a type that was added based on the interviews.

Subsequently, we ran an exploratory factor analysis based on the survey data to explore whether unobserved factors are underlying the added building block types of the most modified building blocks (key partners, key activities, key resources, and cost structure). The Kaiser–Meyer–Olkin measure of sampling adequacy ranges from miserable (0.55) to middling (0.70), but exceeds the 'unacceptable' threshold in all cases (Kaiser, 1974). We only select factors with an eigenvalue larger than 1. Since postestimation analyses indicate correlation between the factors, we apply oblique (promax) instead of orthogonal rotation to facilitate interpretation of these factors.

In the key partners block, two factors emerge. the first factor is oriented towards transportation, and contains the types distributors, logistics, and service partners. The second factor is oriented towards upgrading towards IoT, and contains hardware producers, software developers, and data interpretation. In the key activities block, a two factor solution emerges as well. The first factor consists of the types marketing and sales and is clearly oriented towards these activities. The second factor consists of product development and implementation and is interpreted as research, development, and engineering. The factor analyses of the building blocks key resources and cost structure each yield only one factor with an eigenvalue larger than 1, and do not result in interpretable factors. Appendix D contains the tables with factor loadings for the key partners and key activities building blocks.

5.2. Relative importance of building blocks and types

Fig. 2 shows the relative importance of the building blocks, as measured through the survey, together with their 95% confidence intervals and the average score over all building blocks. The survey respondents indicated value proposition as the most important building block for IoT business models, as it scored significantly higher ($\bar{x} = 6.38$) than all other building blocks at the <0.01 level of significance. Furthermore, the measured differences between the importance of the other building blocks is low, although channels are considered significantly less important at the <0.02 level of significance. Interviewees mainly indicate the building blocks value proposition (9 times), customer relationships (6) and key partners (5) to be among the most important in their business models for IoT applications. Thus, the results from the interviews support the results from the survey.

Fig. 3 shows the relative importance of the specific types within the building blocks. The types are ordered according to the score that they received from the respondents. Types that score significantly more important than the average score in a building block are above or to the left of the grey area. Types that are considered significantly less important than other types are below or to the right of the grey area. All reported differences are significant at the <0.05 level, but most are even significant at the <0.01 level.

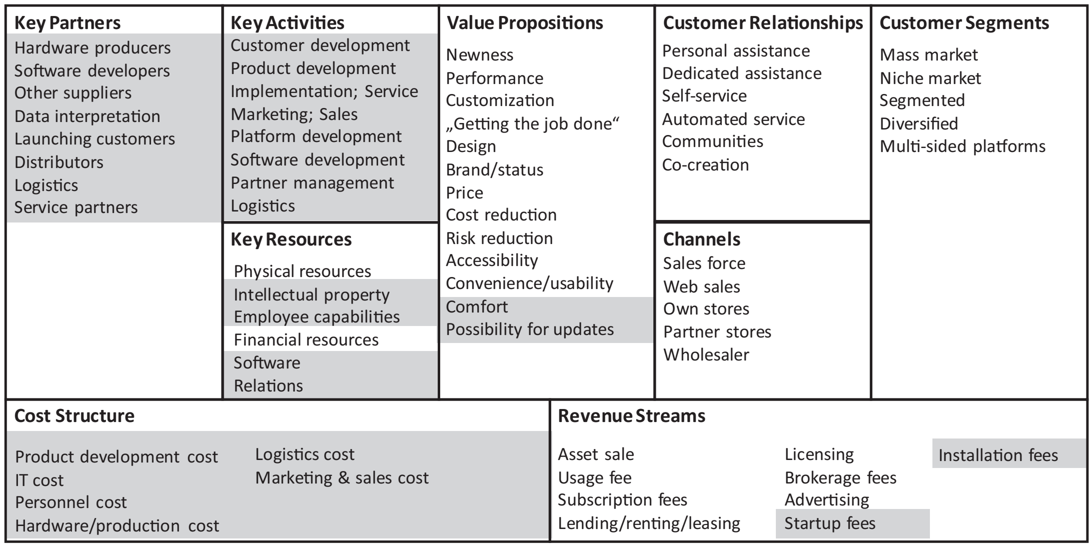

Fig. 1. Business model framework for IoT applications

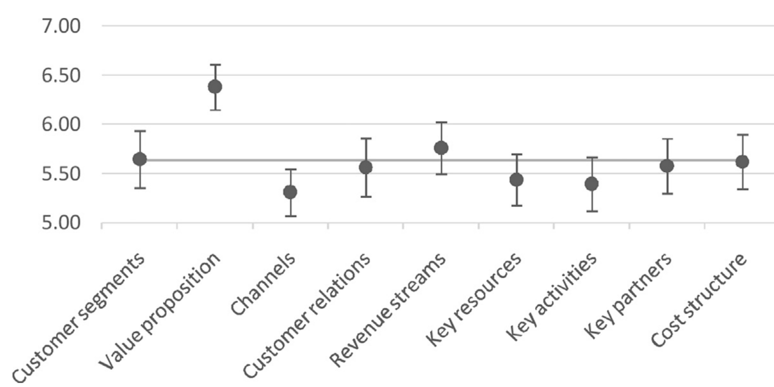

Fig. 2. Relative importance of building blocks.

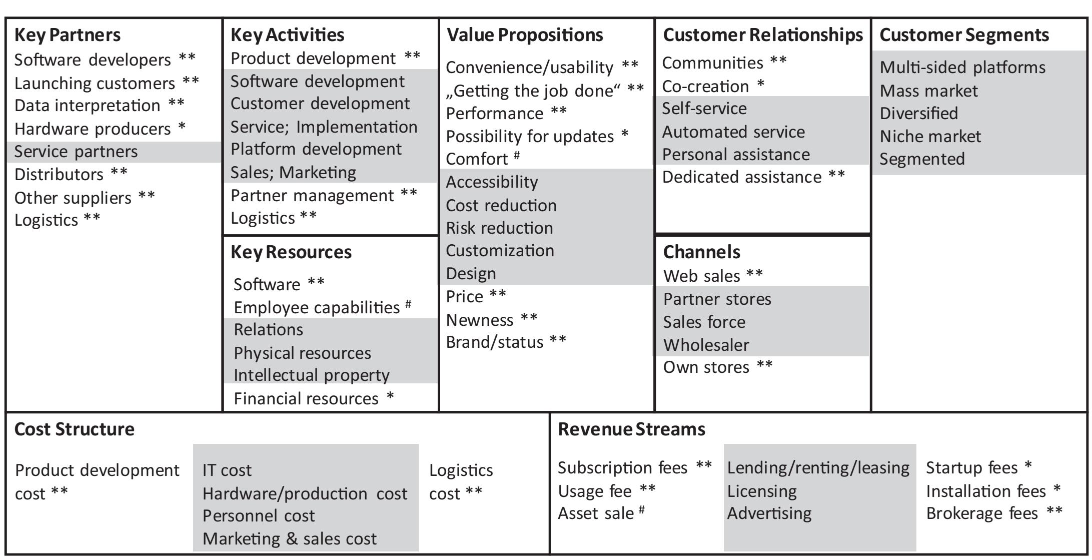

Fig. 3. Business model framework for IoT applications with relative importance of specific types. #<0.05 significance, *<0.02 significance, **<0.01 significance.

In an attempt to determine whether there are any logical clusters in the data that form coherent business models, we determined the positive correlations between all of the types. The results of this are shown in Appendix E. These results should be seen as exploratory.

6. Discussion

The survey indicated that the value proposition is the most important building block in IoT business models, which resembles the central role for this building block in the literature (Chesbrough & Rosenbloom, 2002; Morris et al., 2005). It is also in line with the result from the interviews; the interviewees indicated that value proposition was the most important building block. Besides the value proposition, the customer relationships and key partnerships are also considered to be important building blocks in IoT business models. This result is also amplified by the fact that in 4 of the 11 interviews the specific combination of these three building blocks was most important in their business model.

Within the value proposition block, the types convenience, performance, getting the job done, comfort and possibility for updates were indicated most important by the survey respondents. For the first two types, the interview results were accordingly (respectively 10 and 7 of the 11 companies indicated the presence of the types in their business models). For the second two types getting the job done and comfort, the interview results did not match (respectively 2 and 1 of the companies indicated the presence of the types in their business model). Strikingly, 7 of the 11 interviewed companies indicated cost reduction to be present as a type of their value proposition, but the survey did not confirm these results. Openshaw et al. (2014) argued that cost reduction in IoT business models is not bad, but it also is not enough. Businesses should extend from cost reduction models to exploring revenue models, such as additional revenues from the data being generated. This implies that, although cost reduction is not the only possible type of value proposition, it belongs to the most important value proposition types.

In the customer relationships block, a split is noticeable. The survey results indicate that IoT applications will be mostly focused on co-creation and communities, and 4 of the 11 interviewed companies pointed out to use co-creation in their business model For instance, Philips indicated to use of co-creation as type of customer relationship for their IoT product ‘Hue’, since customers can design their own light recipes. Mieloo & Alexander indicated that co-creation is only used in the development phase of their product. Communities were however indicated to be used by only 1 of the 11 companies. Another focus within customer relationships is on the self-reliance that can be achieved with IoT products: 7 of the 11 companies indicated that the relationship type self-service is present in their business model. The survey results confirm this, since the type is scored higher, though not significantly higher, than the average in the building block and significantly higher than 2 of the 5 other types. Lastly, the data generated by IoT applications enables customer involvement, among which on an individual basis. For instance, conventional washer manufacturers only have after sales customer contact when the machine breaks down. In the business model of Bundles, which offers a connected washer, customers get monthly feedback about their washing behavior. Furthermore, where customers of Essent used to see their energy usage once a year, the E-thermostat currently enables customers to monitor their use of energy daily. This finding is in line with Hui (2014): IoT business models add personalization and context through information gained over time. Access to the customer data enables quicker and more personalized customer contact.

Key partnerships is the third and last building block that is considered more important than the others in IoT business models. The survey results indicate that software & app developers, launching customers, hardware partners and data analysis partners are the most important partnerships types to shape in IoT business models. The interview results confirm the first three, as respectively 8, 9 and 10 of the 11 interviewed companies pointed out that these types are among the key partnerships in their business models. Combined with the results of our factor analysis, these results hint at that incorporating IoT products in the product portfolio is a specialization that is (partly) acquired by outsourcing. For instance, Bundles argued that it is not possible to build your solution alone and IoT companies will have to outsource also crucial activities to partners. This corroborates Quinn's (2000) observation that innovations combining software and technology are prone to be outsourced.

However, this also points out an increasing complexity in partnerships in business models for IoT applications (Hui, 2014). An additional question in the survey shows that respondents agree with the statement that the partner structure of IoT applications' business models is more complex than the partner structure of conventional business models ($\bar{x} = 5.43$). Moreover, Mieloo & Alexander stated that partnerships are becoming crucial and that more collaboration causes long term relations, information sharing and joint cost reduction. Thus, understanding how others in the ecosystem make money becomes important for achieving long-term success.

As expected the correlation results from Appendix E show that types from the same building block correspond far more often to each other than types from different building blocks. They also show logical correlations between key activities, key partners and cost, when it comes to hardware development, software development and logistics (i.e. if hardware development is more important as an activity, it is also more important as a cost factor and in key partnerships). Zooming in on particular value propositions also provides some potentially interesting insights. For example, the value proposition ‘comfort’ seems to be related to outsourced software and hardware development, with the service delivered by the company itself and revenue collected through asset sale, via partner stores and wholesalers. However, these results should be seen as exploratory and require further research.

7. Conclusions

This paper presents empirical research that leads to a framework for business models for Internet of Things applications. Using a literature survey, interviews and a survey among 300 respondents that led to 72 observations, we established the building blocks of a business model and specific types within those building blocks. Subsequently, we established the relative importance of those building blocks and types.

Our research is subject to some important limitations. First of all, although our study yields novel and insightful results for IoT business models, the downside of our wide exploratory research approach is that it lacks the finesse of a more detailed approach whereby a specific building block or industry sector is targeted. Such a study would result in more specific recommendations, albeit for a narrower target group. Moreover, the relatively low number of observations prevented us from doing a factor analysis on all building blocks and types, which could have revealed important insights into patterns of various business models. Lastly, as mentioned before, our respondents the majority of our respondents is based in the USA or the Netherlands. Our results thus should not be generalized to dissimilar cultures and economies.

Notwithstanding these limitations, however, we believe our research also has some important contributions. For academics, this research project contributes by filling the literature gap regarding IoT business models and can serve as starting point of future research on IoT business models. It is the first study that extensively maps which building blocks are most important, what types are used to shape IoT business models blocks, and which types within the building blocks of IoT business models are important. Moreover, based on the Business Model Canvas, it proposed and validated a measuring instrument to determine how IoT business models are configured. For practitioners, this research project helps managers in their decisions on how to construct the business models of their future IoT applications. When a company decides to apply IoT technology into a specific proposition, this study serves as a tool to guide on how the IoT application's business models could be configured.

Based on a mix of quantitative and qualitative research, we have identified the most important building blocks for business models for IoT products. Furthermore, we have extended and adapted the Business Model Canvas (Osterwalder & Pigneur, 2010) by identifying building block types that are especially relevant for IoT business models. We hope our findings help practitioners and academics in developing, designing, and studying IoT business models in more specific settings.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.ijinfomgt.2015.07.008

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