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INTERNET OF THINGS-BASED PRODUCTS/SERVICES: PROCESS AND CHALLENGES ON DEVELOPING THE BUSINESS MODELS

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ABSTRACT

Many companies nowadays are struggling to understand the unprecedented complexity of developing business models for products and services based on the Internet of Things (IoT). This article aims at investigating what are the elements to be taken into account in order to create a business model for IoT-based products/services and what are the main challenges faced in this process. To address these questions, we review the literature on the creation of business models for the IoT and we analyze data from an action research involving the generation of a business model for an IoT-based product - a smart door lock – in a small company. We explore how this process occurred and the challenges faced.

Keywords: Internet of Things, Business Models, Business Model Canvas, Challenges.

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INTRODUCTION

The technologies of the Internet of Things (IoT) are increasingly embedded in previously non-digital products of everyday life, which impacts the nature of goods and services, and, in consequence, on overarching business models (Yoo et al., 2012, Turber & Smiela, 2014; Weinberger et al., 2016). The separation between physical and digital industries is now consigned to the past because the IoT makes possible hybrid solutions that merge physical products and digital services (Fleisch et al., 2014).

The concept of IoT surpasses several areas of knowledge and can be considered as potentially relevant in any supply chain, creating unprecedented opportunities in the public and private sectors to develop new products and services, increase productivity and process efficiency, improve decision making, solve critical social problems and develop new user experiences (Borgia, 2014; Barrett et al., 2015, Yoo et al., 2012). Perera et al. (2015) present a broad view and concrete examples of IoT applications in several domains of private and public sectors.

IoT-based products/services allow for a radical change in existing business models (Porter & Heppelmann, 2014). However, a mediocre technology used in a great business model can be better than a great technology explored in a poor business model (Chesbrough, 2010); therefore, we must understand how to generate proper business models for IoT-based products and services (Dijkman et al., 2015; Turber & Smiela, 2014; Weinberger et al., 2016).

Nevertheless, still little is known about how the IoT change business models; the larger literature stream is focused on technical IoT challenges and few empirical studies investigate IoT-specific business model innovations in detail (Diaz, Muñoz & Gonzáles, 2017); most of the studies on this subject only provide anecdotal evidence and do not base their findings on empirical data (Bilgeri & Wortmann, 2017). In sum, regardless the fast technical progress of IoT technologies, the business and management literature do not explicitly consider the logic of digitized business environments based on it (Turber & Smiela, 2014; Leminen et al., 2015; Zhang & Wen, J., 2016) and how business models for the IoT should be constructed (Dijkman et al., 2015). Reviewing the literature, as we are going to show in section 4, one can find a set of works on the creation of business models for the IoT, but there are two clear pitfalls in these works: (1) most of them are not based on empirical research in organizations and; (2) most of them are based on general business models frameworks, such as the Business Model Canvas (BMC).

The IoT brings numerous opportunities for products and services innovations and, at the same time, it brings a set of uncertainties, for example, it can increase the complexity and the level of competition in most manufacturing systems (Ehret & Wirtz, 2017). It is key to understand what can be gained by connecting current products to the IoT and not simply doing it because the IoT is a hype (Saarikko, Westergren, & Blomquist, 2017).

Therefore, this article aims at investigating two research questions: (1) what are the elements to be considered to create a business model for IoT-based products/services? (2) What are the main challenges faced in this process? To address these questions, we review the literature on business models for the IoT and we analyze data from an action research involving the generation of a business model for an IoT-based product - a smart lock – in a small company. We explore how this process occurred and the challenges faced.

The research results indicate the elements that need to be considered beyond those already appointed in current business models frameworks such as the Business Model Canvas (BMC). The main challenges faced during the process of business modelling for the IoT-based product are discussed; they are related to six main categories: (1) the IoT ecosystem (2) the product/service development, (3) the value proposition, (4) the firm's internal capabilities (5) the technology infrastructure, (6) the generation of revenues.

The remainder of this article presents its key theoretical concepts, the literature review on business models for the IoT, followed by the research method, the action research results, and discussion. Finally, we present a conclusion section that highlights the article's contributions and we point out some questions that can be addressed in future research.

THE INTERNET OF THINGS (IOT)

The IoT refers to an emerging paradigm consisting of a continuum of uniquely addressable things communicating to one another to form a worldwide dynamic network (Koreshoff et al., 2013; Borgia, 2014). According to Mattern and Floerkemeier (2010), the IoT is not the result of a single technology, but it is the combination of several complementary development technologies that provide capabilities, which help to bridge the gap between the virtual and the physical world. These capabilities include (Mattern & Floerkemeier, 2010; Porter & Helpperman, 2014):

Communication and cooperation – in the IoT the objects have the ability to network with Internet resources and with each other, to make use of data and services and update their state; they use several wireless technologies for it, such as 4G, Wi-Fi, Bluetooth, ZigBee, Wireless Personal Area Networks (WPANs), among others.

Addressability - the objects are located on the Internet of Things and can be remotely configured and addressed via discovery, look-up or name services; they can be remotely interrogated or configured.

Identification - the objects are uniquely identified, using technologies such as RFID (Radio Frequency Identification) and NFC (Near Field Communication). Identification enables objects to be linked to specific information associated with them.

Context-aware sensing – in the IoT the objects collect data about their surrounding environment with the use of sensors, they record and forward data and react according to the context;

Monitoring – sensors enable the monitoring of a product'sproduct's condition, the product's operation, and usage; it also enables alerts and notifications of changes.

Actuation - the objects contain actuators that can be used to remotely control real-world processes in the environment via the Internet (for example, converting electrical signals into mechanical movements);

Embedded information processing - the smart objects have microcontrollers or processors, and storage capacity. These resources can be used, for instance, to process and interpret sensor's information, or to give products a "“memory”" of how they are used.

Localization - the smart objects know their physical location and can be located via the use of GPS, mobile phone networks, ultrasound time measurements, UWB (Ultra-Wide Band), radio beacons and optical technologies.

> **User interface** - the objects can communicate with people by means such as flexible displays, image or gesture recognition. Innovative interaction forms are relevant because the IoT must provide natural interfaces with users.

All these capabilities that result from the integration of the IoT technologies generate a wide range of possibilities to create innovative products and services with aggregate value, connecting the physical and the digital worlds (Borgia, 2014). Servitization is here defined as the act of adding value to a company's core offerings through services (Vandermerwe & Rada, 1988) is a key concept to the IoT because all the technological infrastructure and data collected must result in innovative services that can be associated with traditional physical products, as exemplified in Figure 1.

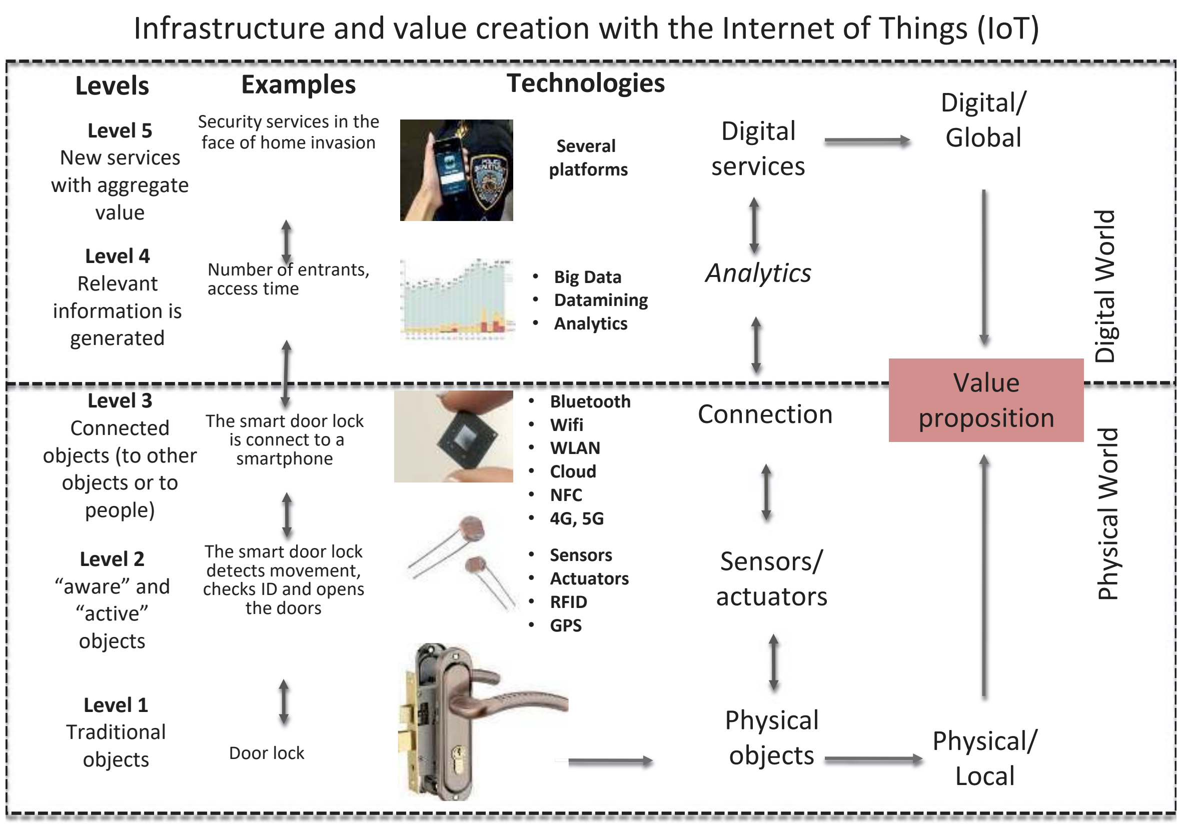

Figure 1. Innovation and value proposition with the IoT

Source: Created by the authors, based on Fleisch, Weinberger & Wortmann (2014) and Perera et al. (2015)

As illustrated in Figure 1, a traditional object (such as a door lock – as we are going to discuss later in this article) is transformed (through IoT technologies) into a smart object that can collect and transmit contextual data, that can be used to generate services – it is not a "dumb" door lock anymore; it can be a key component of a security system (for example). Therefore, the IoT can allow firms to offer packages of customer-focused combinations of goods, services, support, self-service, and knowledge, with a servitization logic (Vandermerwe & Rada, 1988)

This transformation demands to rethink the business model of IoT-based product/services, to profit from innovation.

BUSINESS MODELS

The business model literature has its origins in the late 1990's (Timmers, 1998). Since then, there has been an increasing interest in this topic in practice and various research areas (Osterwalder & Pigneur, 2009). For Zott, Amit and Massa (2011), business models have been used to address or explain the e-business phenomenon and the use of IT in organizations, as well as the management of technology and innovation. Companies must understand how to unlock value from technology, which has stimulated research on this concept (Timmers, 1998; Ehret & Wirtz, 2017).

Zott, Amit and Massa (2011) claim, after an extensive literature review, that a business model has different definitions: it can be referred as a statement, a description, a representation, an architecture, a tool or a conceptual model, a structural template, a method, a framework, a pattern, or a set of elements. A business model can be defined as a bundle of specific activities conducted to satisfy the perceived needs of the market, along with the specification of which parties (a company and its partners) perform the activities, and how these activities are linked to each other (Amit & Zott, 2012).

According to Turber and Smiela (2014), a business model is a holistic representation of a business formed by the combination of internal and external factors. There is no consensus on the elements that compose a business model. Timmers (1998:4) claims that a business model has to indicate (1) an architecture for the product, service and information flows (2) a description of the various business actors and their roles; (3) the potential benefits for the business actors; and (4) the sources of revenues. Gassmann, Frankenberger and Csik (2013) indicate that it must set the target customer, the value proposition to meet customer's needs, the value chain necessary to deliver the value proposition and finally the revenue model used to capture the value. Dmitriev et al. (2014) reviewed the literature, indicating that the most frequently identified elements in business models are: value proposition, target market, revenue model, partner network, internal infrastructure, and processes. Rethinking and reconfiguring them constitutes a highly complex and transversal management task.

There are various business model frameworks, at the enterprise level and at the industry level (Sun et al., 2012; Leminen et al. 2012). At the enterprise level, the most used frameworks are: the Value Chain, the Strategy Map, the Four-Box Business Model, and the Business Model Canvas (BMC). At the industry level, one can consider: the Five Forces, the Value Net, Supply Chain models, and the Business Model Environment. Among these models, the Value Chain and the BMC are the most widely used (Sun et al., 2012). In the next section, we analyze the state of art of business models for the IoT.

BUSINESS MODELS FOR THE IOT: WHAT WE KNOW SO FAR

We reviewed the literature (search day was 11.20.17) using the keyword search: "Internet of things" AND "business model", in the following databases: the Web of Science (48 results); Science Direct (413 results); Proquest (18); EBSCOhost: (17) Google Scholar (5350 - the top 100 articles were analysed and selected according to their titles and abstracts), and the AIS (Association for Information Systems) Library (114 results). In this first round of search, the results were filtered, excluding conferences papers (except when the keywords were present in the title of the papers), and purely technical articles, as well as repeated articles (located in different databases). In total, we selected 64 articles, and, after reading them through their abstracts and overview, 24 were selected and read thoroughly, leading to the search for other 9 articles cited by them. The 33 articles in total were saved in an NVivo® database and analyzed through their classification data (date, type of publication, source, method, etc.) and content. We codified the information on the goals of each article, the theoretical foundation of the IoT business models discussed or proposed by them, and also the challenges for the creation of business models for the IoT presented – see the data about the selected articles in Table 1.

As we can observe at Table 1, there are several approaches on business models for the IoT, considering different concepts, models, and frameworks, including: the Laws of information (1); Resource-based Perspective (1); Entrepreneurship and Transaction Cost Theories, High-resolution management (2), Service Dominant logic (3), Product Portfolio, Business Ecosystems literature (4), the St. Gallen Business Model Navigator (3), Supply chain analysis (1), Five competitive forces (1) Scenarios Models (1), Analytic Network Process (ANP) (1), Innovation stages (1) and Pricing models (1). There are two main approaches considered: the BMC (7) and Value models (6).

Most of the papers focus on the value proposition and competitive gains related to the IoT (such as Porter & Heppelmann, 2014), forms of generating revenues from the IoT (Fleisch et al., 2014), while others focus on a broader view of the business model components, using, for instance, the BMC (such as Buchener & Uckelmann, 2011 and Dijkman et al., 2015) while others expand the business model not only to a single organization but to the IoT ecosystem (like Leminen et al., 2012 and 2015 and Saarikko, Westergren, & Blomquist, 2017).

The variety of approaches to IoT business models in the literature and the use of “generic” business model frameworks can be related to two factors: (a) it is a recent research subject; the articles started to be published in 2011; 19 of them were published in academic journals, the others in conferences (7), and the remaining in book chapters or public reports (b) the IoT is a complex phenomenon, as we are going to discuss later, which brings a set of challenges to business modelling.

However, it is important to highlight that the majority of works (19) are theoretical papers. Most of the papers that perform some empirical research use only illustrative cases, scenarios or experts interviews and perceptions surveys on the subject to create or validate their proposed frameworks for IoT business modeling; none of them presents data on the **process** of business modeling for the IoT in a real company.

Even so, these works indicate several challenges related to developing business models for the IoT. We analyzed these challenges (via open codification) and classified them into 6 categories: value proposition, product/service development, technology infrastructure, ecosystems, firm’s internal capabilities and revenues, as shown in Table 2.

As Table 2 shows, it is evident the higher complexity in designing business models in a context of multi-sided platforms and ecosystems, which is the case in the IoT paradigm (Tesch, 2016; Turber & Smiela, 2014; Verdouw et al., 2013; Wortmann & Flüchter, 2015). The technological complexity is high, due to the multi-layered IoT infrastructure (software, hardware, network, protocols), which involves an ecosystem that includes the individual firm and its several business partners. All these partners must realize what is the value of the IoT for their own organizations and align it with the other actors.

Table 1. Articles on business models for IoT.

Author(s)	Year	Goal	Method	Theory/Literature
Bilgeri and Wortmann	2017	Investigates specific barriers to technology-driven IoT business model innovation	Interviews	Innovation stages
Buchener and Uckelmann	2011	Discusses the Internet of Things from an economic perspective, based on the business model concept.	Theoretical paper	Laws of information and B.M.Canvas
Chan	2015	Proposes a business model for IoT that consists of three dimensions: "Who, Where, and Why"	Case Studies	Previous business models for IoT
Diáz, Munhòz and Gonzáles	2017	Business models of public services provided with the IoT and other technologies in smart cities	Case studies (8)	BMC
Dijkman et al	2015	Presents a business model framework specific for IoT applications	Survey	BMC
Ehret and Wirtz	2016	Explores the conditions for designing nonownership business models for the emerging IIoT (Industrial Internet of Things)	Theoretical paper	Entrepreneurship and Transaction Cost Theories
Ehret and Wirtz	2017	Explores the conditions for designing nonownership business models for the emerging IoT	Theoretical paper	Entrepreneurship and Transaction Cost Theories
Fleisch et al	2014	Derive general business model logic for the Internet of Things and some specific components and patterns for business models	Theoretical paper	HRM, Service-dominant logic/St. Gallen Business Model Navigator
Gerpott and May	2016	Provides a foundation for firms trying to evaluate the suitability of IoT-enhanced offerings against the background of their current portfolio.	Theoretical paper	Product portfolio
Ghanbari et al.	2017	Discuss the relevance of vertical cooperation in the IoT and highlight the need to develop new value networks that leverage this cooperation	Theoretical paper	Value Chain
Glova et al	2014	Applies an originally value-based requirement technique, e3-value, to model value creation and value exchange within an e-business network of multiple business actors	Theoretical paper	Value Model (e3-value)
Hognelid and Kalling	2015	Analyzes the impact of IoT on business models and sources of value creation by applying a proposed framework to empirical illustrations.	Theoretical paper	Value creation for e-business and Porter & Heppelmann's IoTcapabilities
Ju et al	2016	Develops a generic business model framework for IoT, based on BMC, through literature analysis and interviews.	Interviews, Case Studies	BMC
Keskin and Kennedy	2015	Addresses the need for e-Commerce service models in an IoT-enabled industry by defining players and predicting possible states in which a firm can choose to do business	Theoretical paper	Multi-sided markets and platforms

Table 1. Cont.

Author(s)	Year	Goal	Method	Theory/Literature
Leminen et al.	2012	Discusses how the technological advancements and convergence with IoT shape and affect IoT businesses and dynamic IoT ecosystems.	Theoretical paper	BMC
Leminen et al.	2015	Investigates ecosystem business models or "value designs" in the IoT field.	Delphi and Interviews	Value design, ecosystems
Li et al.	2012	Provides a theoretical framework which classifies IoT strategies into four archetypes from two dimensions of managers' strategic intent and industrial driving forces	Theoretical paper	Resource-based Perspective and IS perspective
Li and Xu	2013	Proposes a business model for IoT-based on concepts of MOP (Multiple Open Platforms)	Theoretical paper	MOP and business models literature
Novales et al.	2016	Provides an overview of the different terms and identifies five conceptual elements that form the building blocks of digitized products	Systematic literature review	Literature on digitized products
Niyato et al.	2015	Proposes a new pricing scheme for IoT service providers	Theoretical paper	Pricing models
Porter and Heppelman	2014	Deconstructs the smart, connected products revolution and explore its strategic and operational implications.	Theoretical paper	Five competitive forces
Qin and Yu	2015	Studies the Value Net Model and the elements of the business model for IoT for telecom operators.	Theoretical paper	Value Net Model
Rong et al.	2015	Investigates how IoT could lead to a co-evolving business ecosystem rather than a supply chain.	Case Study	Business ecosystems (3c 36 model)
Saarikko, Westergren, and Blomquist	2017	Discuss value creation with the IoT and the need to form partnerships to develop intricate solutions	Case studies (3)	Value creation/value chain
Sun et al	2012	Proposes the Business DNA Model - a representation of a business model regarding Design, Needs, and Aspirations.	Theoretical paper	BMC
Tesch	2016	Discusses scenario planning as a means for evaluating business models in the IoT context.	Design Research	BMC and Scenarios
Turber and Smiela	2014	Describes the design and evaluation of a model to capture, visualize and analyze firms' current and future business models in IoT.	Design Research	St Gallen business navigator/ dominant service logic
Turber et al.	2014	Addresses the need for a business model framework in IoT-driven market environments, which recognizes the specific impact digitization.	Design Research	Modular layered architecture, service dominant logic
Verdouw et al.	2013	Assesses how IoT can enhance virtualisation of supply chains in the floricultural sector	Case Study	Supply chain analysis

Table 1. Cont.

Author(s)	**Year**	**Goal**	**Method**	**Theory/Literature**
Wan et al.	2016	Discusses O2O business model and IoT, identifying 10 core elements with Analytic Network Process (ANP)	Delphi	Value Net Model, ANP
Weinberger et al.	2016	Introduces the concept of high-resolution management (HRM) in IoT	Theoretical paper	St. Gallen Business Model Navigator, HRM
Westerlund et al.	2014	Examines networked and more comprehensive ecosystem business models; focuses on the challenges that hinder the emergence of IOT business models.	Theoretical paper	Value design
Wortmann and Flüchter	2015	Discusses Internet of Things Technology and the value added by this new technology	Theoretical paper	Porter and Heppelmann 2014
Zhang and Wen	2016	Propose an IoT E-business model specially designed for the IoT E-business and blockchain.	Theoretical paper	N/A

Table 2. Challenges on developing business models for the IoT

Categories	Challenges	Sources
The IoT Ecosystem	Find a value proposition to all actors involved in the ecosystem.	Buchener and Uckelmann (2011) Ehret and Wirtz (2017); Leminem et al. (2015); Ghanbari et al. (2017); Saarikko, Westergren, and Blomquist (2017).
	Increasing complexity in coordinating all the partners involved in IoT.	Buchener and Uckelmann (2011); Glova et al. (2014); Leminem et al. (2015); Novales et al (2016), Porter and Heppelman (2014), Verdouw et al. (2013), Wortmann and Flüchter (2015), Bilgeri and Wortmann (2017), Ghanbari et al. (2017); Saarikko, Westergren, and Blomquist (2017).
	Define the control over hybrid solutions, the hardware, and the software side.	Ehret and Wirtz (2017)
	Security in the transactions between business partners.	Burkitt, (2014), Ehret and Wirtz (2017); Keskin and Kennedy (2015); Novales et al (2016), Porter and Heppelman (2014), Rong et al. (2015), Verdouw et al. (2013)

Table 2. Cont.

Categories	Challenges	Sources
The Product/ service development	Higher complexity in product design - servitization and products as-a-service demand new capabilities in traditional products.	Porter and Heppelman (2014), Tesch (2016), Wortmann and Flüchter (2015)
	Synchronizing the processes of software and hardware development.	Novales et al (2016), Wortmann and Flüchter (2015)
	Keep simplicity of product design/user experience.	Novales et al (2016)
The Value proposition	Define the value proposition for clients – services with real aggregate value. Customer demands and expectations are still hard to discern.	Ehret and Wirtz (2017); Leminem et al. (2015), Porter and Heppelman (2014), Burkitt, (2014), Verdouw et al. (2013); Bilgeri and Wortmann (2017), Ghanbari et al. (2017)
	Privacy issues need to be considered in the value proposition.	Burkitt, (2014), Ehret and Wirtz (2017); Keskin and Kennedy (2015); Novales et al (2016), Porter and Heppelman (2014),
The firm's internal capabilities	Chance of new entrants and nontraditional competitors increase as smart, connected products become part of broader product systems; it challenges the firm's capabilities.	Porter and Heppelman (2014)
	Identify specific organizational capabilities to support the strategic implementation of IoT based products/services.	Burkitt, (2014), Li et al (2012); Novales et al (2016), Porter and Heppelman (2014)
	A realistic assessment of which capabilities should be developed in-house and which new partners should develop is key.	Burkitt, (2014), Porter and Heppelman (2014)
The Technology Infrastructure	The high complexity of technology components and IoT infrastructure.	Burkitt, (2014), Ehret and Wirtz (2017); Ju et al. (2016), Leminem et al. (2012); Novales et al (2016); Porter and Heppelman (2014), Tesch (2016), Wortmann and Flüchter (2015)
	Definition of interfaces, interoperability protocols, and standards.	Burkitt, (2014), Buchener and Uckelmann (2011); Hognelid and Kalling (2014); Leminem et al. (2015), Verdouw et al. (2013); Ghanbari et al. (2017)
	Large volumes of data need to be kept and analyzed	Burkitt (2014)
The generation of Revenues	Forms of monetization of data are complex/difficult to define/ forecast	Tesch (2016), Verdouw et al. (2013); Bilgeri and Wortmann (2017)

Finding valid and clear value propositions for clients also becomes more complex, because the IoT applications are related to servitization (Fleisch et al., 2014), integrating the physical and the digital worlds. It allows offering new services related to tangible products, which increases the complexity of product development. It is also important to consider that privacy issues are crucial to the value proposition.

Considering all these challenges, a company needs to identify the capabilities needed to profit from the IoT, deciding which ones need to be developed in-house and which ones are dependent on business partners.

Finally, sources of revenue need to be rethought; for instance, the opportunities to profit from Products as Services (PaaS) and how to get value for data generated through the IoT (Buchener & Uckelmann, 2011). Most of the articles in Table 2 also discuss the complexity of the IoT due to social, regulatory and institutional elements such as policies for technology standardization, legislation regarding privacy issues and diffusion of the IoT in the society as a whole.

Considering that most of the references in the literature on business models for the IoT are theoretical papers, we present, in the next sections, data from an action research project that have explored the process of business modeling for the IoT in a real company, allowing us to better understand the related challenges.

ACTION RESEARCH METHOD

One key assumption of action research is "action brings understanding" (Baskerville, 1999); in this case, we assumed that one of the best ways of understanding the process of creating a business model for the IoT, and the challenges faced in this process, was to get involved with a real company dealing with this task. In this section, we explain the method of the action research project (Avison et al., 1999; Baskerville, 1999) involving the generation of a business model for an IoT-based product (a smart door lock).

First, regarding the types of action research, Berg (2004) classify them into three main modes:

Technical/scientific/collaborative – early advocates of action research proposed it as the application of a very rigorous scientific method of problem- solving; the goal was to test a particular intervention based on a pre-specified theoretical framework. In this mode, the researcher identifies a problem after collaborating with the practitioners and provides information for them.

Practical/mutual collaborative/deliberate mode – in this mode, both the researchers and the practitioners work together and collaboratively identify potential problems and issues, underlying causes and adequate interventions. This mode is more flexible and empowers the practitioners; however, the level of control and measurement is lower than in the first mode.

Emancipating/enhancing/critical mode – This type intends to promote emancipatory praxis of practitioners and critical and political consciousness. This type of action research develops some sort of social criticism. The goal is to empower practitioners to promote social changes.

We identify the action research performed with the mode 2 (practical/mutual collaborative/ deliberate mode). The intention was to solve a practical problem (the definition of a business model for an IoT-based product) discussed, from the beginning, with the practitioners involved. The action plan was also discussed and approved by them. The action research was conducted from December 2014 to April 2015.

The company studied (here called "DELTA") is a small Brazilian company founded in 2004, specialized in the development of electronic products. DELTA has a process of RD&I that focuses on projects involving hardware and software with microprocessors. The company's vision is: "Taking innovation, comfort, and economy through technology to domestic and corporate environments." The production line is divided in two: one with low-cost products with a traditional design: presence sensors, dimmers, and electronic buzzers; the other production line is composed of products with innovative design, including presence sensors. In addition to these products, DELTA also works with OEM (Original Equipment Manufacturer) contracts. The structure of the company consisted of one manager and two electrical engineers; a technical team with one administrative assistant and 15 employees working at the production line.

The two owners of DELTA were involved in the process of business modeling, because, as a small company, DELTA does not have administrative departments. There was no involvement of other employees, which were engaged in operational tasks. The research project was carried out by an interdisciplinary team involving researchers from management and computer science, which helped the company in the development of the technological infrastructure for their IoT-based product, and in the development of the business model for it. The action research phases are depicted in Figure 2 and described next, according to the steps suggested by Baskerville (1999).

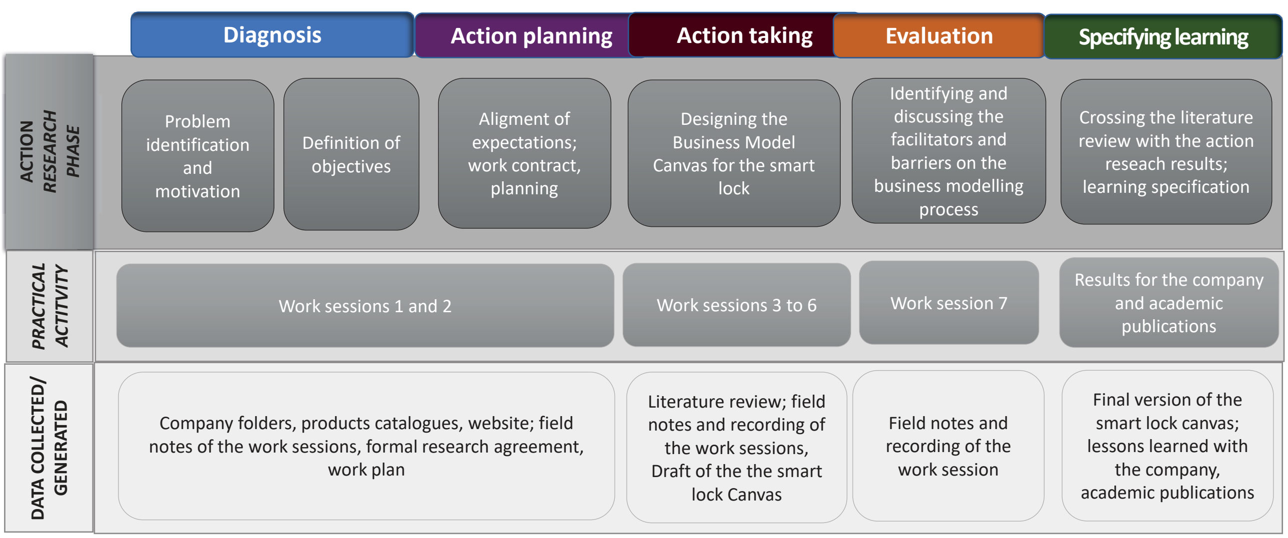

Figure 2. Research method – steps of the action research

Table 3 shows the details of the work sessions with the company, places, and durations.

Table 3. Work sessions with the company

Session/Activity	Place	Duration (hours)
Session 1 – Understanding the company and needs	University	1:50
Session 2 - Team mobilization and planning	Company	1:30
Sessions 3 and 4 - Designing the business model	Company	2:15
Session 5 - Designing the business model	Company	0:45
Session 6 - Discussion of the technological aspects of the model	University	0:55
Session 7 - Validation of the business model and evaluation of the process	Company	1:45

Diagnosis (work sessions 1 and 2 at Table 3): This first phase of research involved the identification of the problem and the definition of expected results by the practitioners. It was a collaborative process; the delimitation of the problem was made during the first two meetings with the company. In the first meeting, the owners have made a presentation of the company and their needs. We identified that the company had projects for products based on the IoT but did not have a formal strategic plan or business models established for them. Based on this first interaction, we established the calendar of activities and the delimitation of the research objectives and motivations of the company. We attempted to understand the company needs and characteristics, as well as the profile of the managers involved and what could be the best form to help them in the business modeling.

Action planning (Literature search and work session 2 at Table 3): In the second meeting with the company the research team has presented a draft of the research procedures, still attempting to understand and align the needs of practitioners with the focus of research and define the action planning. In this second meeting, the research team has visited the company premises; a consent form was signed with the practitioners and a presentation was done by the researchers with a draft of the work plan. This plan was created after a review of the literature on business models and business models for the IoT (which was incipient at that time – 2014/2015).). The BMC was suggested as a possible framework for business modelling, because (1) it is a broad, didactic and straightforward approach to business modelling (2) it is one of the most used frameworks for business modelling, including digital businesses and the IoT (Buchener & Uckelmann, 2011; Sun et al., 2012) (3) the managers involved were acquainted with this model (although they had not applied it in their own company). The practitioners agreed that it could be an adequate framework for the process of business modeling the smart door lock. The research team and the practitioners defined together which components of the BMC would be drawn in the following work sessions.

Action taking (work sessions 3 to 6 at Table 3): in this phase, a set of meetings was held with the company, involving the two owners, to develop the business model for the smart door lock. The Canvas application followed thesteps proposed by Osterwalder and Pigneur (2009): (1) Mobilize: gather all the elements for the design of a successful business model, describe the motivation behind the project and establish a common language to design, analyse and discuss the business model; (2) Understand: develop a good understanding of the context in which the business model will be applied, including: environment mapping, study of potential customers, collection of ideas and opinions; (3) Design: transforming information and ideas of the previous phases in business models prototypes that can be explored and tested. Two more steps (implementing the chosen business model and managing it) were not performed because these two last phases require a product ready to be sold in the market, something that had not happened with the smart door lock until the conclusion of this research.

Evaluating (work session 7 at Table 3): After generating the business model, a specific meeting was conducted to evaluate this process, especially considering the facilitators and barriers. A long conversation with the practitioners was conducted to understand their views on the process of business modeling and the adequacy of the BMC as a framework to support this process.

Specifying learning: After finishing the practical meetings and evaluating the experience with the company, the research results were crossed with the updated literature review to specify learning, as showed in the next sections. We used NVivo® as the qualitative analysis software to organize the ideas brought by the literature review and the recording and field notes of the work sessions with the company to analyze the data according to the research questions.

ACTION RESEARCH RESULTS

During the diagnosing stage of the action research, it was clear that the company had difficulties to define the broader business model for its IoT-based products. Thus, at first, we decided to focus on a specific product, the smart door lock. The main motivations to be addressed during the research were: how to create a technological and business platform to extend it for several IoT-based products, and to establish a business model suitable for the smart door lock, with the participation of current business partners of the company or not.

The company intended to develop the smart door lock using open platforms and allowing the use of Application Programming Interfaces (APIs) so that other people could develop software for other IoT-based products. The owners believed that the smart door lock is an attractive product for hotels, for example, allowing the consumption of virtual keys, and also for domestic use, permitting the entering of specific people at specific times (e.g., visitors, day workers, etc.).

After planning the action, considering the BMC as the framework for business modeling, a set of meetings was held to generate the model. We describe in summary how each component of the business model for the smart door lock was designed:

Customer Segment - Two customer segments for the smart door lock were identified: domestic users and business users. This component of the business model was evaluated by the research participants as one of the most important, and the partners emphasized that it is one of the most difficult to define, not only for IoT-based products but for other products in the company's portfolio. For instance, a key issue is to identify not only the target consumers' income level but also their level of familiarity with IT use.

Value Proposition - the main values perceived by the two types of customers (domestic and business) were raised. As an example, we can highlight security services related to the smart door lock, ease of generating copies of digital "keys", access to traffic reports, among others.

Customer relationships - the creation of a website for the product (smart door lock) was required, as well as pages on social media where customers could comment and share their experiences with the product, helping to promote it. An app would be another way to interact with clients, who could send their impressions on the product. The product website could also offer an online chat for support and resolution of queries and complaints in general. Another form of relationship, especially with business customers, is the participation in tradeshows and technology conferences.

Channels **–** one of the owners raised the importance of offering the product in major online marketplaces. However, there was no consensus about this move. The other owner argued that this type of product would not be sold in this kind of stores, only in those specialized in locks. So it would be interesting to use a network of partners to distribute the product, for instance, a partnership with a traditional local manufacturer of locks, which could use its commercial channels.

Key partners **–** during the definition of this component one of the owners mentioned that the first key partner would be the University, for generating the business model, and for RD&I and development of the cloud platform for IoT-based products of the company. Other key partners are the supplier of microchips, the cloud service provider and potentially the current business partners, yet to be consulted to verify if they had the interest in entering into new lines of smart products.

Key Activities **–** Some key activities are the development of embedded software in the smart door lock, the software that goes in the Cloud (middleware) and the smartphone's app. Besides software development, there is also the application maintenance of the developed software. Other activities mentioned were the distribution of products in retail outlets or via the web, the purchase of raw materials, and product assembly, testing and packaging. During the validation session of the business model, we wondered how DELTA would develop and maintain the software, given that the company had no expertise and staff for doing this. It indicated the need of having a new partner - a company specialized in software development.

Key resources **–** During the design of this component the focus was on identifying the human resources needed, such as software and hardware development teams and an advertising and communication team, responsible for promoting and disseminating the innovative product, as well as an external consultancy for patenting the smart door lock (a product innovation, at least to the national market, at that time).

Cost Structure **–** costs of raw materials, labor costs, costs of the cloud services and software providers, freight and distribution costs, taxes and costs with advertising were some of the items mentioned. Other costs are storage/warehouse, headquarters rental and commission to the sellers.

Revenue Sources **–** revenue sources could come from the monthly payment of services provided via the cloud platform and extra fees for using the software. Revenues from additional services included access to a larger period of coverage for traffic reports and extra keys to the smart door lock. The rental of equipment to the business segment would be a possible source of revenue, and also the sale of the smart product in OEM contracts.

After designing the BMC of the smart door lock, the first step of the evaluation phase of the action research was to identify the challenges faced in this process. Overall, the DELTA managers evaluated the experience of creating the business model as positive and useful, which also helped them to think and gain insights for other IoT-based products that could be created in the future.

Regarding the nine elements of the Canvas, the managers pointed out the Value Proposition and the Customer Segment as the most significant ones to generate the business model for the smart door lock. Another element considered as important was the key partnerships. For instance, an aspect that emerged during the research was the OEM contracts, something that has already been done by DELTA for various products in its portfolio and could be applicable also for the smart door lock. The concept of OEM is linked to areas such as supply chain, production management, and marketing and it is an important decision on the strategic positioning of a company that intends to develop IoT-based products, for example, strengthening its own brand or becoming a supplier that innovates to other company that owns the brand.

The Channel component is intrinsically associated with the Key Partners component. In the case of the smart door lock, it was necessary to clearly define which will be the partners, and finally to get a definition of Channels. Formerly, DELTA had attempted to keep its own sales channel, with dedicated sellers, but the result was not ideal, due to high operational costs. The lack of a solidified brand in the market, as well as the product's price is slightly higher than those of the competitors' products, which made it impossible for the company to maintain the strategy of having its own sales channels.

Besides that, during the working sessions it became clear that to design IoT-based products, a well-defined technology infrastructure is necessary. It occupied most of the interaction time during the sections, mainly with the computer science researchers who were part of the research team.

One of the DELTA managers involved in the business model creation mentioned that: *"*[...] *What is behind it (the product), regarding technological infrastructure, it* [the BMC framework] *does not say. It serves both to business modeling a high-tech product as for business modeling a bookstall. It is very generic."*

This pitfall led to the design of a new area (called IT INFRASTRUCTURE) in the smart door lock Canvas, highlighting decisions and key aspects concerning the technological infrastructure that needed to be considered by the company, as shown in Figure 3, which presents the generated business model. Some of the IT infrastructure requirements mentioned were (for example): in order to send data to user's devices, the smart door lock needs to have 3G or preferably 4G communication links available; the communication between the smart door lock and the Internet could also occur via domestic or corporate Wi-fi networks; the identification of the smart door lock could occur by Near Field Communication (NFC), allowing authorized mobile devices - especially smartphones - to access and to configure the smart door lock. The application to access the smart door lock should be developed for both Android and IoS platforms; the cloud computing service offered to the customer could be provided as Software as a Service (SaaS). This means that users have access to the systems in a virtual environment with user-friendly interfaces, and finally, one of the protocols used in the development of the embedded software could be MQTT, specified by IBM.

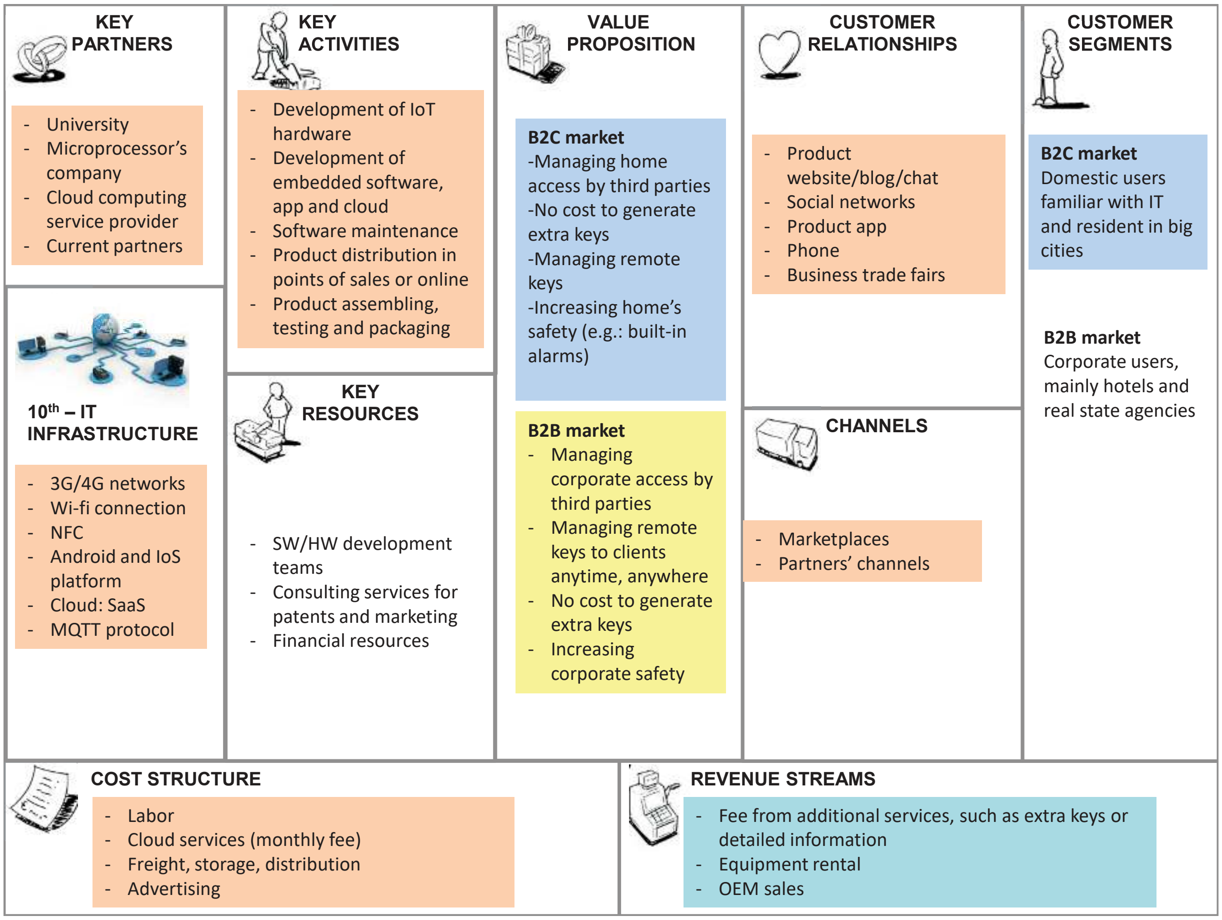

Figure 3. The business model Canvas for the smart door lock

The discussion about the business modeling process is presented in the next section.

DISCUSSION

The first lesson that can be learned through the action research with DELTA is that the process of business modeling of an IoT-based product/service expands the view on the individual firm and needs to be extended to the role the firm wants to play in the IoT ecosystem. To decide upon what sort of product/service is going to be offered by the firm is related to its position in a broader value chain. For example, Ehret and Wirtz (2017) propose three main types of industrial IoT-enabled business models: (1) the provision of manufacturing assets, their maintenance, repair and operation; (2) innovative informational and analytical services that support manufacturing (e.g., based on artificial intelligence, big data, and analytics), and (3) new services to end-users (for instance: customization by integrating end-users into the manufacturing and supply chain ecosystem). These types are similar to a typology of IoT business models pointed out by Burkitt (2014) and Saarikko, Westergren and Blomquist (2017), which highlight four main types of players in the IoT ecosystem:

Enablers – those firms that develop, implement and maintain the fundamental IoT technology infrastructure. These are technology companies.

Embedders – companies that apply IoT technologies to improve their operations and optimize their business processes (which include many manufacturing firms), but do not offer an IoT solution for their clients.

Engagers – firms that create their own connected product/services. They design, develop, integrate, and deliver IoT services to customers. For instance, by linking a washing machine to the Internet, the appliance maker captures a wealth of data about how the device is used.

Enhancers – are the firms that devise their own value-added services, on top of the services provided by Engagers, which are unique to the IoT. They can provide integrated services that reframe and repackage the products and services of the Engagers.

The DELTA challenge was to transform itself into an "engager" – in this case, they should develop a set of capabilities and resources such as software development to offer services based on the data generated by the smart product. As a small firm, they could not make it on their own – the need to develop partnerships to play this new role is paramount. Even for an engineering firm such as DELTA, there is an obvious difficulty in providing all the resources to develop activities in all the areas encompassed by the IoT. The search for appropriate external partners to deliver the smart product and associated services adds complexity to the product development process and the coordination of cooperative work (as previously pointed by Buchener & Uckelmann, 2011; Glova et al., 2014; Leminem et al., 2015; Novales et al., 2016, Porter & Heppelman, 2014, Verdouw et al., 2013, Wortmann & Flüchter, 2015).

Another valuable insight from the DELTA experience is that traditional products (such as door locks) can be completely rethought through servitization, but it is a big challenge to define the services that actually generate real value for consumers (as also highlighted by Ehret & Wirtz, 2017; Leminem et al., 2015, Porter & Heppelman, 2014 and Verdouw et al., 2013).

In the case of the smart door lock, the convenience generated by the services provided, such as permitting the entering of specific people at specific times (e.g., visitors, day workers, etc.), or the provision of security information and reports on peoples' circulation are very important. Experimenting on specific pilot projects is important because the IoT adoption is not reaching a mass market yet; there are no killing applications of it until now (Buchener & Uckelmann, 2011; Ju et al., 2016; Leminem et al., 2015, Verdouw et al., 2013).

Another aspect that became clear in the work with DELTA is that the complexity of the IoT technologies deeply affects the process of business modeling; the technology infrastructure must be clearly defined since it changes the way the value proposition can be designed and delivered. Technology definitions will also affect the selection of key partners and the revenue models.

In this sense, generic business models frameworks, such as the BMC (Osterwalder & Pigneur, 2009), used in the action research, covers major areas of business but do not give emphasis on the technology infrastructure and do not help to clearly connect and explore the interdependencies between the technology, the services provided and the value proposition. Even though the BMC has a component called Key Resources, in which the IT infrastructure could be included, we consider that the weight of this element is higher for IoT-based businesses, influencing the definitions for all other areas of the business model.

It is also necessary to rethink the value capture for IoT-based products/services. Once that the IoT increases the opportunities for servitization, exemplary business model patterns can include Rent instead of Buy, Subscription, Freemium, Razor and Blade and Add-on (Fleisch et al., 2014). Assets that have not traditionally been viewed as such, for example, traffic (i.e. visitors to a website), content and eyeballs (i.e. users seeing adverts) can generate new revenues, but still are poorly explored by firms (Ng & Wakenshaw, 2017).

DELTA should define the revenue model from services and information provided by the smart door lock for customers, for instance, through the provision of additional keys or granting access to data for a larger period. Regarding these services, one key issue is privacy, because IoT enables the collection of vast amounts of privacy-sensitive data (Derikx, De Reuver, & Kroesen, 2015), for instance, in the case of the smart door lock, data on the circulation of people in private and public spaces.

CONCLUSIONS

This article aimed to investigate what are the main elements to be considered to create a business model for IoT-based products/services and what are the key challenges faced in this process.

We contribute to the literature by analyzing the state of art on business modeling for the IoT, and also by confronting this knowledge with a real experience of creating a business model for a smart product. The research results reveal that “generic” business model frameworks, such as the Business Model Canvas (BMC) can help a company to design its business model for the IoT, but still lacks some specific areas (such as IT infrastructure) that need to be considered to encompass the complexity of this process. For instance, the firm needs to think about its role and the business model considering the IoT ecosystem, being aware that the process of developing solutions in this new platform will demand strong cooperation in a broader value chain. The definitions regarding the IoT technological infrastructure deserve special attention when designing the business model.

We also analysed the main challenges faced during the process of business modelling for the IoT in the action research, and, together with a categorization of previous works on business models for the IoT presented in the literature (Figure 2) we propose six main categories of challenges to be considered, related to (1) the IoT ecosystem (2) the product/service development, (3) the value proposition, (4) the firm’s internal capabilities (5) the technology infrastructure, (6) the generation of revenues. In Table 4 we present some practical recommendations to firms that need to design their business models for IoT-based products and services, in order to help them to overcome these challenges.

Table 4. Practical recommendations for the business modeling of IoT-based products

Challenges	Practical recommendations
Ecosystem	The business model needs to be thought considering the IoT ecosystem and not only the individual firm The firm needs to define what role it will play in the IoT ecosystem (for instance: Enabler, Embedder, Engager; Enhancer)
Product/ service development	It is fundamental to understand that the level of complexity in product development increases; partnerships are essential to deal with the complexity Several channels to interact with customer and monitoring their user experience for constant improvements are important
Value proposition	Is important to define clear value propositions considering customers' needs, profile and level of familiarity with the technology The convenience provided by the services related to smart products is a key aspect Experimenting on specific pilot projects of IoT-based products is a good way of learning and understanding the complexity of business modeling for the IoT It is essential to consider privacy issues related to the data services provided by smart products
Firms' Internal capabilities	The firm needs to make a realistic assessment of its assets and capabilities to develop the IoT-based product/service It needs to reevaluate what are the potential competitors and partners in the offering of smart products
Technology Infrastructure	This element is underestimated in most of the "generic" business models frameworks and needs to be carefully considered in business modeling IoT applications because it strongly influences the value proposition and the forms of value capture The firm needs to develop technology partnerships and the capacity to manage them Interoperability is essential and an open platform can be generative and profitable in new business models based on the IoT
Revenues	The range of possibilities of revenue generation related to smart products can be explored, including value captured through data services and the provision of flexible, additional, on- demand services

As research limitations, we can highlight the small size of the researched company and the short period of research. We also carried out only 3 of the 5 steps to generate a business model using the Business Model Canvas since the core product of this process (the smart door lock) was in the prototyping stage. The high degree of involvement of the researchers with the company also needs to be considered.

For future studies, we suggest the creation and the empirical testing of specific frameworks for the generation of business models for the IoT. These frameworks should consider the idiosyncrasies of the IoT platform and its level of complexity, as well as the challenges for business modeling for IoT as discussed in this article. The need of expansion of the BMC in the DELTA study signals that we need improved frameworks which can include new areas in the business models and, especially, to connect the areas and explore the interdependencies between them. Finally. it is important to advance the discussion of the concept of IoT ecosystems (and the different roles firms can play on it), as well as the servitization enhanced by the IoT, issues that are clearly highlighted in this research.

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