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Abstract

Purpose – *This paper aims to provide a foundation for firms trying to evaluate the suitability of Internet of Things (IoT)-enhanced offerings against the background of their current portfolio. Currently, quite a number of companies consider revising or extending their portfolio of products and services by incorporating IoT components to achieve competitive advantages. However, an unsystematic and autotelic addition of connected sensors and actuators to present offerings does not necessarily lead to substantial market success.*

Design/methodology/approach – *The approach of this paper is to identify different roles which IoT components can play in offering portfolios; clarify business development objectives, which can be achieved by the combination of products and services with IoT components; and report case examples which help to highlight how business development objectives can be reached with the help of IoT components fulfilling specific roles.*

Findings – *IoT components may play three different roles when integrated into product or service offerings. This role differentiation is crucial in understanding how IoT amendments can be instrumental in supporting the achievement of specific business development objectives pursued by a firm.*

Research limitations/implications – *The framework is based on conceptual considerations. To overcome this limitation, empirical research on technology-, cost- and customer-related impacts of IoT-enhanced offerings is desirable.*

Practical/implications – *Firms need to evaluate three roles which IoT components can play against the background of their present product portfolio when developing new business strategies.*

Originality/value – *This paper combines literature on the principles of operation of IoT applications and business models with current use-cases to provide implications for IoT-related business development issues.*

Keywords *Business development, Cyber-physical systems, Internet of Things (IoT), Offering portfolio, Product revision, Smart objects*

Paper type *Conceptual paper*

1. Introduction

The term "Internet of Things" (IoT) was introduced by Ashton (2009) already more than 15 years ago, but both management scholars and practitioners largely ignored the concept. However, recently, the popularity of the IoT paradigm, which describes the self-organized interconnectivity of uniquely identifiable everyday objects (e.g. cars, home appliances, clothing), has soared. Communications modules embedded in the objects make it possible to exchange data concerning the objects themselves or their environment without direct human intervention across various networks and, thus, enable innovative applications (Gubbi *et al.*, 2013, pp. 1646-1647). IoT subsumes a vast variety of technology subfields, such as cyber-physical systems, smart objects, smart grids or smart meters (Li *et al.*, 2011, Li *et al.* 2015; NIST, 2015; Wilson *et al.*, 2015). Triggered by the development of low-cost sensors and actuators, possible IoT applications have evolved from digitally enhanced barcodes, such as radio-frequency identification-tracking technology (Welbourne *et al.*, 2009), to adjunct product or service features, which promise to provide substantial value

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added to customers and open up new business perspectives for suppliers of industrial and consumer products and services.

There are plenty of recent examples of how the use of the IoT changes existing offering portfolios of established firms. For example, the e-commerce retailer Amazon announced a program called Amazon dash button. It allows consumers to order household goods such as detergent or bottled water by pressing a branded, wirelessly connected single-function button that can be mounted anywhere in the household. The items are then delivered to the customers' home via Amazon's prevailing distribution channels (Economist, 2015). Another more complex example for IoT integration is a smart home platform, which enables users to remotely and/or automatically control and monitor home appliances, such as the heating and lighting (Balta-Ozkan *et al.*, 2014). These examples show how the IoT enables companies to extend their existing offerings by incorporating previously uncharted complementary or new product or service features. Home deliveries of commodities or electronically controlled household appliances themselves are long-established service or product categories, respectively. However, IoT-based amendments enable firms to offer them in a way, which may provide significant additional benefits for the customers. Hence, IoT applications can serve as a driver for the transformation of a firm's product and service range.

A comprehensive survey of the scientific literature by Whitmore *et al.* (2015) concluded that, in spite of an exponential recent growth in the number of scientific articles on *technological* issues of the IoT on the one hand, there is a lacuna of scholarly work on IoT in a *business* development context on the other. In this regard, Whitmore *et al.* (2015) identified only four articles on IoT business models, half of which date back to 2009 (Bohli *et al.*, 2009; Haller *et al.*, 2009; Fu *et al.*, 2011; Li *et al.*, 2012). Bohli *et al.* (2009) distinguish between three different protagonists of the IoT market, i.e. hardware suppliers, consumers as well as intermediaries and service providers. However, the authors limit their analysis to wireless sensor networks and, thus, discuss the IoT isolated from the products and services it enhances. Haller *et al.* (2009) predict the impact of the IoT on various industries, i.e. manufacturing, logistics, energy, health, automotive and insurance. Fu *et al.* (2011) examine the roles of Internet service and content providers and their contractual relationships with their counterparts in a business-to-business and business-to-consumer context. Li *et al.* (2012) focus on drivers of IoT strategies for firms based on their internal capabilities (e.g. the firms' knowledge and skills) without tying well-known business strategy concepts (e.g. push vs pull, innovator vs imitator) to the innovative capabilities of IoT applications.

Additional reflections on IoT business models by Bucherer and Uckelmann (2011), Leminen *et al.* (2012) and Westerlund *et al.* (2014) are built on Osterwalder and Pigneur's (2010) groundwork of business model generation. Bucherer and Uckelmann (2011) focus on the impact of IoT on the core elements of business models, i.e. value proposition, distribution channels and (targeted) customers. Leminen *et al.* (2012) and Westerlund *et al.* (2014) evaluate business models within the context of (IT-)ecosystems and customer types. Additionally, Porter and Heppelmann (2014) discuss how existing product categories and technologies are transformed by IoT implementation. Finally, Fleisch *et al.* (2015) analyze how the extension of physical products by a digital dimension may boost the value added for customers.

In summary, the literature agrees that "the IoT is likely to both undermine old business models and require further development of new business models specific to particular applications" (Dutton, 2014, p. 15). However, the mechanisms of *how* IoT components affect a firm's offering portfolio and thus generate customer value remain rather unclear. Our key tenet is that the revision of existing and the development of new product offerings by means of implementing IoT elements requires to differentiate between various roles or functions, which IoT can play in supplementing or expanding a firm's product portfolio against the background of processes of service transformation (Cusumano *et al.*, 2015;

Porter and Heppelmann, 2014; Bruhn *et al.*, 2015). Consequently, the present paper develops a conceptual framework, which enables scholars and practitioners to identify specific roles of IoT in changing a firm's sales program and to categorize IoT-related business development efforts in the light of restructuring or expansion targets concerning its product portfolio.

The article proceeds as follows: In the second section, we introduce the three different roles which IoT component integration can play in a firm's current and potential product/service portfolios. The third section structures the potential directions for a firm's portfolio development strategy. The fourth section comprises an analysis of actual examples of IoT integration against the background of the previously introduced IoT roles and business development targets. The final section summarizes the insights derived from our analytical framework and suggests directions for future management research in the IoT field.

2. Roles of IoT components in offering portfolios

The novelty of IoT-enhanced products is that previously non-connected physical objects are assigned digital representations, which can interact with other digital and physical systems or humans. This digital representation enables the context-aware execution of (partially) automated processes and tasks with minimal human interaction, which, without connectivity, are too complex or unfeasible (Perera *et al.*, 2014; Wortmann and Flüchter, 2015). Therefore, to examine potential contributions of IoT-enhanced products toward the improvement of current or new offerings, the analysis has to focus on the functional roles of IoT components in a firm's product and service portfolio.

From the perspective of a firm which generates sales from "physical" products, IoT elements promote a "servitization" of the respective offerings. Servitization is defined as the process an organization goes through, when it shifts from selling standalone products ("boxes") to selling products, which are inextricably intertwined with value adding complementing service offerings (Martinez *et al.*, 2010). To explain the impact of IoT components on the servitization of a firm's offering portfolio, we modify the *taxonomy of services offered by product firms*, introduced by Cusumano *et al.* (2015) in a way that accounts for the peculiarities of the technology profiles of IoT components.

Table I depicts our adaptation of Cusumano's *et al.* (2015) service taxonomy. Accordingly, there are three roles of IoT component applications[1]. Two roles are characterized to complement elements of a firm's current offering portfolio (left and middle column), whereas the third role seeks to fully substitute the current sales goods of a firm and/or its competitors by generating a completely new sales category (right column). The roles differ in the way they affect the use of the respective product or service by complementing, replacing or extending the current offerings.

Table I Roles of IoT components in offering portfolios

	Complement		*Replacement*
Role of IoT	Smoothing (enabler)	Adaptation (adjunct service/product)	Innovation (core service/product)
Role characteristics	IoT component: – is pivotal to *initiate transaction* – potentially *reduces transaction costs* – is <u>*not*</u> a part of the *core product/service*	IoT component: – significantly *increases value* but <u>is not</u> the main value driver – enables *additional functionality* to an otherwise standalone product/service	IoT component: – is the *main value driver* of the product/service – creates product/service features which were *not available in the past*
Examples	Amazon dash button Car2Go	Parcel tracking Augmented reality product information	Smart home Mobile health monitoring

Note: Adapted from Cusumano *et al.* (2015, p. 562)

The left column portrays the characteristics of IoT in a smoothing role or, as we suggest to call it, as an enabler. As an enabler, the IoT component is not a part of the core product or service. Rather it is pivotal to initiate a sequence or transaction, while the basic functionality of an already existing offering is not significantly changed by the use of sensors or actuators (Cusumano *et al.*, 2015, pp. 562-563). One example of the IoT components as enablers is the aforementioned Amazon dash button. In this case, the main service is still the sale and delivery of the various goods ordered via various electronic media. However, the process of ordering the products is smoothened by the use of an IoT-enabled single-function device, which serves as a means to simplify the purchase procedure for customers. Another example is the car-sharing service Car2Go, a subsidiary of the German automobile manufacturer Daimler. In a nutshell, Car2Go is a car rental service, which enables its customers to rent cars on an hourly pay-per-use basis. However, by integrating IoT technology, the process of obtaining and returning a car is made easier by introducing a smartphone application and ensuring that the cars are connected to the rental company's scheduling platform. The IoT integration allows rentals without the need to pick-up the vehicle at a limited number of outlets and to bring back the car to a predefined location. Furthermore, users can rent a vehicle on the spot without prior reservations (Hermann *et al.*, 2014). At its heart, the service is still the rental car service, but the IoT reduces the extent of pre- (e.g. reservations) and purchase (e.g. car pick-up and return) interactions, thus, decreasing overall transaction costs.

The column in the middle clarifies the role of the IoT as an adjunct service/product functionality or adaptation. Similar to an enabler, the adaptation of IoT components does not alter the core functionality of the respective product or service. Instead, it significantly expands the functionality of previously existing offerings. An instance of an adjunct service which is enriched by IoT functionality is the tracking and tracing of shipments within the logistics industry. The key functionality, which is not altered by IoT integration, is the movement of physical goods. At the same time, the sender's or recipient's ability to track the current location of the shipment significantly increases the value of the respective dispatch service (Chen *et al.*, 2014).

The column on the right highlights service or product innovation, which has IoT components as its predominant value driver and creates previously unknown offering categories. These innovations are only possible through IoT components. The newly offered product or service may replace a non-IoT-enabled product or create a completely novel offering. Examples for products/services where the IoT functionality is the main value driver are smart home suites, which perform tasks such as automated regulation of the room temperature or remote monitoring and adjustments of the energy consumption of household appliances. Without the IoT components, these tasks would be either not fulfilled or achieved by inconvenient manual activities (Balta-Ozkan *et al.*, 2014).

When developing IoT strategies, it is not sufficient to distinguish the roles which various technical IoT components may play. Instead, it also has to be analyzed to what extent each of the three IoT offering types is suitable to support the achievement of a firm's generic strategic objectives. A prerequisite for this analysis is a classification of generic objectives firms pursue with their business development strategies.

3. Directions of portfolio strategies

Generally, firms can introduce IoT-based offerings in their portfolios against the background of two strategic thrusts, namely, either a *revision* of their current sales program or an *extension* by newly developed offerings. The three levers for a *portfolio revision* are to increase or decrease the degree of complexity or customization of its existing products, or to replace currently sold goods by more advanced ones in the course of an incremental product or service evolution (Shostack, 1987; Chao and Kavadias, 2008). An *extension* strategy can increase the firm's degree of vertical integration (up- or downstream) along its currently covered value chain or add new offerings, which are unrelated to the market arenas presently addressed.

The main idea behind a *portfolio revision* by integrating IoT features is to keep the original value proposition of the product or service and to add further functionalities to the offering. The first approach, which is available to firms as a means to restructuring their portfolio, is the adaptation of an offering's *complexity*. Complexity refers to the number and interrelatedness of process steps visible to and, more importantly, modifiable by customers (Shostack, 1987). By integrating a connected object into the process, the visibility of process elements for end-customers is altered, so that customers are able to either reduce or increase their involvement in the process. A real-life example of a complexity reduction by means of the IoT is the aforementioned Amazon dash button. It reduces the steps a customer has to take to place an order, while the initiation (*place order*) and the outcome (*receive order*) of the process of value creation remain unchanged.

The second option for a portfolio revision is to integrate IoT components as a tool to change the *degree of customization*. To provide the user with a more tailor-made offering, the end-customer can now influence process elements, which without IoT-based functionalities were unamenable. An example for an increased degree of customization is the aforementioned parcel tracking option within the logistics industry, which enables customers to reroute their shipments at key points in the formerly invisible delivery process.

The third variant of a portfolio revision is to replace an established process of value creation by means of an *evolutionary advancement*, which is only made possible with the use of IoT components. The newly integrated IoT functionalities "rewire" the whole process without significantly changing the outcome. A rental car service in the fashion of Car2Go can serve as an example for process restructuring. While the initiation (*place a reservation*) and the result (*pick up the rental car*) of the purchase process remain unchanged, the steps in between are rearranged in a process, which fundamentally differs from those of "traditional" car rental forms. Hence, an evolutionary advancement is the most disruptive of all portfolio revision strategies.

However, it is also possible to integrate IoT-enhanced objects to extend a firm's portfolio with additional complementing offers but without altering or substituting currently sold products/services. Naturally, an *extension* of a firm's offering portfolio could include a virtually infinite number of products and services, which are not part of the current program. A portfolio extension is conducted with offerings that can either be incorporated in the existing value network of a firm's current product lines, or require the creation of new value chains unlinked to a supplier's past business fields (Basole and Rouse, 2008).

If a firm wants to pursue an extension strategy within its current value chain activities, this can be performed vertically by using IoT components to bridge two or more consecutive up- or downstream tiers of this chain. Whereas the revision strategies focus on the product level, the *vertical extension* of the product portfolio by means of incorporating IoT components is driven by the integration of various offerings into or the development of a platform or superordinate system (Cusumano, 2010; Magnusson and Pasche, 2014). In the case of an *upstream* extension of the portfolio, the IoT components enable the current offering to be integrated into a superordinate system, which broadens the field of application of the current product or service, or provide the basis for the integration of processes in upstream tiers. An example is the announcement of the transportation network company Uber to integrate self-driving cars into their service portfolio (Harris, 2015). The firm's current core offer is a smartphone-based alternative service to "traditional" taxi services. The Uber app allows customers to book a trip from their current location to another location of their choice. The customer's request is subsequently carried out by a self-employed driver, who is registered to the service using her own car. Uber's key service thus used to be the platform, which brings together passengers and drivers and, additionally, processes the payments for the trips taken. With the advances in autonomous driving, Uber has announced a pilot program to instate self-driving cars instead of *human* drivers. IoT components enable Uber to manage its fleet of autonomous cars and to cater its customers without drivers, thus integrating upstream processes into their offering portfolio.

The second option for a vertical extension of the firm's portfolio is a *downstream* amendment by introducing IoT-enabling offers, which can be separately bought by customers. The IoT components enable the firm to offer additional products or services, which enable end-customer-related activities that used to be performed by other independent suppliers. A real-life example of such a downstream integration is the *instant ink* program of the printer manufacturer Hewlett-Packard. Connected printers automatically order replacement ink cartridges, so subscribers of *instant ink*, who are charged on a pay-per-use basis, do not have to monitor ink levels and to contact independent services vendors, if they need new cartridges (Hewlett-Packard, 2015). The IoT functionality replaces the necessity for the customers to make a purchase from an independent supplier and thus integrates downstream value chain elements into Hewlett-Packard's offerings. Put differently, Hewlett-Packard does not only manufacture the printers and cartridges but also introduces their proactive distribution to the customers as a separate service offering.

The third option for extending a firm's offering portfolio is to enter market fields, which so far have not been addressed. The strategy in this scenario is to combine a firm's core capabilities with IoT components and to apply the newly created products and processes to a targeted market arena. A current example for this strategy is Google's effort to develop a self-driving car. Google's proven core competences are the collection and analysis of big data. By leveraging these competences to the development of autonomous vehicles, the firm extends its portfolio toward a completely new market compared to previous Google offerings (Hars, 2015).

Along with these two main strategic thrusts, i.e. portfolio revision and extension, the analysis of IoT-enhanced offerings also needs to incorporate the value amount of value added by the integration of IoT components. To convince customers to purchase the newly developed product or service, the revised or new IoT-related offering has to entail a perceivable and significant comparative (monetary or value-based) advantage over a "traditional" good. The advantage can either stem from lowered transaction or overall costs due to a streamlined process of value creation or from an increase in the variety of functionalities. However, firms need to be aware that there could be a trade-off between the two (Thompson *et al.*, 2005; Stock, 2011; Goebel *et al.*, 2012). Lowering transaction costs can be achieved by limiting the range of product or service functionalities. Widening the range of functionalities, on the other hand, can lead to a usage process, which better fits customer needs but also is more sophisticated to manage for customers and therefore raises transaction costs.

4. Analysis of IoT-based portfolio strategies

Against the background of the strategic directions outlined in Section 3, the objective of this section is to analyze how the different IoT roles (see Section 2) fit to the various business development thrusts of a firm. Three recent examples of actual IoT-enhanced offerings (see summary in Table II) are used to carve out such linkages between IoT roles and strategic directions.

The first example is a *digital front-desk* service that was announced by the hotel group Hilton (Hilton Worldwide, 2014). In this case, IoT offering components have a smoothing role used to achieve a portfolio revision. The hotel chain offers its guests to make a reservation with a smartphone application. The app also allows the customers to check-in and out, select their room of choice, make special requests and use their mobile device as their room key. Implementing this application along with the required IoT-enabled facility management components (e.g. smart locks) significantly smoothens the check-in process.

Table II Analysis of exemplary IoT-enhanced offerings

Offering	*IoT role*	*Portfolio strategy*	*Impact on value added*
Hilton *digital front desk*	Smoothing (enabler)	Portfolio revision: – service evolution – decreased complexity	– faster check-in/-out process – refined access control to hotel facilities – shift from "face-to-face" to electronic interaction
Philips *hue*	Adaptation (adjunct functionality)	Portfolio revision: – increased customization – increased complexity	– extends range of functionalities – user is confronted with a learning curve
Nike *FuelBand*	Innovation (core product)	Portfolio extension: – new market field	– complexity reduction – broad range of potential applications

Additionally, the IoT-enhanced hotel infrastructure can grant travelers who frequently stay at Hilton hotels with general or limited access to other areas of the premises, which are typically restricted to current house guests (i.e. pool area, parking garage, etc.). Furthermore, data on a connected room's status (e.g. occupied, ready for housekeeping) are available at any time without potentially disturbing the customer. Consequently, hotel guests have to interact less frequently with the hotel employees. This reduces the complexity for the customers. At the same time, operating costs decrease for the hotel, because the front desk can be run with reduced staff, as a large number of common requests are handled by the guests themselves. While the core service, i.e. accommodation, remains the same, the IoT technology enables hotel guests to reroute transactions, which are otherwise rigidly bound to the hotel's reception, to their personal mobile devices. Consequently, the IoT implementation helps to reduce transaction costs and complexity for both guests and the firm. However, the impact on the offering's degree of customization remains ambiguous. The new check-in process shifts the interaction from a "face-to-face" situation to a process completely bound to electronic devices. While hotel visitors can customize their stay to a certain degree with the app, an actual (frequently more costly and time-consuming) personal encounter with the hotel staff still offers more possibilities regarding customization. The smoothing IoT role in this context serves as a means to increase the efficiency of the process of service provision by lowering the complexity. However, the new way to conduct the overall process also decreases its degree of customization.

The second example is the residential lighting system *hue* offered by the Dutch technology company Philips (Philips, 2015). The system is composed of LED light bulbs that are wirelessly connected to a control unit. The unit can be actuated with a smartphone or other device that runs the dedicated applications. Not only can customers use the wireless control to turn the lights on and off. But also, they can change the light's color or brightness and enable context-aware triggers, which adjust the lighting according to user-defined events (e.g. flashing light on each ring of the doorbell; color change according to the colors on the TV screen). In terms of potential IoT roles (see Table I), the concept of Philips *hue* can be characterized as an adaptation, as it adds significant value (i.e. lighting and interconnectivity options) to the otherwise standalone product (i.e. light bulbs) but is not the main value driver. Regarding Philips' business development thrusts, the introduction of the *hue* series can be categorized as a portfolio revision. At its core, it is manifested as an evolutionary product advancement which increases both the offering's customization and its complexity. The light bulbs are not longer merely the source of light but also provide additional functionalities in combination with other connected ("smart") devices, such as TVs, doorbells or motion sensors. In contrast to its predecessor, the product has a wider range of functionalities, which the customer has to value more than the learning challenges she is confronted with when she starts to install the new system. Thus, the adapting IoT role increases the potential degree of customization, but at the same time adds complexity to the usage process of the product.

The third example, which serves as a case for an innovation with regard to the IoT role, is the *FuelBand* launched by sports equipment manufacturer Nike (Nike, 2015). The *FuelBand* is a wristband that monitors fitness-related body metrics of the wearer and wirelessly transmits these data to a smartphone which, in turn, enables the analysis of the collected metrics with a complementary app. With this wearable device, customers can keep track of their training progress in a way which required enormous effort or was completely unfeasible before the device was available. In light of potential IoT roles, the *FuelBand* can be categorized as an innovation, because its core functionality, i.e. the accurate collection of training session metrics, completely builds on the IoT sensors of the wristband and is the product's main value driver. In terms of Nike's product portfolio, the *FuelBand* can be characterized as a portfolio extension into a new market field, as Nike previously did not provide connected electronic devices. For customers, the offering significantly reduces the complexity of the respective task, i.e. monitoring one's training status. The *FuelBand* is designed to monitor a broad variety of sports activities. However, this variety is not synonymous with a high degree of customization. Instead, while customers can use the device on multiple occasions, they are still restricted to a rigid usage pattern with no particular possibility of further customization.

Depending on the nature of the respective IoT component, firms have to consider the consequences of the introduction of these offerings as to how much they depend on additional supportive infrastructures. Such prerequisites have to be designed along with the actual services or products, or, in other words, the necessary commitment to sustain the product or service. The targeted degree of sustainability determines the offering firms' indispensable efforts to provide the soft- and hardware infrastructure for the respective IoT-based product or service offering. This necessity can be clarified by the aforementioned examples. While for customers, the effort and costs to use Hilton's *digital front-desk service* are relatively low, the hotel group itself faces significant upfront investments and operational expenditures. They result from the installation, operation and maintenance of the IoT system at every single site, which is available via the service, as long as it is provided. For the other two aforementioned examples, the firms' commitment to sustain an infrastructure ensuring the functionality of their IoT-enhanced offerings is relatively low. The only sustainability issue with regard to the *hue* lighting system is the availability of spare parts. Along the same lines, Nike's *FuelBand* just requires to ensure its compatibility with current and future mobile operating systems.

5. Conclusions

Prior work has tended to discuss IoT-related changes of a firm's product offerings without distinguishing various roles IoT components can play in enhancing the firm's products and services. In contrast, the present investigation suggests to differentiate between three functional roles in the integration of IoT elements in a firm's offering portfolio. Several examples are taken to propose that the achievement of a company's strategic business development objectives through the introduction of IoT components, at least in part, depends on the fit between the pursued targets and the chosen IoT roles. As a result, a "role-aware" integration of IoT components into existing or innovative offerings can create a comparative advantage over established non-connected equivalents.

The findings of our theoretical analysis suggest that the users' value added, which is generated by the IoT components, depends on the change in functionality as opposed to the non-connected offering. Firms need to be aware that the generation of a small increase in convenience for the customer can require a great deal of effort in the form of capital and/or operating expenditure (cf., Hilton use-case). On the other hand, simple unified IoT-enhanced products, which can easily be integrated into a firm's current product lines, can open a whole range of useful applications for customers (cf., Nike and Philips use-cases).

Our conceptual case-driven analysis has several limitations, which imply directions for future research. First, the work is solely based on theoretical propositions and a few cases rather than a data collection in a large sample of firms which have launched IoT-based offerings. Therefore, our analysis only provides a small subset of a vast variety of IoT-enhanced offerings and hence is not necessarily representative. Furthermore, even if the introduced effects can be observed empirically in a representative sample of IoT-enhanced product or service portfolios, the question remains whether the fit between the three aforementioned IoT roles and a firm's business development objectives is the most important driver of a successful transition from non-connected to connected offerings. Future studies should empirically compare the success of IoT-based offerings in contrast to established non-connected products and services. Second, little is known about predictors of customers' intentions to switch to IoT-enhanced offerings and their actual adoption behaviors, especially with regard to perceived advantages, risks and other usage barriers. Consequently, our findings are to be combined with other conceptual "macro" work on feasible IoT business models and with empirical "micro" research dealing with customer IoT-acceptance issues. Third, our analysis focused on the impact of IoT integration in products or services a firm sells on markets to (external) customers. Thus, it does not look at the necessary intra-organizational measures promoting operational excellence and customer closeness, which need to be taken to achieve such an integration. Further work should address this gap and thereby add further elements to a more comprehensive analytic framework for the successful management of the business impacts of IoT technologies.

Note

1. Instead of the three categories introduced by Cusumano *et al.* (2015), an anonymous reviewer proposed to differentiate the following five categories to classify the business impacts of the IoT: (1) augmentation of the existing product or service, (2) improvement and extension of the customer interface/experience, (3) substitution of services or products, (4) creation of a new category of service or product and (5) revision of the internal business processes. While these categories can be of relevance in the context of IoT business impacts in general, we refrained from extending our framework accordingly for at least three reasons. First, the impact category 2, improvement and extension of the customer interface/experience, does not stand on equal footing with categories 1, 3 and 4 because the former causally depends on the mentioned other three categories. Therefore, adding this category in many cases results in substantial ambiguity and overlap of potential roles of IoT components in a firm's offering portfolio. Second, our analysis focuses on IoT-induced changes in the features and range of products and services a firm sells *on markets to its (external) customers*. Hence, the impact category 5 suggested by the referee is beyond the scope of our work because this category deals with intra-company changes. Third, to the best of our knowledge, the *ad hoc* five-class categorization developed by the referee is not deeply rooted in a substantial number of prior publications of renowned authors. In sum, we take the position that the three-part taxonomy of Cusumano *et al.* (2015) provides a more useful basis for the present analysis because it facilitates a less ambiguous segmentation of potential roles of IoT components in the offering portfolio of a firm.

References

Ashton, K. (2009), "That 'Internet of Things' thing", in RFID Journal, available at: www.rfidjournal.com/article/print/4986 (accessed 4 January 2016).

Balta-Ozkan, N., Boteler, B. and Amerighi, O. (2014), "European smart home market development: public views on technical and economic aspects across the United Kingdom, Germany and Italy", *Energy Research and Social Science*, Vol. 3, pp. 65-77.

Basole, R.C. and Rouse, W.B. (2008), "Complexity of service value networks: conceptualization and empirical investigation", *IBM Systems Journal*, Vol. 47 No. 1, pp. 53-70.

Bohli, J.-M., Sorge, C. and Westhoff, D. (2009), "Initial observations on economics, pricing, and penetration of the internet of things market", *Computer Communication Review*, Vol. 39 No. 2, pp. 50-55.

Bruhn, M., Hepp, M. and Hadwich, K. (2015), "Vom Produkthersteller zum Serviceanbieter – Geschäftsmodelle der Servicetransformation", *Marketing Review St. Gallen*, Vol. 32 No. 1, pp. 28-38.

Bucherer, E. and Uckelmann, D. (2011), "10 Business models for the internet of Things", in Uckelmann, D., Harrison, M. and Michahelles, F. (Eds), *Architecting the Internet of Things*, Springer, Heidelberg, pp. 253-277.

Chao, R.O. and Kavadias, S. (2008), "A theoretical framework for managing the new product development portfolio: when and how to use strategic buckets", *Management Science*, Vol. 54, pp. 907-921.

Chen, S.-L., Chen, Y.-Y. and Hsu, C. (2014), "A new approach to integrate Internet-of-Things and Software-as-a-Service model for logistic systems: a case study", *Sensors*, Vol. 14 No. 4, pp. 6144-6164.

Cusumano, M.A. (2010), *Staying Power – Six Enduring Principles for Managing Uncertainty in an Uncertain World*, Oxford University Press, New York, NY.

Cusumano, M.A., Kahl, S.J. and Suarez, F.F. (2015), "Services, industry evolution, and the competitive strategies of product firms", *Strategic Management Journal*, Vol. 36 No. 4, pp. 559-575.

Dutton, W.H. (2014), "Putting things to work: social and policy challenges for the internet of things", *Emerald Insight*, Vol. 16 No. 3, pp. 1-21.

Economist (2015), "Of sensors and sensibility", The Economist, 2 April 2015, available at: www.economist.com/news/business-and-finance/21647715-connected-devices-home-are-becoming-more-widespread-sensors-and-sensibility (accessed 4 January 2016).

Fleisch, E., Weinberger, M. and Wortmann, F. (2015), "Geschäftsmodelle im Internet der Dinge", *Schmalenbachs Zeitschrift für betriebswirtschaftliche Forschung*, Vol. 67, pp. 444-464.

Fu, C., Zhang, G., Yang, J. and Liu, X. (2011), "Study on the contract characteristics of internet architecture", *Enterprise Information Systems*, Vol. 5 No. 4, pp. 495-513.

Goebel, P., Moeller, S. and Pibernik, R. (2012), "Paying for convenience – Attractiveness and revenue potential of time-based delivery services", *International Journal of Physical Distribution and Logistics Management*, Vol. 42 No. 6, pp. 584-606.

Gubbi, J., Buyya, R., Marusic, S. and Palaniswami, M. (2013), "Internet of Things (IoT): a vision, architectural elements, and future directions", *Future Generation Computer Systems*, Vol. 29 No. 7, pp. 1645-1660.

Haller, S., Karnouskos, S. and Schroth, C. (2009), "The internet of things in an enterprise context", in Domingue, S., Dieter, F. and Paolo, T. (Eds), *Future Internet – FIS 2008, Lecture Notes in Computer Science*, Vol. 5468, Springer, Berlin, pp. 14-28.

Harris, M. (2015), "Uber could be first to test completely driverless cars in public", *IEEE Spectrum*, 14 September, available at: http://spectrum.ieee.org/cars-that-think/transportation/self-driving/uber-could-be-first-to-test-completely-driverless-cars-in-public (accessed 4 January 2016).

Hars, A. (2015), "Self-driving cars: the digital transformation of mobility", in Linnhoff-Popien, C., Zaddach, M. and Grahl, A. (Eds), *Marktplätze im Umbruch*, Springer, Berlin, pp. 539-549.

Hermann, S., Schulte, F. and Voß, S. (2014), "Increasing acceptance of free-floating car sharing systems using smart relocation strategies: a survey based study of car2go Hamburg", in González-Ramírez, R.G., Schulte, F., Voß, S. and Caroni Díaz, J.A. (Eds), *Computational Logistics*, Springer, Cham, pp. 151-162.

Hewlett-Packard (2015), "HP instant ink – What is HP instant ink?", available at: http://support.hp.com/us-en/document/c03760650 (accessed 4 January 2016).

Hilton Worldwide (2014), "Hilton revolutionizes hotel experience with digital check-in, room selection and customization, and check-out across 650,000-plus rooms at more than 4,000 properties worldwide", 28 July, available at: http://news.hiltonworldwide.com/index.cfm/news/hilton-revolutionizes-hotel-experience-with-digital-checkin-room-selection-and-customization-and-checkout-across-650000plus-rooms-at-more-than-4000-properties-worldwide (accessed 4 January 2016).

Leminen, S., Westerlund, M., Rajahonka, M. and Siuruainen, R. (2012), "Towards IoT ecosystems and business models", in Andreev, S., Balandin, S. and Koucheryavy, Y. (Eds), *Internet of Things, Smart Spaces, and Next Generation Networking*, Springer, Berlin, pp. 15-26.

Li, S., Xu, L.D. and Zhao, S. (2015), "The internet of things: a survey", *Information Systems Frontiers*, Vol. 17 No. 2, pp. 243-259.

Li, X., Lu, R., Liang, X., Shen, X., Chen, J. and Lin, X. (2011), "Smart community: an internet of things application", IEEE Communications Magazine, Vol. 49 No. 11, pp. 68-75.

Li, Y., Hou, M., Liu, H. and Liu, Y. (2012), "Towards a theoretical framework of strategic decision, supporting capability and information sharing under the context of internet of Things", *Information Technology and Management*, Vol. 13 No. 4, pp. 205-216.

Magnusson, M. and Pasche, M. (2014), "A contingency-based approach to the use of product platforms and modules in new product development", *Journal of Product Innovation Management*, Vol. 31 No. 3, pp. 434-450.

Martinez, V., Bastl, M., Kingston, J. and Evans, S. (2010), "Challenges in transforming manufacturing organisations into product-service providers", *Journal of Manufacturing Technology*, Vol. 21 No. 4, pp. 449-469.

Nike (2015), "Nike+ Fuel", available at: www.nike.com/us/en_us/c/nikeplus-fuel, (accessed 04 January 2016).

NIST (2015), "Cyber-physical systems public working group – Update webinar", NIST, Gaithersburg, available at: www.cpspwg.org/Portals/3/docs/Resources/NIST%20CP.S%20PWG%20update%20webinar%2015Jan2015%20final.pdf (accessed 4 January 2016).

Osterwalder, A. and Pigneur, Y. (2010), *Business Model Generation – A Handbook for Visionaries, Game Changers, and Challengers*, Business Model Foundry, Zürich.

Perera, C., Zaslavsky, A., Christen, P. and Georgakopoulos, D. (2014), "Context aware computing for the internet of thing: a survey", *IEEE Communications and Tutorials*, Vol. 16, pp. 414-454.

Philips (2015), "Meet hue", available at: www.meethue.com, (accessed 04 January 2016).

Porter, M.E. and Heppelmann, J.E. (2014), "How smart, connected products are transforming competition", *Harvard Business Review*, Vol. 92 No. 11, pp. 64-86.

Shostack, G.L. (1987), "Service positioning through structural change", *Journal of Marketing*, Vol. 51 No. 1, pp. 34-43.

Stock, R.M. (2011), "How does product program innovativeness affect customer satisfaction? A comparison of goods and services", *Journal of the Academy of Marketing Science*, Vol. 39 No. 6, pp. 813-827.

Thompson, D.V., Hamilton, R.W. and Rust, R.T. (2005), "Feature fatigue: when product capabilities become too much of a good thing", *Journal of Marketing Research*, Vol. 42 No. 4, pp. 431-442.

Welbourne, E., Battle, L., Cole, G., Gould, K., Rector, K., Raymer, S., Balazinska, M. and Boriello, G. (2009), "Building the internet of things using RFID", *IEEE Internet Computing*, Vol. 13 No. 3, pp. 48-55.

Westerlund, M., Leminen, S. and Rajahonka, M. (2014), "Designing business models for the internet of things", *Technology Innovation Management Review*, Vol. 4 No. 7, pp. 5-14.

Whitmore, A., Agarwal, A. and Xu, L.D. (2015), "The internet of things – a survey of topics and trends", *Information Systems Frontiers*, Vol. 17 No. 2, pp. 261-274.

Wilson, C., Hargreaves, T. and Hauxwell-Baldwin, R. (2015), "Smart homes and their users: a systematic analysis and key challenges", *Personal and Ubiquitous Computing*, Vol. 19 No. 2, pp. 463-476.

Wortmann, F. and Flüchter, K. (2015), "Internet of things – technology and value added", *Business and Information System Engineering*, Vol. 57 No. 3, pp. 221-224.

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