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Products and Processes in the Age of the Internet of Things (Extended Abstract)

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1 Introduction

Digital technologies, also known as SMAC technologies (i.e., Social, Mobile, Analytics, and Cloud), have led to profound changes in our private and professional lives (Bharadwaj et al. 2013; Borgia 2014; Legner et al. 2017). One digital technology that has received considerable attention in recent years is the Internet of Things (IoT). The IoT involves physical objects equipped with sensors, actuators, computing logic, which are able to communicate via the Internet (Oberländer et al. 2018; Porter and Heppelmann 2014; Rosemann 2013; Yoo et al. 2012). These physical objects, usually referred to as smart things, are the nucleus of the IoT and connect the physical with the digital world (Borgia 2014).

As a fast-moving, global megatrend, digitalization in general and the IoT in particular transforms value networks across all industries and presents organizations with many challenges (Collin 2015). When it comes to digital technologies such as the IoT, many organizations are uncertain as to which technologies have the potential to enhance their processes, products, services, and business models (Legner et al. 2017). Despite the prevailing uncertainty, the IoT holds enormous potential for organizations. Digital technologies such as the IoT make it possible for internal processes to be handled more efficiently (i.e., they have a positive impact on the typical dimensions of Business Process Management: quality, flexibility, throughput times, and costs) and allow the development of entirely new business models, products, and services (Gimpel et al. 2018; Legner et al. 2017). By 2015, IoT market spending amounted to USD 690 billion and could reach USD 11.3 trillion by 2025 (IDC 2019; Johansson et al. 2019). Due to its high potential in different applications fields, an in-depth understanding of the IoT is a necessary prerequisite. In particular, products and processes are essential elements for organizations to survive in competitive markets and for putting digital technologies into context (Gimpel and Röglinger 2017). Thereby, not only essential elements of organizations are influenced by digital technologies such as the IoT, but also the related academic disciplines such as Business Process Management (BPM) and the product development. How *products* and *processes* are influenced by the IoT will be shown in more detail below.

Innovative technologies such as the IoT have led to the integration of information technologies in many products (e.g., to enable new service offerings). New products

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and digital services emerge and existing products and related services are complemented and/or enriched by digital technologies such as the IoT (Legner et al. 2017). As a result, offering digital services in addition to a physical product is increasingly becoming a prerequisite for market entry in many industries (Fleisch et al. 2015; Porter and Heppelmann 2014; Yoo et al. 2012). In a 2019 study by the Harvey Nash Group and KPMG, over 3,600 participating organizations estimate that, within the next three years, "44% of organizations are undergoing some kind of major digital change that will fundamentally impact their organization. This is either through introducing new products and services that will be equal to or more dominant than existing ones (38%) or – more radically – fundamentally changing their business model, for instance moving from selling products to selling services (6%). A further 41% of organizations will be introducing new products and services to supplement existing ones" (Harvey Nash Group and KPMG 2019). Based on the potential of the IoT, organizations have now to decide how the IoT should be used to enrich already existing products or to develop entirely new products (Porter and Heppelmann 2014).

Process orientation as an important paradigm with the goal of designing and redesigning organizations' internal operations (Recker and Mendling 2016) is also affected by digital technologies such as the IoT (Legner et al. 2017). Business Process Management (BPM), which is the related management discipline of process orientation, focuses on two overarching topics: business processes improvement and BPM capability development (vom Brocke and Rosemann 2015). Process improvement (i.e., the improvement of organizations' business, support, and management processes), in particular, has long been recognized as an important topic and continues to be a top priority topic for process managers (Harmon and Wolf 2016). The 2019 study by the Harvey Nash Group and KPMG confirms that improving businesses processes is still ranked as number two of the top five priorities by company boards (Harvey Nash Group and KPMG 2019). Digitalization has an ever-increasing influence on the processes of established organizations, leading to significant changes in their existing work routines (Lasi et al. 2014; Legner et al. 2017). Companies in many industries are still trying to increase the automation and digitalization of their business processes (Legner et al. 2017; Matt et al. 2015). Nevertheless, due to the current lack of in-depth knowledge, organizations are still struggling to identify which digital technologies they should adopt in order improve their business processes (HBRAS 2015; Legner et al. 2017).

In addition to the individual design and redesign of products and processes, products and processes can be influenced simultaneously by the IoT. The fundamental characteristics of smart things, such as sensors, actuators, computing logic, and the ability to communicate via the Internet (Fleisch et al. 2015), enable the (remote) integration of different actors, such as customers and organizations, with the goal of creating value for both sides in an innovative way (Beverungen et al. 2017). For example, in a business-to-customer (B2C) context, a smart thing can integrate a customer, who uses the device, and an organization, which can use the device in order to provide its knowledge and skills. Thereby, the integration changes the customer's behavior (i.e., its processes) and the organization's processes. In addition, smart things not only integrate customers and organizations. In a business-to-business (B2B) context, for example, they can also integrate organizations with the aim of building so-called product systems, consisting

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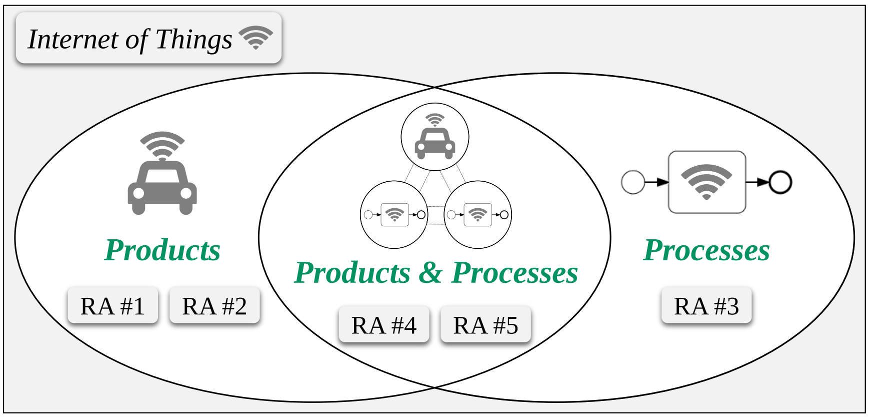
of interacting smart things, and IoT ecosystems, consisting of interconnected product systems. Similar to the B2C context, the integration of organizations leads to changes in operations (i.e., processes) within and among participating organizations (Legner et al. 2017; Porter and Heppelmann 2015; Beverungen et al. 2017).

2 Structure of the Thesis

In order to tackle the impact of the IoT on products and processes, this cumulative doctoral thesis consists of five research articles structured along the overarching topics of *products* and *processes*, as well as the integrated perspective of both *products and processes*. Figure 1 shows how the individual research articles are assigned to the overarching topics.



RA = Research Article

Fig. 1. Assignment of the Research Articles to the Structure of the Doctoral Thesis

Firstly, as in the age of the IoT a shift has seen in the nature of products towards smart products, namely smart things, an in-depth understanding of smart things as the nucleus of the IoT is a prerequisite to tap the full potential of the IoT (i.e., in research or practice). Despite the need for detail insights into smart things in supporting organizations with profound knowledge (e.g., for product development), the academic literature has failed to provide appropriate works until now. The literature has discussed the IoT from multiple perspectives (e.g., technical fundamentals and needs as well as B2B and B2C perspectives). While the individual contribution of the literature is undisputable, smart things are nevertheless treated as a black box in most of the works. In order to provide a better understanding of smart things, research article #2 as extension of research article #1 examine the individual smart thing as the nucleus of the IoT. The results of research article #2 are twofold: (1) In order to capture the nature of an individual smart thing, a taxonomy based on the method by Nickerson et al. (2013) has been developed. The development and validation of the taxonomy were based on the latest insights from the IoT literature and on a sample of 200 smart things chosen from

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all important IoT application fields across the B2C domain. (2) Based on the classified sample of 200 smart things, a hierarchical cluster analysis was conducted in order to identify which combinations of smart thing characteristics typically occur together (Everitt et al. 2010; Ferreira and Hitchcock 2009; Fraley and Raftery 2002; Kaufman and Rousseeuw 2009). To confirm robustness, clarity, and meaningfulness, the identified clusters were evaluated using the Q-Sort. Both the taxonomy of individual smart things and the smart thing clusters emphasize that smart things should not be treated as a black box. This new understanding of smart things facilitates the adoption and affordance of smart things in further settings and provides a basis for the use of smart things in broader contexts such as IoT ecosystems. In addition, practitioners might leverage the results in, for example, product development processes. In this case, the clusters would provide an initial understanding of common types of smart products. The taxonomy could then be used to discuss in more detail the fundamental characteristics a smart product should address.

Secondly, with research article #3 this thesis enables a process-oriented view by addressing a method providing guidance how organizations can optimally exploit the digitalization potential of their business processes. The existing literature provides a huge variety of approaches aiming to improve business processes (e.g., process enhancement or process redesign patterns) (Dumas et al. 2018b; van der Aalst 2013; Vanwersch et al. 2016). For example, some works consolidate the diverse ideas of process improvement in so-called process enhancement or process redesign patterns (Dumas et al. 2018c; Limam Mansar and Reijers 2007; Recker and Mendling 2016). Other works focus on approaches which prioritize process improvement projects which are evaluated in terms of their influence on process performance (Darmani and Hanafizadeh 2013; Limam Mansar et al. 2009; Linhart et al. 2015; Ohlsson et al. 2014). In addition, there are holistic approaches, such as frameworks, which provide organizations with methods for generating improvement ideas along different decision dimensions (Vanwersch et al. 2016). Although these works represent a significant contribution to the knowledge of business process improvement, they fail to link the fields of business process improvement and digitalization. To connect these fields, research article #3 of this doctoral thesis proposes a method which guides organizations in evaluating which digital technologies they should consider in order to exploit the digitalization potential of their business processes. Thereby, research article #3 goes beyond the evaluation of IoT technologies (e.g., smart things), and enables organizations to identify and select digital technologies independently of a particular type of digital technology. To support the selection of digital technologies for process improvement, a method based on the action design research (ADR) (Gregor and Hevner 2013; Rijsdijk and Hultink 2009; Sein et al. 2011) and the situational method engineering (SME) approach has been developed (Braun et al. 2005; Vanwersch et al. 2016). In line with ADR, the method has been co-developed with, and continually evaluated by, five organizations along two design cycles (i.e., first cycle with five and second cycle with three organizations). The method comprises four activities, each including techniques, tools, roles and a distinct output. The detailed description of activities and further related elements guides organizations through an evaluation of digital technologies in order to reveal those best suited to improving specific business processes. The proposed method aims to reduce

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organizations' uncertainty when it comes to the evaluation of digital technologies. Thirdly, in the age of the IoT, it is increasingly important for organizations to take an integrated view of products and processes. In order to address this topic, research articles #4 and #5 suggest ways in which organizations can be supported in the introduction of smart things and the possible (re-) alignment of the underlying processes.

Thanks to their ability to integrate various actors (e.g., customers, organizations, and smart things), smart things are a prerequisite for building complex interaction relationships, such as IoT ecosystems, which are enabled by interconnected product systems or so-called smart service systems (SSS) (Beverungen et al. 2017; Lim and Maglio 2018; Medina-Borja 2015; Wuenderlich et al. 2015). However, smart things in broader contexts such as IoT ecosystems respectively SSS have so far received little academic attention. Research article #4 therefore responds to this absence, proposing a domain-specific modeling language (DSML) that involves all relevant actors for analyzing and designing SSS respectively IoT scenarios (e.g., in B2C and B2B contexts) from a process-oriented and structural view. The DSML draws on the literature on service science and the IoT as justificatory knowledge. To develop the DSML, the design science research approach (Gregor and Hevner 2013; Peffers et al. 2007) was combined with the domain-specific modeling language engineering method (Frank 2013). The result of this development process is an abstract – i.e., semi-formal – metamodel for describing how to build a conceptual model (Eriksson et al. 2013) and a concrete syntax – i.e., textual and graphical notational elements for representing diagrams (Mannadiar 2010). The DSML has been evaluated by modeling fictitious and real-world examples, interviewing domain experts, conducting a competing artefact analysis and its discussion along different design objectives.

Organizations may be interested in assessments of the economic feasibility of IoT scenarios developed using the DSML from research article #4. Research article #5 picks up this topic by supporting organizations in this decision process. Thereby, most of the prevailing IoT literature focuses on describing the impact of IoT on products, processes, and business models (Boos et al. 2013; Bucherer and Uckelmann 2011; Fleisch et al. 2015; Porter and Heppelmann 2014). Very few works focus on an economic perspective regarding the IoT (Lee and Lee 2015). Hence, research article #5 provides an economic decision model to assess which IoT investments (i.e., IoT projects) lead to the largest increase in the long-term firm value of an organization. Thereby, research article #5 focuses on manufacturing companies. By determining an optimal sequence of IoT projects, the decision model indicates whether it is a product, process, and/or an infrastructure project that an organization should execute next. The decision model builds on value-based management (VBM) (i.e., value contributions to a company's long-term firm value are used for control purposes) (Buhl et al. 2011; Rappaport 1986; vom Brocke and Sonnenberg 2015) and project portfolio selection (PPS) (i.e., determining an optimal project portfolio) (Archer and Ghasemzadeh 1999) as justificatory knowledge. In order to develop the decision model, the design science research approach was applied (Gregor and Hevner 2013). The evaluation was conducted in line with the evaluation framework by Sonnenberg and vom Brocke (2012) (i.e., deriving design objectives, feature comparisons and expert interviews, demonstrations using a prototype).

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