THE IMPACT OF THE INDUSTRIAL INTERNET OF THINGS ON ESTABLISHED BUSINESS MODELS

DANIEL KIEL
Friedrich-Alexander University Erlangen-Nürnberg (FAU), Industrial Management, Lange Gasse 20, 90403 Nürnberg, Germany, daniel.kiel@fau.de (Corresponding)

CHRISTIAN ARNOLD
Friedrich-Alexander University Erlangen-Nürnberg (FAU), Industrial Management, Lange Gasse 20, 90403 Nürnberg, Germany, christian.arnold@fau.de

MATTHIAS COLLISI
Friedrich-Alexander University Erlangen-Nürnberg (FAU), Industrial Management, Lange Gasse 20, 90403 Nürnberg, Germany, matthias.collisi@fau.de

KAI-INGO VOIGT
Friedrich-Alexander University Erlangen-Nürnberg (FAU), Industrial Management, Lange Gasse 20, 90403 Nürnberg, Germany, kai-ingo.voigt@fau.de

Abstract

The Industrial Internet of Things (IIoT) has gained much attention in practice and research over the last years. It serves as a novel manufacturing paradigm ensuring flexibility and adaptability of production systems and value chains in order to maintain the future global competitiveness of manufacturing enterprises. Its implicated technological change will additionally result in extensive organizational consequences; existing value chains will change resulting in opportunities for new business models (BM). Consequently, established BMs have to be reflected critically.

In general, the IIoT constitutes a relatively young research field. While prior literature concentrated on technological aspects, economic has a backlog compared to technical research. Nevertheless, some authors are already dealing with potential influences of the IIoT on BMs in general, but merely focus on specific aspects and have to be regarded in the respective light of their field of research. Thus, there is no comprehensive picture about the impact of the IIoT on established BMs. Hence, this paper addresses this research gap by answering the research question: In what way does academic literature address the impact of the IIoT on BMs of established manufacturers?

For this purpose, a systematic literature review is chosen as research method. After a structured selection process with regard to high quality and subject relevance, we eventually identified 87 articles of journals, collected editions, as well as studies of research institutions published between 2011 and 2015, which are analyzed in detail. Subsequently, these were synthesized according to the nine components of the BM Canvas by Osterwalder and Pigneur serving as the analytical framework of this review.
Our results show that existing academic literature mainly focuses on IIoT-triggered changes of companies’ key resources and activities, whereas particularly the entire customer perspective is mostly disregarded. Furthermore, none of the reviewed scientific works comprehensively deal with the influences of the IIoT on the entire set of BM components at all. Regarding the most prominent qualitative BM changes, we disclose that the IIoT enables an increasing offering of customized, individualized, and smart products and services associated by a consequent service-orientation. For the purpose of the latter, customers are increasingly integrated in development and manufacturing processes on a collaborative basis. In addition, the IIoT-inherent generation of enormous amounts of undirected data, i.e. big data, requires target-oriented data analysis, which then again necessitates specific experts capable of data mining and processing activities. For all the IIoT’s intelligent production systems, human beings associated with their keen senses still represent resources of particular importance. Since one of our research goals is to derive need for further research, the review enables us to identify areas to be examined more extensively in future. For instance and among others, we suggest to investigate the customer perspective in more detail as well as to examine the BM as an entire system contributing to a more comprehensive understanding of changes in the context of the IIoT.

In conclusion, our paper contributes to a better understanding of IIoT-triggered BM changes, which is not only valuable for academia, but also for enterprises facing the integration of the internet into their value creation processes.

**Keywords:** Industrie 4.0, Industrial Internet of Things, Business Models, Business Model Innovation, Industrial Manufacturing, Systematic Literature Review

**Introduction**

**Problem outline**

Today, manufacturing companies have to deal with an increasingly globalized world that leads to an accentuation of competition, especially by new competitors from Asia (Sendler, 2013). This intensification of competition is further enhanced by both shortened technology and innovation cycles as well as deregulation resulting in a particularly more dynamic competition. Besides this substantial impact on the manufacturing environment, the industrial sector has to cope with a strengthened volatility of markets, which complicates quantity forecasts. Another challenge for industrial companies is inherent in an increased product and process complexity (Bauer et al., 2014; Bauernhansl et al., 2014; Hirsch-Kreinsen and Weyer, 2014; Spath et al., 2013; Wirtz, 2011). Consequently, companies’ competitiveness highly depends on their capability of flexibly and fast supplying customized products at the cost of a large-scale production (Bauernhansl, 2014; Dais, 2014). This requires production and logistics systems that are in particular flexible, efficient, and adaptable (Bauer et al., 2014).

Against this background, several future projects emerged all over the world, e.g. the “High-Tech Strategy 2020” in Germany or the “Industrial Internet Consortium” in the USA. These initiatives aim at developing and implementing the Industrial Internet of Things (IIoT), which is known as “Industrie 4.0” in the German-speaking world, in order to maintain and strengthen the global competitiveness of the respective industrial locations (Ramsauer, 2013). Besides a production-technical change, the IIoT also results in extensive organizational consequences and opportunities (Bauernhansl, 2014; Botthof, 2015). The implementation of
IIoT technologies enables the restructuring of entire value chains, which is reflected by cooperations between companies, product and service offerings, as well as a company’s relationship to its customers and employees (Kagermann et al., 2013). These shifts in value creation make it necessary for established manufacturers to critically reflect their current strategy, systematically and early identify new business opportunities, and consequently innovate and adapt their business models (BM) in order to stay competitive (Bieger and Krys, 2011; Chesbrough, 2007; Gausemeier and Amshoff, 2014; Jonda, 2007; Sendler, 2013). According to Wirtz (2011) and Schallmo (2014), a BM represents the characterization of how a company operates. In this context, a BM describes value creation, the value proposition to customers, relevant resources, as well as the cost and revenue model.

Essentially, the IIoT characterizes the proceeding digitized connection of industrial manufacturing. Corresponding to its official definition, the IIoT is constituted by the real-time capable, intelligent, horizontal, and vertical connection of people, machines, objects, and information and communication technology (ICT) systems to dynamically manage complex systems (Bauer et al., 2014). This will ultimately result in a “smart factory”, where production facilities are entirely digitized, intelligent, connected, and arising problems are solved independently. Moreover, intelligent products contain all necessary information to autonomously head for production plants and overview future production stages (Kagermann et al., 2013; Lichtblau et al., 2015).

In general, the IIoT constitutes a relatively young research field. While prior literature concentrated on technological foundations, challenges, and opportunities, economic has a backlog compared to technical research (Brettel et al., 2014; Emmrich et al., 2015; Krückhans and Meier, 2013). Nevertheless, some authors are already dealing with potential influences of the IIoT on BMs in general (e.g. Bauernhansl, 2014; Herterich et al., 2015a; Russwurm, 2013; Spath et al., 2013). Since these contributions all focus on specific aspects and have to be regarded in the respective light of their field of research, there is no comprehensive picture about the impact of the IIoT on established BMs. Hence, this paper addresses this research gap by answering the following research question: In what way does academic literature address the impact of the IIoT on BMs of established manufacturers? In this context, this paper aims specifically at:

(i) identifying the most frequently analyzed BM components when it comes to IIoT-triggered changes,
(ii) analyzing academic literature regarding the comprehensive consideration of BMs when it comes to IIoT-triggered changes,
(iii) identifying the most prominent qualitative BM changes discussed in academic literature,
(iv) identifying potential research gaps having need of further investigations.

To answer the research question, we conduct a systematic and integrative literature review to reveal IIoT-triggered consequences on BM parts discussed in academic literature to date. The remainder of this paper is structured as follows: The next section outlines the relevant theoretical background by defining both the terms “IIoT” as well as “BM”. Furthermore, the BM Canvas, which serves as the theoretical framework for the analysis of our findings, is explained. Next, the research design is outlined before the key findings are presented and subsequently discussed. Eventually, our paper’s contribution to theory and practice is disclosed.
Theoretical foundations

**Definition and opportunities of the IIoT**

Today, manufacturing enterprises have to cope with increasing competition, highly volatile markets, rising product and process complexity, rising customer expectations, as well as shortened technology and innovation cycles. As a result, flexibility and adaptability serve more and more as success factors. Against this background, several initiatives all over the world aim at developing and implementing the IIoT in order to maintain and strengthen the global competitiveness of the respective industrial locations (Ramsauer, 2013).

The IIoT, which is often referred to as the fourth industrial revolution, integrates recent trends from the ICT area into industrial production systems (Spath et al., 2013). Essentially, the IIoT characterizes the proceeding digitized connection of industrial manufacturing. Correspondent to its official definition, the IIoT is constituted by the real-time capable, intelligent, horizontal, and vertical connection of people, machines, objects, and ICT systems to dynamically manage complex systems (Bauer et al., 2014).

Nowadays, technological achievements in the information and communication area like sensors and actors are also applicable to the production environment since they are high-performance and favorable at the same time. In this regard, the IIoT can be seen as a new manufacturing paradigm triggered by recent ICT developments. In this novel production environment, intelligent and self-controlling objects result in smart products that are constantly identifiable, steadily locatable, as well as know their latest condition and alternative paths to their destination (Ramsauer, 2013; Spath et al., 2013). The core element required for the implementation of the IIoT are cyber-physical systems (CPS), which enable the connection of information and software technologies on the one hand with mechanical and electronic parts on the other hand. Furthermore, CPS allow the mutual communication of these elements by applying communication technologies like the internet (Kagermann et al., 2013; Ramsauer, 2013), which leads to the connection of the virtual and the real world (Spath et al., 2013).

The vision of an entire penetration of the production environment with this manufacturing approach can be summarized as a “smart factory”. In this manufacturing plant of the future, workpieces control themselves through the shop floor to machines using the fastest possible route and book both these machines as well as all required materials. Furthermore, machines in a smart factory employ information of workpieces to set-up automatically. After being produced, smart products are further able to organize their delivery to customers autonomously. In the case of a predicted error, affected machines just reschedule the production themselves (Kagermann et al., 2013; Kaufmann, 2015; Lichtblau et al., 2015; Spath et al., 2013). The factory of the future is in control of complexity and consequently less vulnerable to losses of production. This leads to increased resource efficiency in terms of material usage, energy consumption, and human work (Kaufmann, 2015; Rehage et al., 2013; Wildemann, 2014). Moreover, increasing flexibility (Hinrichsen and Jasperneite, 2013; Kagermann et al., 2013),
customization (Kagermann et al., 2013; VDMA, 2014), demography-sensitive job design, improved work-life balance (Hirsch-Kreinsen and Weyer, 2014; Kagermann et al., 2013; Speth et al., 2013; von Garrel et al., 2014; Wieland and Pfizner, 2014), optimized decision making (Ganiyusufoglu, 2013), and highly profitable BMs (Baunehansl, 2014; Botthof, 2015) represent further opportunities facilitated by the IIoT.

Definition of BM

The BM construct is research subject for more than 20 years (Ghaziani and Ventresca, 2005). Nevertheless, academia has not yet been able to agree on one clear and consistent definition (e.g. Casadesus-Masanell and Ricart, 2010; Enkel and Mezger, 2013; George and Bock, 2011; Johnson, 2010a; Zott et al., 2011). This is evidenced by the fact that the characteristic of describing the blueprint of how a company creates and incorporates value is the only widespread consensus about the nature of a BM (e.g. Gassmann et al., 2011; Johnson, 2010b; Magretta, 2002; Osterwalder et al., 2005; Teece, 2010; Wirtz et al., 2010; Zott and Amit, 2010). Beyond this lowest common denominator, several different opinions exist about what a BM is. Demil and Lecocq (2010), for instance, identified two different perceptions of a BM: a transformational and a static approach. The first one understands a BM as a tool to initiate changes within the organization. The latter approach regards a BM as the blueprint of the relations between a business’ core components and represents the majority. However, this perception constitutes only a frame, which again contains various definitions and perspectives. Chesbrough (2010) and Chesbrough and Rosenbloom (2002), for instance, follow a very technology-focused comprehension. In their concepts, a BM links technical potential with value creation and therefore makes the technology’s latent value exploitable. Another view is enrooted in the transaction theory. Here, a BM is constituted of the content, structure, and governance of value creating transactions. Furthermore, the BM describes the steps required to execute these transactions (Amit and Zott, 2001). According to the BM understanding of Hendrix (2005), a BM describes all parties concerned with the value creation as well as the value proposition, whereby he directs his attention towards the necessary process steps, i.e. a very process-oriented BM conceptualization. Morris (2009) also follows such a process-oriented BM approach, but is rather market-concentrated. He determines a BM mainly as a company’s relationship to the market and all processes required for establishing these relationships. Another approach is an architectural one, which is consistent with most approaches in academic literature (Wirtz, 2011; Zott and Amit, 2010). It defines a BM as the configuration of tasks an organization has to conduct to create and deliver value to its customers. Beyond a company’s own activities, this approach also considers the organization’s partner network, which is necessary to create value. Furthermore, it illustrates how these single elements are related to each other (Amit and Zott, 2012; Chesbrough, 2007; Osterwalder et al., 2005; Santos et al., 2009; Sorescu et al., 2011; Teece, 2010; Zott and Amit, 2010).

For further proceeding, it is necessary to agree on one definition. Osterwalder et al. (2005), as representatives of an architectural approach, compared the most frequently mentioned BM definitions and deduced nine components constituting a BM. Therefore and since it is widely spread in academic literature, their BM concept should be applied for the purpose of this study. Moreover, the illustrative character of the BM Canvas, a graphic presentation of this BM concept developed by Osterwalder and Pigneur (2010), facilitates its understanding without over-simplifying the complexity. This is doubtless one reason for its high relevance for the application by organizations all over the world (Osterwalder and Pigneur, 2010). Consequently, its utilization also qualifies for the IIoT’s highly practical nature. According to Osterwalder.
and Pigneur’s (2010) definition, “[a] business model describes the rationale of how an organization creates, delivers, and captures value” and consists of the following nine building blocks shown in figure 1.

![Figure 1: The BM Canvas](image_url)

The center is formed by the value proposition, which describes products and services that add value for the particular customer segments representing the different groups of customers the company intends to address. The channels characterize how the company reaches its customers and communicates with them. The description of the customer relationships represents a third customer-oriented field. The key resources are those resources that are mandatory to perform the key activities, which describe the activities a company has to perform to create the value proposition and to run the entire BM. The firm’s network of crucial suppliers and other important partners is described by the key partnerships. Finally, both the revenue streams and the cost structure give some indication of the financial aspects (Osterwalder and Pigneur, 2010).

**Methodology**

In a general sense, this paper aims at reviewing and displaying relevant, existing, and academic literature in terms of manufacturers’ BM changes triggered by the IIoT. We apply a systematic and integrative literature review as an appropriate methodological approach for the achievement of our objectives for two reasons. First, it is systematic, scientific, transparent, elaborate, and replicable for the identification, evaluation, synthesis, and discussion of existing works of researchers, academics, and experts (Fink, 2013; Tranfield et al., 2003). Associated, anybody using the same databases, keywords, and selection criteria should obtain the same set of results (Leseure et al., 2004). Second, the exemplary collocation of several studies serves not only the presentation of the state-of-knowledge but also the disclosure of critical and disregarded aspects or unsolved problems. Eventually, areas where knowledge is still lacking can be observed and needs for further research can be derived (Fink, 2013). The results and
novel insights of an integrative research review are able to replace former studies and provide significant scientific benefits (Cooper, 1989; Cooper, 1998). The methodological approach used in this paper follows the works of Rashman et al. (2009), Soni and Kodali (2011), and Winter and Knemeyer (2013). Thus, the subsequent explanations refer to the aspects of time horizon, database selection, journal selection, article selection, article classification, and classification analysis.

**Time horizon for article selection**

For the review and evaluation process, the publication date of the articles is between April 2011 and November 2015. The reason for choosing 2011 as the starting point for the collection of relevant material is that in 2011 the term “Industrie 4.0” was officially published the first time by the German government in the context of the world’s most important and popular industry trade show, the “Hannover Messe”. The date of the official definition of the term by the Industrial Internet Consortium (USA) was some time later, in March 2014. Consequently, it is made sure that these terms were not used before. The reason for choosing November 2015 as the end point is to collect the most recent scientific publications addressing this highly significant and forward-looking topic.

**Database selection**

In the paper at hand, we collected data from three different databases: Business Source Complete (EBSCO), Science Direct, and Google Scholar. Additional potential articles were identified by applying the snowball method, which aims at collecting literature from previous publications’ reference lists. In doing so, we avoid to leave out potential relevant articles, which may not be registered in the databases. This procedure is widely accepted and has been employed in existing literature reviews (e.g. David and Han, 2004; Franke and zu Knyphausen-Aufseß, 2014; Soni and Kodali, 2011; Webster and Watson, 2002; Winter and Knemeyer, 2013).

**Journal selection**

There is wide consensus that papers published by highly cited and ranked journals are usually of better quality, whose integration again results in an enhanced quality of a literature review (e.g. Berning and Holtbrügge, 2012; Light and Pillemer, 1984; McKinnon, 2013). Nevertheless, due to the IIoT’s degree of novelty in research, we decided to not restrict our review by the selection of journals with a particular high reputation. On the contrary, we decided to extend it by reliable and relevant collected editions and book chapters. This decision is in line with Cooper (1989), who stated that relying on only journal articles is appropriate “when the published research contains several dozen, or in some cases several hundred, relevant works”. Obviously, this is not applicable to the term IIoT, which has not become apparent until 2011, neither in practice nor in theory.
Article selection

In the first step, we both defined databases to be applied as well as relevant keywords addressing our research project. Since we aimed at the highest possible reliability and relevance of keywords, they were not only derived from existing literature but also from two brainstorming and discussion rounds with three independent research colleagues within the Friedrich-Alexander University Erlangen-Nürnberg. Eventually, the following keyword sample was revealed: “Industry 4.0”, “next industrial revolution”, “fourth industrial revolution”, “internet of things and services”, “industrial internet of things”, “cyber-physical systems”, “business model”, “business model development”, “business model innovation”, “business concept”, “business logic”, and “business creation”. These were extended by their respective German synonyms since the IIoT was first defined in Germany, as mentioned before. To link them, we used the operator “AND”, which is recommended by Theisen (2013).

Subsequently, our search resulted in 146 articles, which contained at least one of the keyword combinations (see figure 2) and was published between April 2011 and November 2015. After having removed duplicates from the sample (Rashman et al., 2009), each of the authors read their abstracts and conclusions independently in order to assess their relevance to our research question. The authors learned that some of the abstracts and conclusions proved irrelevant or low-quality. Thus, the sample was narrowed down to remaining 94 articles, which were subsequently read in their entirety by all authors. The critical requirement, the articles had to fulfill, was a strong relationship between the IIoT and its economic influences on established companies’ BMs. Additionally, the articles’ bibliographies were scanned (snowball method) to avoid leaving out potential relevant articles not registered in the searched databases. These were also read in their entirety by all authors. The full-text review followed the systematic approach of Rashman et al. (2009). Finally, the authors met in a discussion session and evaluated the articles’ relevance and quality. The research goals, definitions of key terms, methodological rigor, results and conclusions, as well as the relevance to IIoT/BM were of particular interest. Non-relevant documents were consequently extracted. In doing so, we received a final list of 87 articles and book chapters, which represented the data corpus of the subsequent integrative literature review. Thereby, we also ensure the high quality and comprehensiveness of the paper at hand. Figure 3 gives an overview of the article selection process in order to ensure a systematic, transparent, and replicable literature review.
Search in electronic databases:
- EBSCO
- Science Direct
- Google Scholar

Are the following criteria fulfilled?
- Time period
- Keywords

Exclusion

146 articles

Reading of abstracts and conclusions

Are the articles lacking in relevance and/or quality?
Are there duplicates?

Exclusion

94 articles

Reading articles in their entirety and scanning of bibliographies

Are the articles of high quality and of subject relevance?

Exclusion

87 articles

Figure 3: Overview of article selection process
Article classification

Afterwards, the final sample of 87 documents was analyzed in depth and the respective authors´ deliberations were classified according to the nine building blocks of the BM Canvas (for their explanation see section “theoretical foundations”), wherever possible and justifiable. Thus, the BM Canvas serves as the analytical framework for the synthesis of the existing body of literature. It gives our analytical review a clear, unambiguous, and comprehensible structure.

Classification analysis

In the final step, all authors of the paper at hand compared, critically reflected, and discussed the classified articles and book chapters. Given the descriptive nature of this systematic review, we did not apply statistical methodologies for the classification of the literature sample and the derivation of future research necessities. The final step of the review process enables us to achieve four research goals we set in the beginning, i.e.:
(i) identify the most frequently analyzed BM components,
(ii) analyze academic literature regarding the comprehensive consideration of BMs,
(iii) identify the most prominent qualitative BM changes discussed in extant literature, and
(iv) identify potential research gaps and future needs for research in the context of IIoT-triggered BM adaptations.

Findings

In the following, we depict the review results in terms of the existing literature´s deliberations with regard to IIoT-triggered BM changes. For this purpose, each of the nine BM building blocks is explained successively and explicitly with regard to its most important aspects.

Value proposition

According to Brettel et al. (2014), under the influence of the IIoT, the portfolio of products and services offered to customers mainly aims at individualizing offerings (e.g. batch size 1 and mass customization) and accelerating time to market. In addition, the increasing integration of ICT systems enhances quality, flexibility, innovativeness, as well as the development and offering of smart products and services (Dais, 2014; Kagermann, 2014; Russwurm, 2013). The latter is e.g. represented by condition monitoring, which serves as the basis for predictive maintenance. Such data-driven product and service offerings are enabled by smart components equipped with sensors, processors, connectivity, and cloud interfaces. Associated, a consequent service-orientation entails opportunities in terms of novel business concepts and income sources (Porter and Heppelmann, 2014).
Customer segments

Manufacturing enterprises integrating the IIoT into their value creation face the opportunity to not merely change existing, but rather create new markets constituted by novel customer segments, which were not addressed previously (Porter and Heppelmann, 2014). Here, car-sharing concepts of several automotive original equipment manufacturers (OEM) serve as a good example: enhanced customer- and service-orientation, implementation of smart ICT systems, and shared-usage models approach customers, who were not willing to afford a car in the past (Davis et al., 2012; Sendler, 2013).

Channels

The IIoT leads to an extended use of social media and online communities. Accompanied by the opportunities of e-commerce and interactive online markets, companies establish a basis for approaching customers and delivering value propositions. Furthermore, social networks provide manufacturing potentials in terms of e.g. replacing emails during escalation management processes, sourcing data to optimize production processes, and analyzing social networks (Schließmann, 2014; Schöning and Dorchain, 2014).

Customer relationships

With regard to customer relationships, the reviewed articles emphasize the importance of collaborative and intensified relations, which are characterized by closer and earlier teamwork with and integration of customers (Schuh et al., 2014). In this context, exemplary methods and concepts are social media, online communities, open source, and open innovation. These produce large amounts of data, which can be used to add value throughout the whole value chain. Therefore, key partners and customers not only have to be provided with sufficient, transparent information, but also have to be integrated in corporate structures. To enable cooperation and co-design with customers, manufacturing enterprises need high collaboration and integration levels (Ehrenberg-Silies et al., 2014; Schuh et al., 2014).

Key resources

One of the most important resources in the context of the IIoT are value creation networks. They enable enterprises to act and react in real-time and across corporate boundaries enhancing flexible value propositions. For this purpose, a standardized, automatized, and intelligent connectivity of several production and logistics systems, manufacturers, suppliers, service providers, and customers via cloud-based platforms is essential (Forstner and Dümmler, 2014; Kleinemeier, 2014). Both these platforms and IT/ICT systems in general represent crucial resources. According to Herterich et al. (2015a; 2015b) and Ramsauer (2013), companies depend on IT capabilities since they enable cost efficiency and added values. Due to the influence of the IIoT and the Internet of Things and Services, established ICT systems have to be adapted, modernized, and optimized. Associated, the primary objectives are a cross-
company connectivity, availability, flexibility, man-machine integration, and mastering of big data. Additionally, the use of ICT systems for the coordination of and interaction with partners and customers plays an important role. In this context, software integration has to be mentioned as well. High levels of software integration into traditional production systems and processes result in significant productivity increases.

Moreover, the integration of cloud technologies into production environments, i.e. cloud manufacturing, constitutes novel key resources. In the course of this, the functionality of cloud computing in terms of offering decentralized on-demand services is adapted to production processes. The most important advantage of cloud manufacturing is billing of services according to real operating times, so that users save capital expenditures and investments. This is particularly important for small and medium-sized enterprises, which are willing to benefit from computer-based analyses and applications, but do not have financial resources available. Examples are IT services such as “software-as-a-service”, “platform-as-a-service”, “infrastructure-as-a-service” or even “everything-as-a-service”. Due to its influences on traditional and established product-oriented manufacturing, cloud manufacturing opens up new possibilities in terms of service-oriented manufacturing. On the one hand, open source approaches and digital platforms form the appropriate basis for customer integration. On the other hand, in the context of smart manufacturing, digital platforms serve technology integration across functional areas and users as well as the collection of relevant information and data with regard to processes, fulfillment of tasks, or procurement/supplier quality (Davis et al., 2012; Marston et al., 2011; Repschläger et al., 2010; Wu et al., 2014; Xu, 2012; Zhang et al., 2014).

The extensive integration of smart components equipped with sensors yields the collection of large amounts of data (= big data) as well as their targeted analysis in order to benefit from innovation and value creation potential. Certainly, data can also be collected from social networks. In this way, consumer sentiment can be observed and, consequently, communication with customers improved. Admittedly, large amounts of data do not necessarily provide valuable information. All the more important is a targeted, reasonable, and professional data mining and processing (Adolph, 2014; Ehrenberg-Silfies et al., 2014).

According to Gaziulusoy and Twomey (2014), Kalva (2015), and Würzt et al. (2015), additive manufacturing (AM) serving as a technological driver of the IIoT represents a further key resource in the context of IIoT-affected BMs. In general, AM is known as 3D printing procedures, which change not only established development processes but also production activities. Based on a digital model, 3D printing applies materials, e.g. plastic, metal, or ceramic, layer-by-layer to construct products. Due to research and development advances, the variety of applicable raw materials continuously increases. Consequently, AM substitutes traditional mindsets of late customer decoupling points, platform strategies, and passive customer roles with fulfilling customized demands under the slogan “mass customization”. Currently, AM is already used for prototype constructions associated with significant savings of time compared to traditional processes. Likewise, development advances, prices decrease, and customers’ attention increases resulting in higher willingness to pay for customized products. Additionally, digital models can be exchanged globally via internet, processed, individualized, and printed locally. Eventually, this is associated with many possibilities for novel BMs based on decentralized manufacturing (Kalva, 2015).

Despite increasing influences of IT and ICT systems, cloud manufacturing, AM, and software integration, Spath et al. (2013) emphasize that human beings assume important responsibilities in the context of the fourth industrial revolution. People are required as decision makers,
sensors, and actuators forming the core of each BM. Due to the complete and network-like connectivity of production plants, single objects and smart components can cause problems, whereupon human beings have to intervene with the aid of assistance systems. For all with intelligent sensors equipped CPS, there may emerge gaps, which can exclusively be closed by keen human senses. Nevertheless, the influence of the IIoT on the work environment is not without consequences. The advancing automation of administrative and manufacturing processes indeed results in productivity increases, but, in return, a highly qualified workforce is required for consequent activities such as data analyses. Victims affected by downsizing are probably employees of lower and middle qualification and wage levels.

**Key activities**

According to Herterich et al. (2015a; 2015b), *customer integration* plays an important role when it comes to a BM’s essential activities in the context of the IIoT. Customers become co-designers participating in development processes to design products in compliance with their needs. These possibilities are enabled by changing key resources as described before. With regard to higher levels of IT and software integration, e.g. by implementing CPS and cross-company connectivity, enterprises are facing respective activities in terms of *IT and software optimization* and adjustments in order to establish an appropriate reference architecture (Ramsauer, 2013). Our literature review indicates that extant literature is convinced of the importance of *analyzing big data* (Bulger et al., 2014; Markl et al., 2013; Stockinger et al., 2015). The collection of process and machine condition data as well as their analysis by applying algorithms and data mining results in an early error detection and correction, reduction of downtimes, and efficiency increases. Additionally, the use and analysis of big data provides new business opportunities and data-driven products. Here, the growing fitness and health market serves as a good example (Bulger et al., 2014; Markl et al., 2013; Stockinger et al., 2015). Eventually, as per Matt et al. (2015), the trend of *distributed manufacturing*, i.e. an IT-driven production network containing geographically distributed production plants, establishes the basis for customized products, shortened delivery times, and production on demand.

**Key partners**

In the context of the IIoT, *customers* are collaborative partners and co-designers, which are integrated via open source or open innovation processes. The basic idea of open innovation is the extension of the traditional inside-out perspective with an outside-in perspective, which specifically opens up companies’ boarders to the market environment. Thus, external players may participate in product development processes, supported by the implementation of cloud technologies (Ehrenberg-Silies et al., 2014). Moreover, according to Porter and Heppelmann (2014), the IIoT influences key partners with regard to changing established *supply relationships*. Since products are increasingly digitized, suppliers are less expected to provide OEMs with physical components but rather with virtual sensors, software, and cloud-based platforms. In addition, data analyses and data mining requires *specialized analysts* as well as *IT experts* from outside, if not available at one’s corporation. Markl et al. (2013) clarify, that manufacturers should make an effort to transform
IT departments into data analytics divisions to benefit from big data. Another possibility is to outsource these activities to specialized service providers in order to reduce labor costs, which is defined as “data analytics-as-a-service” (Bulger et al., 2014; Stockinger et al., 2015). In general, Weiner et al. (2010) emphasize the relevance of a powerful, reliable, and platform-based partner network constituted by IT suppliers and respective service providers.

Revenue streams

Eventually, a BM has to be operated profitably. Fleisch et al. (2014) refer to an increasingly consequent service-orientation, enabled by the integration of physical and digital components and the subsequent offering of hybrid solutions. According to them, companies become able to generate novel revenues streams by establishing up-to-date BM types, e.g. “multi-sided”, “freemium”, or “add-on” BMs.

Cost structure

The literature review reveals several cost saving potentials. Computer-based tests and simulations enable reductions of product and prototype development expenses (Posada et al., 2015). Moreover, according to Bauernhansl (2014), the IT-driven optimization of value chains results in significant savings in terms of operating costs, e.g. energy, labor, and capital costs. Here, smart grids serve as a good example, since they intelligently identify production downtimes, e.g. at weekends or nights, and consequently activate energy-saving modes. Further cost savings are possible with regard to inventory, logistics, quality, maintenance, and complexity, reaching up to 60-70 percent.

Concluding Discussion

In the following sections, we concisely address the four goals of the paper at hand, defined in the introduction: With regard to the most frequently analyzed BM components in literature, we reveal that until now authors mainly focused on the key resources (78 out of 87 articles) and the key activities (75 out of 87 articles) associated with a successful adaption of manufacturing BMs to the IIoT. The next most prevalent BM component subject to IIoT-triggered changes is the value proposition, which is considered by 40 out of 87 articles. As table 1 clearly illustrates, the remaining six components constituting the BM Canvas play a subordinate role in the academic works between 2011 and 2015. Particularly, channels (14 out of 87 articles), customer relationships (11 out of 87 articles), and customer segments (7 out of 87 articles) hardly attract scholars’ attention.
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Concerning the comprehensiveness of BM component considerations in literature, our paper shows that most reviewed articles (21 out of 87 articles) examine exactly two of the nine BM components (based on our applied analytical framework). In addition, more than half of the analyzed articles (49 out of 87 articles) merely deal with a maximum of three BM components, representing only a minor part of an entire BM. As opposed to this, we identified just seven articles referring to more than five BM components. Particularly important, it has to be noticed that there is no article comprising all of the nine components defined by the BM Canvas. In other words, academic literature lacks a comprehensive analysis of IIoT-triggered BM changes. Having a closer look at the most prominent qualitative BM changes in literature, the review at hand identifies customized and individualized value propositions as well as smart products and services, associated by a consequent service-orientation, as critical changes in the context of the IIoT. Thereby, manufacturers are not only able to change existing, but rather create new markets and customer segments. These are approached by the increasing application of social media and online platforms/communities. Eventually, the enhanced offering of service solutions results in collaborative and intensified relationships with customers. Consequently, the latter represent critical key partners with regard to developing products and services jointly. Hence, customer integration into value creation processes plays an important role. However, customers are not the only players integrated from the outside, but are supplemented with specialized data analysts and IT experts capable of mastering big data. This outside-in process is particularly important, if such experts and capabilities are not available at one’s corporation. Otherwise, one’s IT departments have to adapt respective competences and conduct targeted big data analyses by themselves, which plays a crucial role since the integration of key resources such as IT/ICT systems and cloud technologies produces enormous amounts of undirected information and data. For all those intelligent systems, human beings associated
with their keen senses are still resources of particular importance. With regard to the financial perspective of a BM, we learned that a consequent service-orientation is associated with novel revenue sources and that the IIoT implicates far-reaching cost saving potentials. The abovementioned insights can likewise be regarded as managerial implications for manufacturing enterprises facing the implementation of the IIoT into their value creation. Since one of this paper’s research goals is to derive need for further research, the review enables us to identify six areas to be examined more extensively in future:

(i) Due to the IIoT’s degree of novelty in research, we observed that there are far too few scientific works dealing with an economic perspective. Compared to mature research areas such as BMs, industrial services, or technological diffusion, the quantity of high-quality published journal articles has to do a lot of catching-up.

(ii) Not only the financial perspective of a BM in terms of how to generate novel revenue streams as well as how to realize cost saving potentials, but also the crucial network of partners has to be analyzed further and in greater depth. The latter is particularly important against the IIoT’s background of an across-company network and connectivity idea. Additionally, the abovementioned lacking consideration of the channels, customer relationships, and customer segments, which constitute the entire customer perspective of a BM, requires research efforts by e.g. strategic and marketing scholars.

(iii) Since none of the reviewed articles deals with all of the nine BM components, we suggest a more comprehensive understanding and examination of the BM as an entire system entailing interplaying components. It is of high importance to consider BM components not only in isolation, but also with regard to their mutual influences and interdependencies. Besides these needs for future research identified in the course of our review, further points of contact for further research, which result from the fact that our study is, like all research, not without limitations, are derived below:

(iv) Despite the fact that a systematic literature review is an appropriate and powerful method for the provision of a comprehensive overview by structuring, refining, and clustering the existing knowledge on a specific topic (Carter and Ellram, 2003), it does not allow us to elaborate on the specific papers. Consequently, we suggest further qualitative, explorative studies on IIoT/BM in combination with quantitative methods to understand respective issues better.

(v) In the context of the last-named research gap, we recommend future research projects addressing the change management and BM innovation process required to achieve the BM changes revealed by the review at hand successfully. Associated, critical success factors regarding the implementation of the IIoT are of particular interest. Moreover, future research should strive for answering the questions “how to realize IIoT-based opportunities?” and “how to meet IIoT-based challenges?”.

(vi) Since this paper merely reviews articles dealing with IIoT-triggered changes of and influences on established manufacturing BMs, we are convinced of the interestingness and importance of further examining, which completely new and highly innovative BMs will probably emerge. Associated, academia has to understand, which are potential novel market players in this context.

In conclusion, our systematic review of 87 academic articles from 2011 until 2015 contributes to a better understanding of IIoT-triggered BM changes by working up the existing body of relevant literature. As such, this paper provides key insights on where research has been and where additional future research is needed.
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