Innovation management in a digital world
Guest Editor: Marianne Hoerlsberger

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1. Innovation management in a digital world

Introduction

Digitalisation causes a complete paradigm shift of production and innovation options. In the new wave of digitalisation, innovation systems and management of technology (MoT) face new challenges. Digitalisation understood as the use of digital technologies to change a business model and provides new revenue and value-producing opportunities. "Digitisation is the process of changing from analog to digital form", as Gartner states[1]. Digitalisation processes accelerate the need for innovation and for innovating faster. We live in the middle of ubiquitous and mobile supercomputing, ubiquitous presence of internet technologies everywhere, e.g. neuro-technological brain enhancements, genetic editing, robotic applied for instance in all kinds of production, in surgery, in space research and in car driving. Digital technologies are capturing all aspects of life nowadays. This momentum of change will continue to strengthen in the next decade. Driven by ever faster data connections, the miniaturisation of sensors and processors as well as intuitively operated devices with new application functions, networking pervades all areas of everyday life. In the emerging Internet of Things (IoT), physical objects communicate and interact with their environment. The Industry 4.0 approach entails new business models especially for small- and medium-sizes enterprises (SMEs) (Müller, 2019). Advances in the field of artificial intelligence allow the analysis and interpretation of huge amounts of data in real time and enable powerful automation solutions. Robots find optimal solutions even for highly complex tasks, without human intervention. Trends in the context of digital transformation are "digital networking in everyday life", "new opportunities with Big Data", "establishment of the IoT (Internet of Things) paradigm", "breakthroughs in artificial intelligence and robotics" and "vulnerability of critical infrastructures". The consequences for end users and consumers are a challenge. Engaging the customers and consumers into the development of the front-end phase of the digitalised service processes is very important for the success of the services (Saulina, 2019). Hyper-connectivity is expanding fast, while physical-digital integrations, IoT, smart home tech, big data, augmented and virtual reality, and machine learning are changing our entire systems of living and thinking[2]. The developments in the block-chain technology contribute significantly to this digitalisation and to the creation of new business models.

Digital transformation is the rapid growth of digitalisation and is called the fourth industrial revolution (Schwab, 2016). The first industrial revolution covers the mechanisation, which considers the process replacing agriculture with industry as the foundations of the economic structure of society from the end of the eighteenth century to the beginning of the nineteenth century. The second industrial revolution initiated the emergence of new sources of energy, such as electricity, gas and oil with leaded to combustion engines for instants and to completely new production systems as envisioned by Taylor and Ford at the end of the nineteenth century. The third industrial revolution is characterised by the appearance of nuclear energy, the rise of electronics with transistor and microprocessor, the increase of telecommunications and computers, and in industry the high-level automation in production with programmable logic controllers and robots. This fourth industrial revolution is, however, fundamentally different. It is characterised by a range of new technologies that are fusing the physical, digital and biological worlds, impacting all disciplines, economies and industries, and even challenging ideas about what it means to be human (Schwab, 2016). The resulting shifts and disruptions mean that we live in a time of great promise and hazards.
The world has the potential to connect milliards more people to digital networks, dramatically improve the efficiency of processes and even manage assets in ways that can help regenerate the natural environment, potentially undoing the damage of previous industrial revolutions. Industrial Internet of Things (IIOT) technology enables perpetual connectivity with customers. Key factors for new products or design such as value proposition and change in demand or expectation are available in no time (Seetharaman et al., 2019).

However, experts rise also concerns that organisations might be unable to adapt to this revolution, flooding our lives and societal, cultural, economic system and the industries. Governments could fail to employ and regulate new technologies to capture their benefits. Shifting power will create an important new security concern. Inequality may grow and societies fragment. The consequences for various territories with old traditional and heavy industries create big challenges. The innovation processes and the new business models are being revolutionised. There are discussions whether robots or intelligent machines will innovate in the future (Botha, 2019). Since digitalisation affects all our life in production, business, education, health system, at home, it is discussed in many different contexts, in conferences, by policy makers also in relation with funding strategies. Among others, International Association for Management of Technology (IAMOT) offers a platform for discussing digitalisation in the context of innovation and technology management. Therefore, IAMOT2017 Conference emphasised on digitalisation in the context of MoT and innovation management. Selected contributions of the conference are chosen for this special issue, which discusses the context of innovation management and technology management with digitalisation in industry or customer relation, with Industry 4.0, with digitalisation and business models, or with innovation via robots.

2. Method and summary of the papers

The special issue contains eight papers. They contribute to the fields of innovation management and MoT with an emphasis on aspects of digitalisation. Müller (2019) and Rachinger et al. (2019) discuss business models in relation with digitalisation. Seetharaman et al. (2019) and Walwyn et al. (2019) deal with industry and digitalisation (IIOT and energy). Monteiro et al. (2019) and Saunila et al. (2019) expound the problems of customer engagement in digital environment. Tambo and Filtenborg (2019) works out how IT4IT framework (see footnote 3) is linked to MoT; and Botha (2019) discusses whether intelligent machines will be capable to innovate in the future. Table I gives an overview of all eight articles about the core idea of the paper, the research questions, the applied methodology of the analysis, the main results, shortly about the contribution to MoT, and a classification for this analysis.

The applied methodologies are mainly of explorative character such as case studies, interviews, stakeholder survey and questionnaires. Only one article is a concept paper which deals with the future of innovation and whether machines will do this (Botha, 2019). Find here a short description of each of the eight articles.

Müller (2019) investigates business model innovation (BMI) in relation to SMEs, strategies for Industry 4.0. Industry 4.0 is expected to significantly transform industrial value creation. This article develops answers to which specific characteristics regarding user and provider perspectives of Industry 4.0 exist in small- and medium-sized enterprises towards Industry 4.0-triggered business models. The paper gives insight into manufacturing-SMEs-Industry 4.0 and their business models. Industry 4.0 and the nine building blocks of the Canvas Business Model. They work out the differentiation between providers and users’ technology. They find that 25 per cent of the investigated SMEs are providers of Industry 4.0.

Rachinger et al. (2019) discuss digitalisation and its influence on business models. They try to find answers to how does digitalisation influence a firm’s business model, and how do firms cope with the digitalisation of their business model. They investigate two cases,
<table>
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<tr>
<th>Core idea</th>
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<th>Methodology of the analysis applied in the article</th>
<th>Main results</th>
<th>Contribution to management of technology (MoT)</th>
<th>Grouping</th>
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<tr>
<td><em>1. Müller, J. M.</em> Business model innovation, SME, strategies for Industry 4.0; Industry 4.0 is expected to significantly transform industrial value creation</td>
<td>Which specific characteristics regarding user and provider perspectives of Industry 4.0 exist in small and medium-sized enterprises towards Industry 4.0-triggered business models?</td>
<td>In-depth expert interviews within the three most important German industry; the results allocate business model implications through Industry 4.0 to the Business Model Canvas</td>
<td>Insight into manufacturing SMEs-Industry 4.0 and their business model; Industry 4.0 and the nine building blocks of the Canvas Business Model; differentiation between providers and users technology – &gt; 25% of the investigated SMEs are providers of Industry 4.0 technology, 25% of the SMEs in the study are users</td>
<td>Industry 4.0 is a core technology in the context of MoT. How to cope with such technologies and how to improve innovation and business with and in Industry 4.0 are core topics of MoT</td>
<td>Business model innovation</td>
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<tr>
<td><em>2. Rachinger, M.</em> Digitalisation and its influence on business models</td>
<td>(1) How does digitalisation influence a firm’s business model? (2) How do firms cope with the digitalisation of their business model?</td>
<td>Qualitative interviews in the automotive and media industry related to the available literature</td>
<td>The media as well as the automotive industry perceive pressure and opportunities of digitalisation regarding business model innovation. Opportunities of digitalisation optimise the business model innovations; Internal trigger for digitalisation is the process optimisation, external trigger to use these technologies in their value creation process</td>
<td>Digitalisation in connection with business model innovation (BMI) is discussed in two articles, a thematic focus of innovation management and also an MoT topic, since digitalisation is used for management of technology in a broader sense</td>
<td>Business model innovation</td>
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<td><em>3. Seetharaman, A.</em> Control the physical world, including the machines, industrial facilities, and frameworks that characterize cutting-edge technology; Industrial Internet of Things (IIoT)</td>
<td>(1) What are the values that the IIoT can bring to manufacturing firms? (2) What are the prerequisites for the journey towards IIoT adoption? (3) Which factors can augment the adoption process?</td>
<td>Data are collected from 203 respondents predominantly from emerging economies, specifically India and SEA. Most of the participants are working professionals. Structural equation</td>
<td>IIOT- connectivity, big data, advanced analytics, and application development; IIOT provides high level of synergies between the 4 Ms of manufacturing, namely man, machine, material, and method. One of the key expectations from IIOT technology is that it will empower people by supplying on-time and</td>
<td>IIOT needs MoT and MoT gets input from IIOT. IIOT provides high level of synergies between the 4 Ms of manufacturing, namely man, machine, material, and method</td>
<td>Industrial Internet of Things</td>
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<tr>
<td>Things (IIOT). Value creation</td>
<td>modelling (SEM) was applied for analysis</td>
<td>relevant information to identify the cause and effect relationship → help in improved decision making regarding various aspects of manufacturing, such as scheduling and resource optimisation</td>
<td>Digital technology applications for the integration of various sources of energy (wind, solar, coal, nuclear, gas and fuel cell); use of such technologies is essential; South Africa</td>
<td>Industry, energy</td>
</tr>
<tr>
<td>4. Walwyn, D. Building hydrogen economy through digitalisation and niche experimentation</td>
<td>Mixed methods approach; (1) secondary data analysis to build a profile of South Africa’s present energy system; (2) stakeholder survey of the emerging hydrogen economy Survey, data collection, analysis and structure via Technology Availability Index (Techqual) determine a person’s predisposition to use a technology (four dimensions: optimism, innovation, discomfort, insecurity)</td>
<td>Managing energy; generating technology and consumers - strategies for SMEs → MoT and the end users</td>
<td>Digital technologies and consumers - strategies for SMEs → MoT and the end users</td>
<td>Customer engagement behaviour (CEB) in digital environment</td>
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<td>5. Monteiro, T.A. Managing the digital consumer; customer engagement behaviour (CEB) in digital environment; cases from Brazil and Spain</td>
<td>(1) How can the use of technology improve the perception of the business by the consumer? (2) How can it be transformed into a source of competitive advantage by the companies? Consumer attitudes at the time of purchase, reflecting their real intentions, influences their post-purchase behaviour; important is the influence of consumer involvement - continuous commitment on the part of the consumer to thoughts, feelings and behavioural responses to products or services → strategies for SMEs, no significant difference on consumer behaviour in Brazil and Spain</td>
<td>Digital technologies and consumers - strategies for SMEs → MoT and the end users</td>
<td>Customer engagement behaviour (CEB) in digital environment</td>
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<td>6. Saunila, M. Customers’ engagement in digital service processes; customer engagement</td>
<td>Qualitative single-case study; customer-based, firm-based, and context-based factors; Customer engagement differs among different phases of the digital service process; engagement during the front-end Managing the customers’ engagement in digital service processes is</td>
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<td>Customer engagement behaviour (CEB) in</td>
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<tr>
<td>Core idea</td>
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<td>behaviour (CEB) in digital environment. Value creation</td>
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<td>the case: a company providing streaming TV services, market leader in Finland with hundreds of millions in revenue and tens of thousands of customers</td>
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<td>phase of the process is important; customer-based and context-based factors during the back-end phase</td>
<td></td>
<td>managing technology → MoT</td>
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<td>Digital services governance; managing the business of IT; a value chain-based IT operating model and reference architecture</td>
<td>How should the IT4IT™ framework be interpreted as a management of technology framework, with respect to the dualism of IT as both innovation driver of the business, but also IT as focal in development and operational resources spend in the organisation?</td>
<td>Analysis of the IT4IT™ framework for management of technology (MoT); literature study; case analysis</td>
<td>IT4IT framework supports value creation; using value streams will align IT better with manufacturing and services</td>
<td>IT4IT framework is linked to MoT framework</td>
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<td>Possible future evolution of innovation from a human-only initiative, to human-machine co-innovation, to autonomous machine innovation and to arrive at a conceptual mind model that outlines the role of innovation regimes and innovation agents. Value creation</td>
<td>Will intelligent machines in future have the capability to innovate?</td>
<td>Concept paper where a theoretical “thought experiment” is done, using future thinking principles and data that originates from the literature</td>
<td>A conceptual mind model is developed to facilitate a better understanding of complexity at the edge of innovation where intelligent machines will emerge as innovators of the cyber world. It was found that innovation will gradually evolve from a human-only activity, to human-machine co-innovation, to incidences of autonomous machine innovation, based on the growth of machine intelligence and the adoption of human-machine partnership management models in future</td>
<td>Future thinking methodologies for technology management and innovation processes are useful for anticipating and estimating implications; future thinking methods provide approaches for being prepared</td>
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Table I.
automotive and media. The media as well as the automotive industry, perceive pressure and opportunities of digitalisation regarding BMI. Opportunities of digitalisation optimise the BMIs. The internal trigger for digitalisation is the process optimisation. External trigger uses these technologies in their value creation process.

Seetharaman et al. (2019) analyse the technological change through IIOT, the control of the physical world, including the machines, industrial facilities, and frameworks that characterize cutting-edge technology through digitalisation. Answers to the following research questions are developed:

\[ RQ1. \text{What are the values that the IIOT can bring to manufacturing firms?} \]

\[ RQ2. \text{What are the prerequisites for the journey towards IIOT adoption?} \]

\[ RQ3. \text{Which factors can augment the adoption process?} \]

A main result is that IIOT provides a high level of synergies between the four Ms of manufacturing, namely, man, machine, material and method. One of the key expectations from IIOT technology is that it will empower people by supplying on-time and relevant information to identify the cause and effect relationship which will help in improved decision making regarding various aspects of manufacturing, such as scheduling and resource optimisation.

Walwyn et al. (2019) cover the topic concerning building economy in the energy sector through digitalisation and niche experimentation. They develop answers to how South Africa can act to support a new hydrogen-based technological innovation system (TIS) to meet the goals of 2DS (2°C Scenario). One of the core results are that digital technology applications are necessary for the integration of various sources of energy (wind, solar, coal, nuclear, gas and fuel cell). The use of such technologies is essential for South Africa.

Monteiro et al. (2019) ask how to manage the digital consumer. They investigate the customer engagement behaviour (CEB) in digital environment and analyses cases from Brazil and Spain. They look for answers to how can the use of technology improve the perception of the business by the consumer and how can it be transformed into a source of competitive advantage by the companies. Some main results are that the consumer attitudes at the time of purchase reflect their real intentions and influence their post-purchase behaviour. The influence of the consumer involvement, the continuous commitment on the part of the consumer to thoughts, feelings and behavioural responses to products or services are important. From these findings, strategies for SMEs could be derived. There is no significant difference on consumer behaviour in Brazil and Spain.

Saunila et al. (2019) investigate customers’ engagement in digital service processes and CEB in a digital environment. They answer the questions which factors affect the CEB in digital environment. A main finding is that customer engagement differs among different phases of the digital service process. The engagement during the front-end phase of the process is important. She works out customer-based and context-based factors during the back-end phase.

Tambo and Filtenborg (2019) ask the following question: How should the IT4IT TM framework[3] be interpreted as an MoT framework, with respect to the dualism of IT as both innovation driver of the business, but also IT as focal in development and operational resources spend in the organisation? While conducting an analysis of the IT4IT TM framework for MoT, a literature study, and a case analysis they found that the IT4IT framework supports value creation and uses value streams will align IT better with manufacturing and services.

Botha (2019) discusses the possible future evolution of innovation from a human-only initiative to human-machine co-innovation. Will intelligent machines in the future have the capability to innovate? Botha develops a conceptual mind model, which is developed to
facilitate a better understanding of complexity at the edge of innovation where intelligent machines will emerge as innovators of the cyber world. It was found that innovation will gradually evolve from a human-only activity to human-machine co-innovation. Incidences of autonomous machine innovation are outlined based on the growth of machine intelligence and the adoption of human-machine partnership management models in future.

3. Meta-analysis and comparison of the papers
The umbrella over all these eight articles is “innovation management” and “MoT”. Various aspects of innovation management or concepts of MoT are discussed. Their links and contributions to MoT and innovation management are the following (see also Table I):

- Industry 4.0 is a core technology in the context of MoT. How can we cope with such technologies and how to improve innovation and business with and in Industry 4.0 are core topics of MoT.
- Digitalisation in connection with BMI is discussed in two articles, a thematic focus of innovation management and also an MoT topic, since digitalisation is used for MoT in a broader sense.
- IIOT needs MoT, and MoT as well as innovation management gets input from IIOT because IIOT provides a high level of synergies between the four Ms of manufacturing, namely, man, machine, material and method.
- Managing energy-generating technology by use of digital technologies is a contribution where digitalisation improves and accelerates innovation and business opportunities.
- The investigation of CEB in digital environment provides important aspects also for strategies of SMEs and the end users. Thus, these findings are intrinsic for MoT and innovation management.
- Managing customers engagement in digital service processes is MoT and, therefore, contributes to MoT and innovation management concepts.
- The analysis of the IT4IT framework and the MoT framework, and the findings contribute directly to MoT and innovation management.
- Future thinking methodologies for technology management and innovation processes are useful for anticipating and estimating implications; future thinking methods provide approaches for being prepared.

Value creation plays an important aspect in six of the eight articles: especially the both contributions, where business models are discussed, nevertheless also in the papers about Industry 4.0 and IT4IT linked to MoT concept, in the article about the future of innovation by machines, and in one discussing CEB.

The presented articles here discuss aspects of Industry 4.0, or IIOT, or digitalisation of all processes from idea creation to the success of products in the market, or digitalisation and the consumers and provide some insight into the ongoing research. However, the deluge of knowledge creation and innovation in the context of digitalisation can only be touched slightly with these considerations.

4. Conclusion and future research
Organisations have to innovate in order to succeed over time. A fast-growing part of innovation comes directly from the latest digitalisation tools. Many resources and a good deal of attention are directed to the further development of methods, processes, tools, etc. around digitisation. New products and services in all other industries, operation flow,
industrial facilities, work organisation, and, of course, business models have been dramatically impacted by digital technologies. For staying competitive new work skills are required.

The influence and change coming from the digitalisation wave are disrupting almost every industry in all processes starting with innovation, in production, in running the business as well as management. The impact of digitisation is tremendous and is seen in all industries bringing about a disruption of existing business models through new technology. Thus, businesses today have to open up their minds to innovation and continuous learning. In the modern world, customers are better informed and are clear about their expectations. There is a definite shift towards individualised products and services as well as a unique customer experience.

Digitalisation, however, faces big challenges. A machine, a sensor is not able to recognise for instance a cat at a glance. It needs many labelled pictures. Building trust, which might be expressed by ensuring robustness, fairness, explicability, lineage of the data and results, needs still a lot of effort.

The digital transformation and the fourth industrial revolution interlocks various technologies, such as biotechnologies, nanotechnologies and quantum computers (Schwab, 2016). Digitalisation combines and even merges more than ever all aspects of an innovation system, comprising universities and research organisations, industry, government, civil society and media, or even the environment. The far-reaching systemic change calls for improved and joint action in the innovation system, in the economic system, in society, in political action. The approach of the Quintuple Helix might support the development of the general welfare of society and, consequently, of the economy. Carayannis and Campbell have worked out the Quintuple Helix approach, besides others (see Campbell and Carayannis, 2017; Carayannis and Campbell, 2009; Carayannis and Campbell, 2010) (Figure 1).

Paradigm shifts within industries require a new socio-technical system to be created, with a different supporting infrastructure. Niches shaping new technological paradigms may be expected to move through certain stages. These factors constitute a sequence of S-curves or waves, with the historical industrialisation as the First Deep Transition (see Schot and Kanger, 2018). All innovation systems, all economy systems worldwide have to cope with this transition.

A lot of research is going on the creation of a knowledge base for a comprehensive understanding of what digitalisation does with the whole innovation system, with industry,
with the whole economic system and with the whole society. And much research is further needed to understand and to develop models for making it tangible in industry, government and society.

Notes:
[i] www.z-punkt.de/en/

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Notes
1. www.gartner.com/it-glossary/digitalization/
3. www.opengroup.org/it4it

References


Further reading


Business model innovation in small- and medium-sized enterprises

Strategies for industry 4.0 providers and users

Julian Marius Müller
Salzburg University of Applied Sciences, Salzburg, Austria

Abstract

Purpose – Industry 4.0 is expected to significantly transform industrial value creation. However, research on business models affected through Industry 4.0, and on small- and medium-sized enterprises (SMEs), remains scarce. In response, the purpose of this paper is to address both aspects, further elaborating on the role that SMEs can take toward Industry 4.0 as provider or user.

Design/methodology/approach – The paper used an exploratory research design based on 43 in-depth expert interviews within the three most important German industry sectors, mechanical and plant engineering, electrical engineering and automotive suppliers. Interviews were conducted with leading personnel of the respective enterprises, including 22 CEOs. They assign business model implications through Industry 4.0, referring to the Business Model Canvas, while the paper delineates between Industry 4.0 providers and users.

Findings – The paper finds that key resources and value proposition are among the most affected elements of the business model, whereas channels are the least affected. Furthermore, distinct characteristics between Industry 4.0 providers and users can be delineated. In general, Industry 4.0 providers’ business models are significantly more affected than users, except for key partners and customer relationships.

Research limitations/implications – Industry 4.0 remains at its early stages of implementation. As a result, many interviewees’ answers remain at a rather general level.

Practical implications – Strategies for the further alignment of the business models are provided for Industry 4.0 providers and users.

Originality/value – The paper is among the few that investigate Industry 4.0 in the context of SMEs and business models.

Keywords Manufacturing industry, Case studies, Small- and medium-sized enterprises, Industry 4.0

1. Introduction

Industry 4.0 is a concept initiated by the German government that intends to introduce a paradigm shift toward a digital future in industrial production. It is an attempt to ensure future competitiveness for German industry (Kagermann et al., 2013; Lasi et al., 2014). Industry 4.0 attempts to address two developments for German industry within a common program, changing environmental conditions and relevant technological developments (Lasi et al., 2014). Examples of changing environmental conditions include globalization, increased market volatility, abbreviated innovation cycles, intensified competition and increasing complexity (Lasi et al., 2014). Relevant technological developments in industrial production include increasing automation, digitalization and interconnection between machines, products and users. These developments are based on the concept of the Internet of Things, which will be introduced into the German manufacturing industry (Kagermann et al., 2013; Lasi et al., 2014).
In addition to securing Germany’s industrial position in the world through efficient value creation, Industry 4.0 intends to provide flexibility and customization of products and services (Kagermann et al., 2013). Ecological and social benefits, such as reduced energy consumption, waste reduction and new, adaptive work environments, also will be achieved through Industry 4.0 (Kagermann et al., 2013; Kiel, Arnold and Voigt, 2017; Kiel, Müller and Voigt, 2017; Müller, Kiel and Voigt, 2018). Along with technical challenges, organizational conversions must be faced regarding Industry 4.0 (Loebbecke and Picot, 2015). One of the main elements within these conversions is the business model, where highly profitable new or changed models are predicted (Arnold et al., 2016; Kagermann et al., 2013; Loebbecke and Picot, 2015). In contrast to research in technical fields regarding Industry 4.0, economic challenges and potential, especially relating to business models, thus far have been examined less (Arnold et al., 2016; Brettel et al., 2014; Loebbecke and Picot, 2015). Therefore, this paper attempts to support research in the field of Industry 4.0 and correlated effects on business models.

Further, leading personnel of small- and medium-sized enterprises (SMEs) can understand and describe changes for the entire business model (Müller, Buliga and Voigt, 2018). Therefore, investigating the user and provider perspectives of Industry 4.0 regarding business model innovations is especially suitable in SMEs. SMEs have major significance in the German economy, encompassing 99.6 percent of enterprises, 59.4 percent of employees, 54.8 percent of value added and 35.9 percent of annual turnover (German Federal Ministry of Economic Affairs and Energy, 2014). However, research in the field of SMEs and Industry 4.0 remains rare (Müller, Buliga and Voigt, 2018). Conclusively, this paper addresses the following research question:

RQ1. Which specific characteristics regarding user and provider perspectives of Industry 4.0 exist in SMEs toward Industry 4.0-triggered business models?

In response to rare research in this field, this paper applies an exploratory research design that is based on 43 in-depth expert interviews. These were conducted within the three most important German industry sectors: mechanical and plant engineering, electrical engineering and the automotive industry. Interviews were conducted with leading officials of the respective enterprises, including 22 chief executive officers (CEOs). These interviews were used as primary sources, whereas archival data were used as secondary sources. By analyzing the interviews, obtained statements were allocated to the elements of the Business Model Canvas by Osterwalder and Pigneur (2010). Subsequently, those were analyzed regarding the user and provider perspectives of Industry 4.0.

In essence, this paper addresses the research topic of the appropriate design of companies’ business models in order to extract value from new technologies (Chesbrough, 2010). Technologically triggered business model innovation remains an acknowledged but comparatively less researched stream in business model research (Baden-Fuller and Haefliger, 2013). In response to technological developments, such as Industry 4.0, companies need to correspondingly adapt their business model, fostering opportunities and meeting challenges that arise (Saebi et al., 2016). The topic of new or changed business models that are enabled or challenged through Industry 4.0 remains a relatively new topic that few studies have investigated so far (Arnold et al., 2016; Ehret and Wirtz, 2017; Kiel, Arnold and Voigt, 2017; Kiel, Müller and Voigt, 2017). Especially addressing their unique characteristics regarding Industry 4.0, SMEs require research that supports them on redeveloping or extending their existing business models. However, SMEs’ business models considering Industry 4.0 have been neglected thus far (Müller, Buliga and Voigt, 2018). Therefore, this paper addresses the topic of business model innovation through Industry 4.0 in SMEs. It delineates the user and provider perspectives toward Industry 4.0 that play a vital role in how companies approach the concept (Kagermann et al., 2013).
2. Theoretical background

2.1 Industry 4.0

The term Industry 4.0 encompasses the expectations of politics and corporate practice that industrial manufacturing is heading toward a fourth Industrial Revolution (Kagermann et al., 2013; Liao et al., 2017; Maynard, 2015). The previous three Industrial Revolutions have achieved high productivity increases driven by a few fast-spreading general-purpose technologies, such as mechanization, electricity and information technology (Veza et al., 2015). These general-purpose technologies resulted in strong technical improvements and initiated complementary developments (Bresnahan and Trajtenberg, 1995). For Industry 4.0, the underlying technology is represented by cyber-physical systems, whose technological infrastructure is based on the concept of the Internet of Things (Kagermann et al., 2013; Lasi et al., 2014; Xu, 2012). Together with cloud computing, cyber-physical systems and the Internet of Things are regarded as the central technological foundations of Industry 4.0 (Zhong et al., 2017).

In Industry 4.0, cyber-physical systems establish an interconnection between the physical world and cyberspace (He and Xu, 2015; Ren et al., 2013). The systems create mechanisms for human-to-human, human-to-object and object-to-object interactions along the entire value-added chain (Kagermann et al., 2013). The task of integrating humans into this concept remains a challenge as it faces employees’ resistance, including fear of being replaced or having inadequate skills (Frazzon et al., 2013; Gorecky et al., 2014; Hirsch-Kreinsen, 2016; Kiel, Arnold and Voigt, 2017; Kiel, Müller and Voigt, 2017).

The integration of cyber-physical systems into industrial production leads to the creation of cyber-physical production systems (Schlechtendahl et al., 2015). These can fulfill their potential when interconnected across the entire supply chain (Haddud et al., 2017). Cyber-physical production systems enable several data-based services, such as predictive condition monitoring and balancing and reducing energy consumption within production (Shin et al., 2014; Tao et al., 2011). Those features are established along the entire lifecycle of machinery and products (Lennartson et al., 2010).

Aside from cyber-physical production systems, Industry 4.0 is driven by technological developments such as service-oriented architectures (Guinard et al., 2010; Mikusz, 2016; Raja et al., 2013; Vogel-Heuser et al., 2015). These enable the creation of new services and product-service utilities (Kiel, Arnold and Voigt, 2017; Kiel, Müller and Voigt, 2017; Ehret and Wirtz, 2017). Those developments result in the concept of smart production, also termed smart manufacturing (Davis et al., 2012; Radziwon et al., 2014; Wang et al., 2016; Zuehlke, 2010). Smart production is characterized by manufacturing of intelligent, personalized products and by high levels of collaboration through production networks (Lasi et al., 2014; Veza et al., 2015; Xu et al., 2014).

Besides the German Industry 4.0 initiative, similar initiatives have been developed worldwide (Liao et al., 2017). The European Union has started a public-private partnership under the title “Factories of the Future” to achieve sustainable and competitive production (European Commission, 2016). In the USA, similar efforts are underway through the Industrial Internet Consortium. In China, the “Internet Plus initiative” and “Made in China 2025” represent programs comparable to Industry 4.0, and are among several approaches worldwide (Liao et al., 2017; Müller and Voigt, 2018).

2.2 Small- and medium-sized enterprises

In Germany, the term SME refers to companies with less than €50m in sales and fewer than 500 employees (German Federal Ministry of Economic Affairs and Energy, 2014). For this paper, SMEs represent a fruitful research context for various reasons.

First, prospects for Industry 4.0 can primarily be expected because of the horizontal and vertical interconnection of the value chain. In German industrial value creation, SMEs represent an essential part, as they represent 99.6 percent of all enterprises, generating more
than 50 percent of the GDP. In turn, integrating SMEs is perceived as a key success factor of Industry 4.0 (Müller, Buliga and Voigt, 2018).

Second, existing studies reveal that SMEs’ specific challenges differ from those of large companies regarding Industry 4.0. These challenges include resource limitations, low bargaining power and concerns that existing business models might be unsuitable for Industry 4.0 (Müller and Voigt, 2016; Müller, Kiel and Voigt, 2018). SMEs also tend to have distinct characteristics regarding the introduction of information technologies in general (Sharma and Bhagwat, 2006). Therefore, SMEs require solutions tailored to meet their specific challenges, but research has mainly focused on large enterprises rather than on SMEs (Müller, Buliga and Voigt, 2018).

Third, the upper management of SMEs is able to supervise the whole enterprise. The managers’ knowledge reveals information about Industry 4.0 that affects the whole enterprise and the entire business model. They may possess knowledge of key aspects within their enterprise and can therefore provide both an external and internal perspective (Müller, Buliga and Voigt, 2018).

2.3 Business model innovation

Companies can extract value from new technologies only through suitable business models (Chesbrough, 2010). Technological innovation therefore is a key driver for business model innovation (Baden-Fuller and Haefliger, 2013). In response, companies must adapt their business models to external threats and opportunities (Saebi et al., 2016). By introducing Industry 4.0, manufacturers are able to develop new customer value (Arnold et al., 2016; Ehret and Wirtz, 2017; Müller, Buliga and Voigt, 2018). This is expected through new services and product-service systems. Manufacturers can take two roles, the user or the provider perspective of Industry 4.0 (Kagermann et al., 2013).

Whereas different approaches describe business models, most of the current literature agrees on central aspects: creating and capturing value by providing a value proposition to customers (Casadesus-Masanell and Ricart, 2010; Zott et al., 2011; Zott and Amit, 2013). This paper used the Business Model Canvas by Osterwalder and Pigneur (2010). It originates from the Business Model Ontology by Osterwalder et al. (2005). The Business Model Canvas is used in current literature to analyze business models from a practitioner’s perspective. It has proven to be a comprehensive approach to business models, as its nine building blocks assist in generating a holistic and nuanced view on business models (Wirtz et al., 2016).

The following description offers a brief summary of the building blocks within the Business Model Canvas. The value proposition provides an overview of a company’s bundle of products and services. Customer segments describes the groups of customers that a company wants to offer value. Channels describe the various means that the company utilizes to contact its customers. Customer relationships explains the types of links that a company establishes between itself and its different customer segments. Key activities describes the arrangement of activities and resources. Key resources outlines the competencies necessary to execute the company’s business model. Key partners portrays the network of cooperative agreements with other companies necessary to efficiently offer and commercialize value. Cost structure summarizes the monetary consequences of the means employed in the business model. Revenue streams describes the ways that a company makes money through a variety of revenue flows (Osterwalder and Pigneur, 2010). Figure 1 illustrates the nine building blocks within the Business Model Canvas.

Several authors in business model research address the capabilities and impacts of digital technologies on business models. However, the specific impact of Industry 4.0 on business models remains a field scarcely investigated (Arnold et al., 2016). Furthermore, empirical investigations of business models in context of the Industrial Internet of Things
mostly have not focused on the special requirements of SMEs (Arnold et al., 2016; Echterfeld et al., 2016; Kiel, Arnold and Voigt, 2017; Kiel, Müller and Voigt, 2017; Müller, Buliga and Voigt, 2018).

3. Research design
This qualitative empirical study aims to present the impacts of Industry 4.0 on business models of manufacturing SMEs. First, the study generates an overview of business model changes brought from Industry 4.0 for manufacturing SMEs. Changes in the nine building blocks are highlighted, supported by exemplary expert statements. Further, the paper attempts to differentiate between several business model changes that are specific for the user or provider perspective upon Industry 4.0. Therefore, relative frequencies of affected building blocks are used to show differences and similarities. The perspective of providers encompasses manufacturing cyber-physical systems and selling them to customers. Users of Industry 4.0 apply cyber-physical systems in production and services. This delineation presents an important categorization that companies can take regarding Industry 4.0 (Kagermann et al., 2013). The delineation between providers and users of Industry 4.0 investigation is especially suitable in the context of SMEs. SMEs often have a focused and often single business model that can be overseen by top managers, in contrast to larger enterprises (Müller, Buliga and Voigt, 2018). The paper thereby also attempts to overcome the limitation of single key informants not being able to report complex organizational phenomena (Glick et al., 1990; Hughes and Preski, 1997).

Because of scarce prior research on Industry 4.0-related effects on business models of manufacturing SMEs, an exploratory qualitative research design was chosen. This is appropriate in exploratory research as rich data can be obtained, allowing the investigation of concrete managerial problems and extending the existing state of research (Yin, 2009; Eisenhardt and Graebner, 2007). Except for single-case studies, empirical research on business models in the context of emerging technologies remains scarce (Demil et al., 2015). Multiple-case studies enable contextualization, allowing the comparison of distinct findings and increasing the reliability of obtained data (Eisenhardt and Graebner, 2007). Furthermore, case study research has been used successfully in information systems research (Dubé and Paré, 2003).

To conduct the qualitative survey, a representative sample was chosen (Yin, 2009; Eisenhardt and Graebner, 2007; Demil et al., 2015). According to Kagermann et al. (2013), mechanical and plant engineering, the automotive industry and the electrical industry would be primarily affected by Industry 4.0. Therefore, those three industry sectors were chosen for
the study. Case firms were selected to have one predominant business model, as competing business models within a single enterprise are difficult to include in research design (Markides and Charitou, 2004). To ensure these aspects, SMEs were preselected using publicly available data for classification before requesting an interview. Furthermore, a competent interview partner in a leading position, preferably the CEO, was required (Kumar et al., 1993).

Using semi-structured interviews, an interview guideline representing the research question was developed. Publicly available data and internal data provided by the interviewees for triangulation to validate the research were used as secondary sources (Yin, 2009; Gibbert et al., 2008; Huber and Power, 1985). The interview guideline consists of two parts, obtaining information about the interviewee and the enterprise, and then about business model changes from Industry 4.0. The interviews were conducted via telephone and recorded on audio files in accordance with the interview partners. Subsequently, the interviews were transcribed from the audio files, and then subjected to a qualitative content analysis (Miles and Hubermann, 1994). During this process, the initial categories were defined inductively and then aligned to existing research, intending to develop theoretical knowledge (Edmondson and McManus, 2007; Holsti, 1968). In the next step, the final categories were condensed from the initial categories using a frequency analysis (Holsti, 1968). This process was conducted independently by two researchers. Subsequently, the categories were checked for consistency and compared to derive inter-coder reliability (Holsti, 1969), thereby validating the coding process.

All surveyed enterprises fulfill the criteria of SMEs according to the definition of the German institute of SME research: a maximum number of 500 employees and a maximum annual turnover of €50m (German Federal Ministry of Economic Affairs and Energy, 2014). In all, 43 interviews with lengths between 25 and 60 min were conducted and 22 of the 43 interview partners are CEO of their respective enterprises. The others are among the top officials of their enterprises, and all are members of their management board. Within the 43 enterprises, 24 are mechanical and plant engineering enterprises, 13 are automotive suppliers and 6 are from the electrical industry sector. The average number of employees is 91.02, whereas the average annual turnover is €16.09m. Figure 2 reveals the detailed distribution within the empirical sample.

4. Findings

4.1 Changes of business model elements through Industry 4.0

Table I provides an overview for the nine building blocks within the Business Model Canvas, including exemplary changes of the respective building blocks through Industry 4.0.

Key resources is the most named building block within the sample (58.14 percent of interviewees). The interviewees mainly mention two aspects. First, production facilities and equipment need to be altered or especially purchased according to the specifications of Industry 4.0. As one interviewee mentions: “Industry 4.0 will require [us] to either adapt existing machinery, also known as “retrofitting,” or to purchase new machines. Especially the
second will inflict high costs on SMEs” (Interviewee No. 21). Second, the interviewees describe the need for new personnel or required retraining of existing personnel. An SME representative states: “Industry 4.0 technologies require especially trained experts in the field of IT. SMEs cannot afford those easily, as such competencies are rare on the market. Currently, such experts mainly go to larger enterprises” (Interviewee No. 2). Another expert says “[…] it will be a challenge that existing personnel might become obsolete because we can’t train them accordingly” (Interviewee No. 30). This is confirmed by another interviewee, who states: “An SME has a limited workforce. The retraining required for Industry 4.0 is manageable for a larger enterprise. But who runs the daily business in an SME if the workforce is being trained? No SME can easily acquire adequate backup here” (Interviewee No. 14).

Value proposition is the second most named building block (53.49 percent of interviewees). The interviewees mainly describe new products, services or a combination of both to be offered to the customer. As one interviewee explains: “Our machines can produce more individually and tailored to customer demands. The ultimate goal here is often described as ‘batch size one.’ However, it remains questionable if this is really required for each and every product” (Interviewee No. 23). A manufacturer of machinery and equipment states: “We can offer new features with our machines, e.g., predictive maintenance, self-optimization, or reduction of energy consumption” (Interviewee No. 8). New services through Industry 4.0, which are often mentioned together with new products, are mostly described as “data-driven.” As another representative explains: “It is our goal to not only produce the machine, but set it up and connect it with other machines in the factory. We want to produce ‘turnkey’ solutions for our customer, especially regarding the integration in existing production plants” (Interviewee No. 39). Another interviewee describes the aforementioned retrofitting of machines: “As an SME, we can hardly keep up to build the newest equipment everywhere. But our strength is individual service. And this is something that you need if you want to make a 30-year-old machine ready for Industry 4.0” (Interviewee No. 6).

<table>
<thead>
<tr>
<th>Building block</th>
<th>Total ratio (%)</th>
<th>Exemplary changes through Industry 4.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Key resources</td>
<td>58.14</td>
<td>New or altered production equipment</td>
</tr>
<tr>
<td></td>
<td></td>
<td>New personnel, especially with IT competencies</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Retraining of existing personnel</td>
</tr>
<tr>
<td>Value proposition</td>
<td>53.49</td>
<td>More flexible and individual production</td>
</tr>
<tr>
<td></td>
<td></td>
<td>New product features, e.g., predictive maintenance, self-optimization or energy savings</td>
</tr>
<tr>
<td></td>
<td></td>
<td>“Retrofitting” of existing production equipment</td>
</tr>
<tr>
<td>Key partners</td>
<td>48.84</td>
<td>New partners with IT or data expertise</td>
</tr>
<tr>
<td>Customer relationships</td>
<td>48.84</td>
<td>Especially SMEs will require partners in areas such as data expertise</td>
</tr>
<tr>
<td>Customer segments</td>
<td>41.86</td>
<td>More long-term oriented partnerships</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Intensified partnerships between customer and supplier</td>
</tr>
<tr>
<td></td>
<td></td>
<td>New customer segments can be addressed through new data-based value propositions</td>
</tr>
<tr>
<td>Revenue streams</td>
<td>41.86</td>
<td>New payment models, e.g., pay-per-use</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Automation of revenue streams</td>
</tr>
<tr>
<td>Cost structure</td>
<td>37.21</td>
<td>Large investments necessary</td>
</tr>
<tr>
<td>Key activities</td>
<td>23.26</td>
<td>Cost savings through increased productivity</td>
</tr>
<tr>
<td>Channels</td>
<td>18.61</td>
<td>New activities that build upon data analysis</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Data analysis enables, e.g., optimization</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Automation of communication through machine-to-machine communication</td>
</tr>
</tbody>
</table>

Table I. Business model building blocks and exemplary changes through Industry 4.0
Key partners is tied for the third most named building block (48.84 percent of interviewees). In this context, the SMEs' representatives primarily name partners that are experts in IT-related aspects. One interviewee states: “An SME cannot be an expert in machines and in IT easily. But it can look for the right partner, for me preferably another SME, that it can work together with” (Interviewee No. 11). Another interviewee mentions that “data security is a task that requires the right partners for us, but those partners are rare” (Interviewee No. 27).

Customer relationships is also tied for the third most named building block (48.84 percent of interviewees). Most interviewees agree that Industry 4.0 will lead to long-term relationships that include working closer together: “I experience that customers and suppliers are trying to solve these issues regarding Industry 4.0 together. You cannot achieve new technological developments in a short time, or if you only worry about costs in the short run” (Interviewee No. 27).

Customer segments is tied for the fifth most named building block (41.86 percent of interviewees). Here, the interviewees explain that new data-based products and services can lead to new customers being addressed. As one expert mentions: “Industry 4.0 rewrites the rules of the game to a certain extent. Also, the smaller [SMEs] are trying to address new customers, but also other players from abroad or from the IT industry try to enter the market” (Interviewee No. 28).

Revenue streams is also tied for the fifth most named building block (41.86 percent of interviewees). In this regard, all experts state that new pricing and revenue models will be available through Industry 4.0: “Pay per use, pay per feature, or other payment methods like this become possible. But before, this would just have been too hard to supervise. In Industry 4.0, this can be done automatically to a large extent” (Interviewee No. 13).

The Cost structure (37.21 percent of interviewees) is third least named by the interviewees, but still significantly more than key activities and channels. Most statements in this regard relate to investments required for Industry 4.0. As one interviewee mentions: “SMEs have a hard time facing the costs that come with Industry 4.0 implementation” (Interviewee No. 5). Cost savings through increases in productivity are also mentioned: “We will get more flexible and efficient in value creation, decreasing our variable costs through Industry 4.0” (Interviewee No. 26).

Key activities is second least named from all building blocks within the Business Model Canvas (23.26 percent of interviewees). Most interviewees name data-based activities through Industry 4.0: “We will be able to do things like data analysis and thereupon optimize our processes” (Interviewee No. 12). Another SME representative offers a possible explanation for the low number of SMEs naming key activities in the context of Industry 4.0: “SMEs tend to stick to what they did. They just want to do it better and especially more efficiently. For me, Industry 4.0 also includes the chance to do something completely new, even for an SME” (Interviewee No 40).

Channels is the least named building block (17.65 percent of interviewees). The few interviewees who mention this element of the Business Model Canvas relate to digital channels to communicate with their customers. One interviewee explains: “Industry 4.0, from my point of view, is able to save a lot of time in communication. One can now communicate digitally, or even the machines take over that job as they communicate among themselves” (Interviewee No. 17). Another interviewee offers a possible explanation for the lowest naming of this building block: “SMEs' key asset, at least for many of them, is talking personally to each other and knowing the person you talk to. As such, they won't easily turn to new ways of communication, although they should find a form to enter these new ways of communication” (Interviewee No. 40).

4.2 User and provider perspectives on Industry 4.0

In general, the present study finds that SMEs regarding Industry 4.0 from a provider perspective name the highest ratio of building blocks affected within
their enterprise. Five out of nine building blocks are predominantly mentioned from a provider perspective. Two building blocks are stated comparably often from the user perspective and the provider perspective. The building block that both perspectives agree to be least affected by Industry 4.0 is channels, whereas key resources is mentioned by the majority of both perspectives as most affected by Industry 4.0. Key activities is named comparably seldom by the providers and the users, indicating a small impact on this building block for both perspectives on Industry 4.0. Only two building blocks are named by a higher percentage of Industry 4.0 users than from Industry 4.0 providers: key partners and customer relationships. These findings are summarized in Table II.

Figure 3 illustrates the ratio of building blocks affected from the perspectives of Industry 4.0 users and Industry 4.0 providers.

Within the sample of this study, most SMEs perceive themselves as users rather than as providers in the context of Industry 4.0. Only three enterprises regard themselves as both users and providers regarding Industry 4.0. Overall, the findings for both perspectives on Industry 4.0 can be summarized as follows: the providers of Industry 4.0 generally expect a significantly higher impact on their respective business models through Industry 4.0, except for the building blocks of key partners and customer relationships. However, this group

<table>
<thead>
<tr>
<th>Perspective</th>
<th>Total ratio (%)</th>
<th>Building blocks regarded predominantly</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industry 4.0 user</td>
<td>76.74</td>
<td>Key partners, Customer relationships</td>
</tr>
<tr>
<td>Industry 4.0</td>
<td>23.26</td>
<td>Value proposition, key resources, key activities, cost structure, revenue streams</td>
</tr>
</tbody>
</table>

Table II. Total ratio of perspectives and their predominant naming of building blocks

Figure 3. Ratio of building blocks affected for provider and user perspectives of Industry 4.0
constitutes the smaller portion of SMEs surveyed. The users of Industry 4.0 expect less impact on their business models through Industry 4.0 than providers, except for key partners and customer relationships.

5. Interpretation

Key resources is named predominantly by the providers of Industry 4.0-based solutions. This can be explained as manufacturing firms having to obtain competencies regarding IT. This in particular affects human resources, as data analysis experts and associated hardware are required (Müller, Buliga and Voigt, 2018; Rachinger et al., 2018). Fewer changes are expected for employees in production itself, but “creative problem-solvers” are increasingly required (Kiel, Arnold and Voigt, 2017; Kiel, Müller and Voigt, 2017). Both developments are logical in respect to the providers of Industry 4.0-based products and services, as the new value propositions especially will require new key resources. Still, the task of integrating existing workers into Industry 4.0 remains a challenge that requires further investigation. This encompasses the need for training and qualification of the existing workforce that could be especially challenging for SMEs.

Value proposition is named predominantly by the providers of Industry 4.0-based solutions. This seems reasonable, as new value propositions, such as individualized products meeting customer requirements specifically with batch size one products, are expected through Industry 4.0 (Kagermann et al., 2013; Oesterreich and Teuteberg, 2016; Rachinger et al., 2018). Furthermore, individual and customer-oriented services, making use of digital technologies and data analysis, are predicted through Industry 4.0. These include condition-based monitoring and predictive maintenance along with optimization of production systems and value chains (Kagermann et al., 2013; Müller, Buliga and Voigt, 2018). Conclusively, the providers of Industry 4.0-based predominantly mention value proposition, as providers of those solutions and products will primarily generate new value propositions.

Key partners is named predominantly by the users of Industry 4.0. This is confirmed in current literature, which states that key partners is considered to be especially important for operation and control of Industry 4.0-based systems (Kagermann et al., 2013; Porter and Heppelmann, 2014). Due to their limited size, SMEs as providers will most likely require key partners in order to develop new Industry 4.0-based solutions (Müller, Buliga and Voigt, 2018).

Customer relationships is named predominantly by the users of Industry 4.0. Long-term, intensified relationships with manufacturers and providers of products and services are predicted, especially for usage of products and services (Kagermann et al., 2013; Müller, Buliga and Voigt, 2018). The findings are therefore in line with current research but should be extended with further investigation regarding the customer relationships of users and providers in Industry 4.0.

Customer segments is named comparably often by the providers and the users of Industry 4.0. This finding questions the assumption that providers would address new customer segments to a greater extent. Also in literature, no differentiation between provider and user perspectives of Industry 4.0 can be found thus far. However, new customer segments are predicted through Industry 4.0 (Arnold et al., 2016; Kagermann et al., 2013; Kiel, Arnold and Voigt, 2017; Kiel, Müller and Voigt, 2017; Müller, Buliga and Voigt, 2018). This differentiation should be addressed in detail in further research.

Revenue streams is named predominantly by the providers of Industry 4.0-based solutions. New revenue models, such as dynamic pricing and pay-per-use payment models, are expected through Industry 4.0 (Kiel, Arnold and Voigt, 2017; Kiel, Müller and Voigt, 2017; Müller, Buliga and Voigt, 2018). This can be explained as providers might foresee these new possibilities, as they will provide new revenue streams.
Cost structure is named predominantly by the providers of Industry 4.0-based solutions. Large investments are expected for Industry 4.0 to obtain required key resources. However, reductions in fixed and variable costs are predicted through increased quality and productivity (Arnold et al., 2016; Kagermann et al., 2013; Müller, Buliga and Voigt, 2018). For obtaining new key resources, this evaluation seems logical, as providers will require large investments in this respect. For possible savings, those might not yet be seen for users in industry, especially in SMEs (Müller, Buliga and Voigt, 2018).

Key activities is named predominantly by the providers of Industry 4.0-based products and solutions. In general, new key activities are expected through data management, data analysis and data mining to enable knowledge-based decision making (Brettel et al., 2014; Kiel, Arnold and Voigt, 2017; Kiel, Müller and Voigt, 2017). The low estimation for key activities from SMEs can be reasoned as manufacturing SMEs are not as far developed in terms of data management and handling so far. Therefore, they might not regard this topic as important yet (Müller, Buliga and Voigt, 2018). However, the estimation of the providers of Industry 4.0-based solutions is in line with the state of research, as the provision of smart products and services will especially require new key activities.

Channels is the least named for all perspectives (17.65 percent of interviewees), and no differentiation between providers or users of Industry 4.0 can be found. Collaborative ways of value creation are predicted regarding Industry 4.0 that include co-creation between the providers and the users of Industry 4.0-based solutions, based on new communication technologies (Kiel, Arnold and Voigt, 2017; Kiel, Müller and Voigt, 2017; Müller, Buliga and Voigt, 2018). As a result of this co-creation process, individual products can be created, understanding customer needs in detail (Kagermann et al., 2013; Müller, Pommeranz, Weisser and Voigt, 2018). However, the results do not reveal a differentiation between provider and supplier perspectives and offer a low evaluation of channels in general. This can be explained as direct, personal and highly individual Channels are already present in SMEs and provide a highly valuable characteristic of SMEs (Müller and Voigt, 2016).

The finding that providers consider more changes in terms of impacts on their respective business model through Industry 4.0 seems logical. The provision of products and services from design to market affects more elements within a business model than using them. This becomes especially obvious for the low evaluation of key activities from a user perspective. The evaluation of key resources regarded as most important and channels regarded as least important from both perspectives is mostly in line with current research for larger enterprises (Arnold et al., 2016).

6. Managerial implications
Besides presenting the key findings, this paper separates managerial implications for the perspectives of both providers and users of Industry 4.0. Providers in respect to Industry 4.0 are recommended to investigate necessary key activities and required key partners regarding Industry 4.0. Especially for the latter, SMEs as providers will definitely require adequate partners for the provision of Industry 4.0-based solutions due to their limited size. Addressing new customer segments could provide new Industry 4.0-based solutions to a broader group of potential customers. New customer relationships should also be considered, also in respect to the mentioned new relationships that could emerge through digital channels. Furthermore, this paper recommends the possibilities of new channels in terms of Industry 4.0. This includes new technologies for communication in collaboration with existing and well-established channels. For the users of Industry 4.0, it can be suggested to especially regard the value of key partners and customer relationships, thereby finding suitable key partners for the provision of Industry 4.0-based solutions.
In addition, the users of Industry 4.0 are advised to foster customer relationships in terms of Industry 4.0.
Extending these recommendations, special challenges of SMEs toward Industry 4.0 must be regarded: lack of financial resources, low production numbers, low degrees of standardization and a lack of understanding of integration, which are major concerns for German SMEs (Müller and Voigt, 2016). Furthermore, access to skilled employees and concerns regarding data security and privacy concerns are among major challenges for German SMEs that plan to implement Industry 4.0. Conjointly with these findings, this paper presents the following recommendations for users and providers of Industry 4.0.

For users, the reduction of capital commitment regarding Industry 4.0-based solutions that are cost-intensive is essential. Pay-per-use contracts and leasing of machinery could provide ways to reduce capital commitment. This approach could also include financing by customers, especially larger enterprises possessing larger financial resources, relating to the high importance of new customer relationships. Furthermore, finding compound effects with other enterprises regarding Industry 4.0 is recommended, relating to the high importance of new key partners for users regarding Industry 4.0. This approach could assist in reducing costs, establishing standards and gaining access to trained personnel and expertise. Potential solutions could be platforms among SMEs or partnerships with larger enterprises.

For providers, this paper proposes business models building on new value propositions, key activities and revenue streams, such as provision of services, complete product-service systems and payment methods. Thereby, providers of Industry 4.0-based solutions could address the concerns of SME users of Industry 4.0, such as lacking expertise toward Industry 4.0 or insufficient financial resources. Offering complete solutions, such as service provision and hardware conjointly, could assist in generating compound effects and offering new value propositions to customers. Addressing the requirement of new key resources in terms of Industry 4.0, compound effects could be found within platforms among SMEs or partnerships with larger enterprises. These could also assist in developing new cost structures required in terms of Industry 4.0, relating to new key resources required.

Overall, it can be concluded that a provider role toward Industry 4.0 creates larger impacts on SMEs’ business models. Therefore, companies need to decide if this poses a threat toward their established business models, and whether they should therefore avoid the provider role toward Industry 4.0. However, taking a provider role toward Industry 4.0 could also enable SMEs to fully grasp the potentials of Industry 4.0, which remain out of reach of Industry 4.0 users. SMEs are therefore advised to consider both roles but encouraged to take the risks to become an Industry 4.0 provider.

7. Conclusion
This paper attempts to provide insights for manufacturing SMEs and how Industry 4.0 affects their business model, leading to specific integration strategies. Thereby, this study contributes to the current body of knowledge regarding business models and Industry 4.0. It presents findings that are especially focused on SMEs as one of the few studies in this context. The detailed differentiation among the nine building blocks for Industry 4.0 providers and users is unique and unseen in literature thus far. This approach is especially suitable regarding SMEs due to their focused and mostly singular business model.

Furthermore, the approach of differentiating between the perspectives of a provider and a user of a technology has scarcely been conducted thus far. It is expandable to other technologically triggered business model innovations and provides an insightful field for future research. The results show that distinct characteristics between these two perspectives exist, whereas providers of Industry 4.0-based solutions expect the most changes in their business models in regard to Industry 4.0. Notably, a significantly larger proportion of SMEs in this study can be characterized as Industry 4.0 users, with Industry 4.0 providers only constituting about one quarter of the sample. This information can be
extended for the Industrial Internet of Things and comparable concepts to Industry 4.0 outside of Germany.

Because of the exploratory qualitative research design, the study also inherits several limitations. Exploratory research in this case has the difficulty that Industry 4.0 might be at its start of implementation for many of the surveyed SMEs. A generalization to other research settings without verification using different research methods is considered critical. However, as the study follows a replication sampling logic (Yin, 2009) and encompasses 43 interviews, the results can present general patterns about impacts on business models regarding Industry 4.0. As a further limitation, this study mainly relies on qualitative results and uses case materials exclusively for validation. Future research could include case material in order to extend the empirical results obtained.

Further recommendations for future research include quantitative research methods in order to verify the qualitative research results. A comparison to larger enterprises, if those can be condensed to a single business model referring to Industry 4.0, would present further valuable insights for this topic. The interdependence between different elements within a business model is of particular interest, also in connection with reasons for the adoption of new or changed business models and their implementation processes. An investigation regarding the implementation of business model adaptions over time should be considered, investigating the interplay with partners, suppliers and customers. The managerial implications proposed must be verified in practice, whereas their effectiveness needs to be addressed in future research.

References


Digitalization and its influence on business model innovation

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Abstract

Purpose – Increased digitalization has influenced various business activities including companies’ business models (BMs) by enabling various new forms of cooperation between companies and leading to new product and service offerings as well as new forms of company relationships with customers and employees. At the same time, this digitalization has put pressure on companies to reflect on their current strategy and explore new business opportunities systematically and at early stages. While research on digitalization in the context of BMs is now gaining increased attention, a research gap still exists in this field since the number of empirical insights is limited. The paper aims to discuss these issues.

Design/methodology/approach – Qualitative empirical data collected from 12 key informants working in two distinctive industries, the media and automotive industries, were collected. An investigation was carried out to examine the differences and similarities among how digitalization influences a company’s value creation, proposition and capture, as well as how firms cope with challenges presented by increased digitalization.

Findings – The findings of the study show that, whilst digitalization is generally considered to be important, the value proposition itself as also the position in the value network determine the perceived available options for business model innovation (BMI) by digitalization. Moreover, the organizational capacities and employee competences were identified as future challenges that will be faced by both industries.

Originality/value – The findings of this study have revealed that representatives of the media and automotive industries perceive both the pressures and opportunities of digitalization regarding BMI; its application and exploitation, however, remain challenging. This study contributes to the existing body of knowledge by providing empirical insights in the context of digitalization and BMI.

Keywords Digitalization, Innovation, Dynamic capabilities

Paper type Research paper

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1. Introduction

Over the past few decades, global industries not only have faced technological changes that have led to opportunities such as greater flexibility, reactivity and product individualization, but also have presented diverse challenges such as rapid technological change, increased complexity and changing customer preferences and legal requirements. This has led to challenging situations in a corporate context: manifold new technological opportunities are perceived, but people are uncertain how to use and implement them simultaneously in terms of product and service offers (Lerch and Gotsch, 2015). The situation in the field of digitalization and business model innovation (BMI) is interesting because the influence of digitalization on the business model (BM) is fuzzy, and the exploitation of technological opportunities – also from a strategic viewpoint – is challenging (Mezger, 2014; Loebbecke and Picot, 2015; Paulus-Rohmer et al., 2016; Bouwman et al., 2017).

Digitization (i.e. the process of converting analogue data into digital data sets) is the framework for digitalization, which is defined as the exploitation of digital opportunities. Digital transformation is then defined as the process that is used to restructure economies, institutions and society on a system level (Brennen and Kreiss, 2016; Unruh and Kiron, 2017). While the latter embraces changes on all societal levels, digitalization by means of combining different technologies (e.g. cloud technologies, sensors, big data, 3D printing) opens unforeseen possibilities and offers the potential to create radically new products, services and BM (Matzler et al., 2016). These innovations could lead to new forms of cooperation between companies or the modification of relationships with customers and employees (Kiel et al., 2016 referring to Kagermann et al., 2013). As a result of this new embedded usage of digital technologies, companies can achieve success in terms of experiencing optimized resource utilization, reduced costs, increased employee productivity and work efficiency, optimized supply chains, increased customer loyalty and satisfaction, to name but a few (Coupette, 2015; Kagermann et al., 2015; Kaufmann, 2015; Loebbecke and Picot, 2015). However, as argued above, the increasing number of opportunities driven by digitalization also put pressure on companies “to critically reflect their current strategy” and “to systematically and early identify new business opportunities” (Kiel et al., 2016, p. 675) and requires “managers to significantly adapt one or more aspects of their business models” (Wirtz et al., 2010, p. 273) or even design completely new ones. In one of the latest surveys on digitalization (McKinsey Global Survey, 2014, p. NOS), executives reported that their CEOs “are more involved in digital efforts than ever before” but at the same time they say that “their companies must address key organizational issues before the digital can have a truly transformative impact on their business.” In this context, one can assume that digitalization has a de facto influence on every industry as it impacts corporate strategies and challenges existing BMs to be reconsidered and adapted (Linz et al., 2017). The extent, however, to which digitalization impacts corporate activities and leads to BMI differs from industry to industry and takes time since “business models are more context-dependent than technology,” depending on resources and capabilities that are available within the respective company (Teece, 2018, p. 45). In this context, the goal of this research was to explore if and how digitalization influences a company’s BM and leads to BMI. For this purpose, the business logic triangle (Osterwalder and Pigneur, 2002) in combination with the perspective offered by the dynamic capability view (Teece et al., 1997; Mezger, 2014; Teece, 2018) was employed as the conceptual setting. The BM as such is understood as the “architecture of the value creation, delivery, and capture mechanisms [a firm] employs” (Teece, 2018, p. 41). The research questions addressed were:

*RQ1.* How does digitalization influence a firm’s BM?

*RQ2.* How do firms cope with the digitalization of their BM?
To explore these two research questions, two distinct sectors, the automotive industry and the media industry, were chosen as samples. A qualitative empirical research design, incorporating 12 expert interviews, was applied to provide insights and cast light on the practical and theoretical implications of the data collected. While the shift from printed products to a service-based value proposition has already taken place in the media industry (Mezger, 2014), manufacturing industries, such as the automotive sector, are facing different challenges in the context of digitalization. These include the Industry 4.0 movements, although industries in the automotive sector still remain car manufacturers themselves or ancillary industries and not digital businesses (Svahn et al., 2017).

The paper is structured as follows: the theoretical background is described in Section 2; the research method and empirical settings are presented in Section 3; the results of the case study for the automotive and media industry are presented in Section 4; the results of the studies are discussed in Section 5; and conclusions are presented in Section 6.

2. Theoretical background

2.1 Digitalization in the context of the company

Digitalization and, later, digital transformation are drivers for changes in the corporate world, because they establish new technologies based on the internet with implications for society as a whole (Unruh and Kiron, 2017). While digitization describes the process of the conversion of analogue and noisy information into digital data (Brennen and Kreiss, 2016), digitalization is used to describe any changes in the organization and the organization’s BM due to their increasing use of digital technologies to improve both the performance and the scope of the business (Westerman et al., 2011). In a third step, Bloching et al. (2015) interpreted the digital transformation as the continuous interconnection of all business sectors and the actor-side adaptation to the requirements of the digital economy, whilst Unruh and Kiron (2017) defined it as the systems-level restructuring of economies, institutions and society that occurs through digital diffusion. Digitalization as such developed from a form of technical evolution to a phenomenon that can impact any kind of organization. The physical and digital world are converging increasingly frequently and need to work hand-in-hand, so that manufacturing companies can also become digital (e.g. Industry 4.0) (Linz et al., 2017). This can happen, for example, by integrating the Internet of Things and Services into industrial processes (Kagermann et al., 2013) and generating value by analyzing and managing data that can be used as a source of competitive advantage (Porter and Heppelmann, 2015). As such, many changes led by digitalization are disruptive and completely change the existing branches (Matzler et al., 2016). Companies that have dominated the market are confronted by new competitors that redefine the established industries (Linz et al., 2017), so that existing BMs become obsolete and are replaced by new ones (Souto, 2015; Matzler et al., 2016). The recent developments that took place in the 2010s, such as the mobile revolution, social media or the power of analytics, specifically led to the digital transformation of BM. Anything-as-a-service models emerged were platforms with business networks and ecosystems are promoted. In the meantime, customers can receive pervasive access to information via the internet and have multiple channels to choose from (Linz et al., 2017; Berman and Bell, 2011). While competition takes place on the basis of outstanding BMs (Linz et al., 2017), companies need to innovate their BMs to be successful in the digital world. This implies that technologies and BMI are complementary (Chesbrough, 2010).

2.2 BMs and BMI

While it is generally acknowledged that “a business model describes an architecture for how a firm creates and delivers value to customers and the mechanisms employed to capture a share of that value” (Teece, 2018, p. 40), agreement on the theoretical aspects is lacking. This
leads to a situation in which the core constructs are not defined and dimensionalized adequately (Foss and Saebi, 2018), which also makes it difficult to conduct empirical testing. Nevertheless, BMs are helpful concepts that represent elements and relationships in business activities for the purpose of planning, communication or improvement (Massa et al., 2017) as they link strategies with business processes (Osterwalder and Pigneur, 2002). With the help of BM concepts, a company is able to describe its business in terms of “what it does,” “what it offers” and “how the offer is made” (Ritter and Lettl, 2018).

In recent years, the BM itself has increasingly become a source of innovation and competitive advantage (Hossain, 2017). Different executive studies (The Economist Intelligence Unit, 2005; KPMG International, 2006) and scientific studies (Spieth et al., 2014) have defined the reasons for the need to develop innovative BM. As in the definition of the BM concept, there is not yet a consensus for the definition of BMI (Mueller, 2014; Foss and Saebi, 2017). On the one hand, BMI is described as a process (Schallmo and Brecht, 2010; Berglund and Sandström, 2013; Matzler et al., 2013; Foss and Saebi, 2017) for the development of a BM that can be new to the company (Björkdahl and Holmén, 2013; Foss and Saebi, 2017) or an entire industry (Santos et al., 2009; Schallmo and Brecht, 2010; Foss and Saebi, 2017). On the other hand, the BMI is described as the result of an innovation initiative that replaces or revises an organization’s existing BM (Mitchell and Coles, 2003; Foss and Saebi, 2017) or completely changes the existing BM (Lindgarde et al., 2009). Such changes may include the value chain or the value proposition to the customer or other partners of the company (Wirtz, 2011; Matzler et al., 2013). Hence, the degree of innovation is also included in discussions about BMI (Amit and Zott, 2012; Lindgarde et al., 2009; Hacklin et al., 2018).

For the purpose of this study, we defined BMI “as a change in a company’s business model that is new to the firm and results in observable changes in its practices towards customers and partners” (Bouwman et al., 2017, p. NOS). More specifically, we were interested in examining the increasing availability and embeddedness of digital technologies such as the internet that could lead to BM changes (Bouwman et al., 2017). The potential of digitalization and novel applications as well as an integrated view of the product life cycle are changing the way value is generated and new and innovative BMs are developed (Arnold et al., 2016; Burmeister et al., 2016; Kiel et al., 2017; Loebbecke and Picot, 2015). This has also been confirmed frequently: Big Data (new data sources) (Hartmann et al., 2016), automation (changed machine functions), interconnections along the value chain (breakup up of non-transparency) and digital customer interfaces create the foundations for new BMs and potentially restructure the individual sectors (Berman and Bell, 2011; Matzler et al., 2016).

Several studies have also described three different ways in which digitalization influences and changes companies and their BMs: optimization of the existing BM (e.g. cost optimization); transformation of the existing BM (e.g. reconfiguration of existing models, extension of the established business); and development of a new BM (squeezing out established market participants, new products/services) (Coupette, 2015; Kaufmann, 2015; Loebbecke and Picot 2015; Ernst & Young, 2011). Matzler et al. (2016) and Berman (2012) described these three steps as, first, the digitization of products and services; second, digital processes and decision making with the aid of Industry 4.0, Big Data or artificial intelligence; and, third, the transformation of the value proposition and operating model as such.

If the single BM elements and how they change is examined more carefully, the findings of the recent studies have pointed out that the value proposition, internal infrastructure management and customer relationships are mainly influenced by digitalization (Arnold et al., 2016; Kiel et al., 2017). Predominantly changes in the form of new offers (products, services, or solution packages in the form of cloud computing or predictive maintenance) are driving changes in the BM. As the number of offers, such as services and solution packages, increases, customer relationships are intensified. Relationships morph into long-term collaborations to satisfy customer needs. Concerning
the value configuration, the solution packages offered require the modularization of hardware and software. This requires technology development activities, especially software development. Thus, competences in cyber physical systems or analytical data processing know-how are necessary and require changes in workforce qualifications. If manufacturers do not possess these resources, they need to develop a partner network to source them externally. Furthermore, new revenue models are enabled by Industry 4.0 (e.g. dynamic pricing or pay-by-usage) but, due to customer resistance, few changes are currently taking place (Arnold et al., 2016; Kiel et al., 2017).

2.3 Dynamic capabilities and BMI
Companies can be successful over time if they can adapt to their environment. The dynamic capability is a suitable perspective that explains this phenomenon and is even more important in volatile environments. “During recent years, dynamic capability research has developed a framework outlining how firms adapt their physical, human, and organizational resource bases when facing situations of technological or market change” (Mezger, 2014, p. 430). The ongoing transition of economies, given the increasing embeddedness of digital technologies in general, can be classified as just such a change in terms of technological and markets drivers that influence a company’s BM. Schweizer (2005, p. 6) explained that a “dynamic capability can be considered as the ability to seize new opportunities and to change the existing business model by reconfiguring the value chain constellation and protecting knowledge assets, competences and (the access to) complementary assets and technologies in order to achieve sustainable competitive advantage.” Thus, companies can remain competitive if they can change their BMs (Teece et al., 1997; Eisenhardt and Martin, 2000). Not only the internal capacities are central to the BM. The assessment of the BM is bound to the environmental context. In this context, the business environment is seen as a variable that can be selected and shaped by the company, but also vice versa. To increase the success of the designed BM on the market, the company must analyze various alternatives, have a good understanding of customer requirements, a precise understanding of the value chain so as to deliver what customers need as cost-effectively as possible and on time and should also have a neutral perspective on outsourcing (Teece, 2018). Hence, the ability to adapt the BM can be seen as a dynamic capability itself (Dottore, 2009). It is the learning-driven approach of sensing, seizing and reconfiguring in particular, which provides the business with opportunity to adapt and meet changing requirements in alignment with the business strategy (Mezger, 2014; Teece, 2018): first, technology and BM sensing implies both the ability to translate technological capabilities to new BM ideas and recognize alternative BMs that are in place among competitors and across industry boundaries. Second, seizing, on the entire BM level, is understood in terms of focusing on innovation activities by (re)combining elements such as technology, the market and BM knowledge. Third, reconfiguring refers to the selection and sourcing of the respective core competencies and the resources needed while also integrating partners with complementary competences and resources. Sensing capabilities are needed to identify opportunities and threats to the BM, and seizing capabilities are required to address and exploit these opportunities in the BM. Reconfiguration capabilities are needed to design and adapt organizational structures and activities and represent resources that are used to facilitate the implementation of the new BM (Dottore, 2009; Mezger, 2014).

These perspectives on digitalization and BMI taken together – in the context of dynamic capabilities – framed the conceptual setting for this empirical study (see Figure 1). Herein, the business logic triangle (Osterwalder and Pigneur, 2002) offered the perspective to differentiate between the business processes on the bottom and the strategic planning level on the top. In between lies the architectural level, which has been understood to be the BM
that represents the company’s reason for creating and capturing value by offering specific value propositions to existing and potential future customers (Teece, 2018). As such, the BM links the planning with the implementation level. The dynamic capabilities perspective offers an explorative view on the topic of BMI and has allowed researchers to argue that the design and operation of BM are dependent on a firm’s capabilities (Teece, 2018).

3. Methods and empirical setting

3.1 Sample description and data collection

The research study was explorative by nature and used an embedded multiple-case study design (Yin, 2009), whereby each of the two industries chosen constituted one case. The research was conducted at the firm level; the interviewees, representatives of their respective organizations, formed one unit of analysis (Yin, 2009). The choice of this research design was determined by the current knowledge of digitalization BMI, which implies research questions such as those presented above. In the present explorative study, the companies chosen did not constitute a representative sample but served rather to illustrate the connection between digitalization and BMI in two different industries. First, companies in the automotive industry and, second, companies in the media industry were chosen. To increase (internal) consistency and explore potential differences between different contexts, the selection was made for the following reasons: first, the companies in the automotive industry operate in B2B-markets, but the companies in the media industry are mostly active in B2C-market. Second, making a comparison between a (mainly) manufacturing and a service-oriented industry allowed the varying importance of digital technologies in the context of BMs to be contrasted. Third, this is also associated with the historical development of the embeddedness of digitalization in the two industries which form selection criteria. After the first step in the selection process had been taken, the available information on the relevant companies was collected. In a second step, appropriate respondents were selected, all of whom were either working in the top management level and had a strategic perspective on the topic or were responsible for digitalization and/or BM development in the business. In this context, we used purposive sampling to select our key informants (Flick, 2005; Teddlie and Yu, 2007) according to the interviewee’s knowledge and availability (Flick, 2005). Key informants were chosen, not because they were representative for the members of a company in any statistical sense, but because they were knowledgeable about the topic of interest and “able and willing to communicate about it” (Kumar et al., 1993, p. 1634). Once the selection had been completed,
the potential interviewees were contacted. Once they had agreed to participate in the study, they received initial information about the study, including a short list of questions which they answered before the interview took place. The final sample consisted of \( n = 10 \) companies and \( n = 12 \) interviews, of which six were from the automotive industry and six from the media industry. One interview was conducted per company except in the cases of company E and J. In total, 10 out of 12 interviews were conducted personally; the rest were conducted via telephone (compare Table I). An interview guideline for the semi-structured interviews was used to ensure that similar topics were addressed and discussed in all interviews. In ten cases, the interviews were recorded and transcribed afterwards. In two cases, a careful written record was taken. The study was conducted on a broad basis in Austria and Hungary in 2017.

### 3.2 Data analysis

All interviews (except of two) were recorded and fully transcribed. All of the textual information served as a basis for the data analysis in the context of content analysis (Mayring, 2010). The data analysis procedure involved a summarizing technique and structuring qualitative content analysis (Mayring, 2010). The following steps were taken:

1. Establishment of a provisional coding scheme: the initial coding scheme was derived deductively based on theoretical considerations.

<table>
<thead>
<tr>
<th>Company</th>
<th>Interview</th>
<th>Position in the company</th>
<th>Company size (number of employees)</th>
<th>Industry</th>
<th>Data collection</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>A1</td>
<td>Project management</td>
<td>More than 8,000 worldwide</td>
<td>Automotive</td>
<td>Personal interview; audio recorded and transcribed, duration 15 min</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(research and development)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>A2</td>
<td>CEO</td>
<td>65</td>
<td>Automotive</td>
<td>Personal interview; written record, duration 28 min</td>
</tr>
<tr>
<td>C</td>
<td>A3</td>
<td>Technology management contract manufacturing</td>
<td>10,000</td>
<td>Automotive</td>
<td>Personal interview; audio recorded and transcribed, duration 14 min</td>
</tr>
<tr>
<td>D</td>
<td>A4</td>
<td>Head of innovation</td>
<td>5,800</td>
<td>Automotive</td>
<td>Personal interview; audio recorded and transcribed, duration 23 min</td>
</tr>
<tr>
<td></td>
<td></td>
<td>and technology</td>
<td></td>
<td></td>
<td>Telephone interview; audio recorded and transcribed, duration 24 min</td>
</tr>
<tr>
<td>E</td>
<td>A5</td>
<td>Head of engine IT</td>
<td>11,500</td>
<td>Automotive</td>
<td>Audio recorded and transcribed, duration 21 min</td>
</tr>
<tr>
<td>E</td>
<td>A6</td>
<td>CIO</td>
<td>11,500</td>
<td>Automotive</td>
<td>Audio recorded and transcribed, duration 21 min</td>
</tr>
<tr>
<td>F</td>
<td>M1</td>
<td>Head of media technology</td>
<td>3,000</td>
<td>Media</td>
<td>Personal interview; audio recorded and transcribed, duration 30 min</td>
</tr>
<tr>
<td>G</td>
<td>M2</td>
<td>Head of digital CC</td>
<td>400</td>
<td>Media</td>
<td>Personal interview; audio recorded and transcribed, duration 25 min</td>
</tr>
<tr>
<td>H</td>
<td>M3</td>
<td>Head of marketing</td>
<td>40–45</td>
<td>Media</td>
<td>Personal interview; Audio recorded and transcribed, duration 39 min</td>
</tr>
<tr>
<td>I</td>
<td>M4</td>
<td>CEO</td>
<td>25</td>
<td>Media</td>
<td>Personal interview; written record, duration 40 min</td>
</tr>
<tr>
<td>J</td>
<td>M5</td>
<td>Director of subdivision</td>
<td>70</td>
<td>Media</td>
<td>Personal interview; Audio recorded and transcribed, duration 34 min</td>
</tr>
<tr>
<td>J</td>
<td>M6</td>
<td>Subdivision’s head of technology</td>
<td>70</td>
<td>Media</td>
<td>Personal interview; audio recorded and transcribed, duration 42 min</td>
</tr>
</tbody>
</table>

Table I. Data sample
(2) Paraphrasing: the original transcripts of interviews were used and paraphrased. In addition, the main text passages were translated from German into English as part of this process step and transferred to the Excel software tool. The units of analysis were defined according to the research questions, to identify relevant statements on the influence of digitalization on a firm’s BM and how the firms handled the influence of digitalization on their BM and its respective building blocks.

(3) Inductive coding of the data gathered: all interviews were coded according to the previously developed coding scheme. The coding units chosen were the single text paragraphs identified in step 2 (paraphrasing). The coding was performed first for each individual company by one team of researchers. The category system was then refined, and the results of the coding procedure were cross-checked (again) by another team of researchers. This process of coding was iterative. Meanwhile, additional, new interviews were also conducted; however, no major changes in the coding system were made.

(4) Data analysis: after the coding, the data were analyzed by aligning the empirical results with the theoretical considerations.

The data were checked for reliability and validity to ensure the high quality of the results. In principle, the study can be repeated to generate similar results once again, since the data collection process was carefully documented, the interviews were highly structured and all data were collected in a suitable database. Internally, four (out of five researchers) were involved in coding and analyzing the relevant data, and pattern matching was employed (Yin, 2009).

4. Results

In the following section, the results from the case studies are outlined and structured according to the proposed conceptual setting as illustrated in Figure 1. Insights are provided on strategic aspects which provided a framework for the investigated industries’ BMs, the influence of digitalization on the company’s BMs as well as how firms coped with it. The exemplary statements provided serve as a depiction of the insights gained from an analysis of the empirical data. The results are discussed more generally in Section 5.

4.1 Case study: automotive industry

Strategic aspects. Digitalization has been interpreted by businesses as a means to fulfill customers’ needs more effectively (A4), adapt to changes in the sector (A4) and increase their competitive advantage (A6). The need to adapt to changes and developments in a company’s environment and achieve increasingly shorter technology cycles represented triggers for digitalization activities in companies (A1, A4). One interview respondent emphasized the strategic challenge of selecting the right technology at the right time (A1). The effects of digitalization were anticipated for a company’s value chain (A6, A4) and for the value network (A6). Interview respondent A6 stated that digitalization leads to changed or new products and services. A6 added that digitalization leads to new business relations. Furthermore, respondents also indicated that digitalization influenced the company’s internal structures by reinforcing interdisciplinary collaborations (A5).

BM in general. All automotive industry interview respondents perceived the influence of digitalization on the BM. Interestingly, one person (A4) perceived only minor to no influence on their core BM, whereas another interview respondent (A6) saw its influence on all areas from value creation to value proposition and value capture. Interview respondent A4 stated that digital approaches played a major role in all areas of the company. This also included their production facilities (A4). Similarly, interview respondent A2 had seen the influence of digital technologies since the early to mid-1990s.
Value creation. Beside internal initiatives, the availability of digital technologies for the company was viewed as an external trigger to use these technologies in their value creation processes (A4). All the automotive industry interview respondents seized digitalization to improve business processes (A1, A2, A3, A4, A5, A6). Interview respondent A2 also stated that digitalization supported employees during the value creation process. Furthermore, one respondent stated that digitalization could support the product development processes (A5). Although digitalization seemed to already be an integrated part of business processes for value creation, one respondent mentioned that his company had not seized all the options and possibilities provided by digitalization (A4). Respondent A4 stated the company’s role as a tier-2 supplier as a reason for this.

All interview respondents mentioned the effects of digitalization on business partner networks (A1, A2, A3, A4, A5, A6). Interview respondent A1, for example, described an increased intensity in the collaboration with partners. Interview respondents A2 and A6 reported that new partners had been acquired due to digitalization. Interview respondent A3 emphasized that digitalization facilitated collaboration among partners across industry sectors (external) as well as internally between business segments, which did not compete with each other. Furthermore, two interview respondents (A2, A4) had seen the effects of digitalization on interfaces between partners and described intensified collaboration with partners who provided digitalization knowledge and services (A4, A5).

Four interview respondents (A2, A3, A4, A5) stated that digitalization required the hiring of (new) employees with digital competences, and three interview respondents (A2, A4, A5) emphasized the changing needs of competences among their employees. They either pointed out the importance of developing the competences of existing employees or acquiring new employees with the required knowledge. One interview respondent (A3) mentioned that employees need the skills to deal with digital technologies and leverage digital opportunities. Similarly, interview respondent A2 stated that digitalization requires skilled employees. A2 also added that, despite digitalization, the human workforce continues to have high relevance. Respondent A5 also mentioned the aspect of adapting the employee qualifications to meet the new requirements.

Three interview respondents (A3, A4, A6) stated that digitalization had already taken effect in their companies at various times in recent years. Interview respondent A3 mentioned that his company had already dealt with the digitalization of value creation processes before the emergence of the current Industry 4.0 hype. Similarly, interview respondent A4 mentioned that digital approaches play a major role in all areas, including production.

Value capture. Three interview respondents (A1, A3, A6) mentioned the effects of digitalization on revenues in that they saw ways to generate or improve revenues with the artefacts or results of digitalization. A1 and A6 saw a potential to generate revenues with digital products or services. Interview respondent A3 mentioned possibilities to generate revenues by using the experience gained by employees and making use of the generated data. In contrast to this, interview respondent A4 stated that the possibilities currently provided by digitalization in terms of value capture (e.g. sales platforms) are not seized in his company due to the lack of demand from the customer.

Value proposition. Five out of six interview respondents (A1, A3, A4, A5, A6) saw an influence on or enhancement of the value proposition through digitalization. Interview respondents A1 and A6 stated that digitalization led to new products or services in their businesses, whereas A1, A3, A4 and A6 saw influences on or new opportunities for the value proposition through digitalization. For example, one respondent (A1) explicitly mentioned data-driven business as a new aspect for value proposition. Three interview respondents stated that they had been using digitalization in their value proposition for several years (A1, A4, A6). Furthermore, interview respondent A6 emphasized that they believed that
digitalization will have major impact on value proposition in future. Respondent A1 also saw that challenges were imposed by short technology cycles. Five (A1, A2, A4, A5, A6) out of six interview respondents saw an influence of digitalization on the customer contact. Interview respondents A1 and A2 saw digitalization as a lever to improve efficiency of customer contact. A2 reported that digitalization opened up new ways of customer relations via social media, for example. Furthermore, digitalization could be seized to support communication and demonstrate added values in products to customers (A5), as well as generally connect customers and sales representatives (A6).

4.2 Case study: media industry

Strategic aspects. According to interview respondents, triggers for the use of digital technologies came from both external and internal sources (e.g. pressures by large digitization providers). Furthermore, interview respondents perceived that digitalization had the potential to disrupt industries. As a concrete example, interview respondent M5 mentioned the behavior of international competitors (e.g. Netflix). Their use of technology in innovative BMs questioned the way established media companies produce and deliver value as well as their respective capabilities (M2, M3, M4). In general, beginning to use digital technologies (e.g. in data-driven BMs) seemed to require an “extensive transformation process” (M1, M2). Digitalization was also viewed as an organizational topic since the handling of digitalization required permanent structural adjustments within the company. Handling organizational interfaces (e.g. between different systems or value creation processes) was mentioned as a pressing issue in this regard (M1, M2, M6).

BM in general. Except for M4, all interview respondents in the media industry emphasized the influence of digitalization on BMs in the industry as a whole (M1, M2, M3, M5, M6), such that digitalization drives innovations and, therefore, a company’s BM (M3). According to interview respondent M1, the media industry dealt with this influence at a relatively early stage (beginning in the 1990s), and digital technologies have been used for several years (M6). Interview respondents M3 and M4 perceived options provided by digitalization as an addition to the companies’ existing BMs and did not see the need to change established BMs. However, digitalization was described as influencing the execution of these established BMs, acting more as an enabler than a driver (M4, M6). Respondent M2 recognized the potential for digital technologies to generate and capture value in the media industry, especially in the area of communication and sales (e.g. through the sale of personalized advertisements or through programmatic buying). For example, interview respondent M4 stated that digitalization influenced the customer channels of the company but left the residual BM unchanged.

Value creation. Interview respondent M1 argued that the speed in content production and the contents overall reached were major aspects that needed to be considered. Three out of six interview respondents (M1, M3, M6) saw digitalization as a way to simplify company processes, produce media content faster and increase efficiency. This could be achieved by automation of tasks, reduction of staff cost, a higher accessibility of company data or the mobile creation and distribution of media content. According to interview respondent M3, the digitalization of processes needs to be constantly questioned and developed (M1, M3, M6). Editors and journalists were cited as drivers for new or adapted content formats needed for digital publishing (M1, M2). According to interview respondent M6, identifying and satisfying customer needs (e.g. requirements regarding content and distribution channel) required heterogeneous teams. Further, interview respondent M6 explicitly mentioned that digitalization triggered a transformation process in the company that spans several years. During that time, employees were able to adjust to the new circumstances digitalization had initiated. Interview respondent M6 stated that the advantage provided by digitalization was the availability of data (e.g. in the form of digital archives). However, a major issue mentioned
related to the investigated company’s digitalization activities was the handling of the necessary technological solutions (M1). An example is internet streaming of media content, which relies on a completely different infrastructure to that of conventional radio and television (M5). Realizing new possibilities provided by digitalization (e.g. personalization of content or real-time automatization) particularly requires investments (M1, M6).

Two major aspects to be considered while selecting technologies are the technology cycles within the industry and the ability of a company to finance technological changes. The pace of digital development is steadily increasing, and technology lifecycles in the media industry are continuously shortening. Therefore, several respondents mentioned that one needed to take certain aspects into consideration, such as identifying appropriate technologies for the application in a company’s BM, their respective technological lifecycles and the economic sustainability of a selected technology (M1, M3, M5). Furthermore, since digital processes and interfaces are partly used in critical areas (e.g. for online payments), the unfettered functionality of respective technologies needed to be ensured (M1).

All representatives of the investigated media companies recognized the importance of collaborating with internal and external partners. Interview respondents stated that this was because companies need business partners’ know-how and technologies to develop BMs through digitalization (M1, M2, M3, M4, M5, M6). However, while digitalization led to an intensified collaboration with some partners (e.g. mutual development support in the area of telecommunication), relationships with other partners were terminated due to their lack of digital competences (M5).

Value capture. Most of the investigated media companies capture value through approaches like subscription models (M1), advertising and the sale of products (e.g. tickets). A special position was taken by the representatives of company J, which is limited by regulations and partly relies on fees for its income (M1, M2, M3, M4, M5, M6). Digitalization in sales and distribution was perceived to be of high importance (M4). It offers information on a company’s customer groups and provides ways to tailor content to identified groups and, subsequently, to influence customer behavior (M3). As stated by interview respondent M1, opportunities offered by digitalization, such as social media platforms and personalization, were used to generate additional revenue (e.g. by extending the reach of the company’s content). As stated by interview respondent M5, the use of external platforms was also considered to be critical, since companies are usually not able to generate income from content placed on these platforms. Due to the pressure resulting from decreasing profit margins, investments in digital technologies were perceived as attractive (M1). However, according to interview respondent M4, the advantages of digitalization in company processes must be clear in advance in order to implement digital technologies. Interview respondent M5 indicated that customers are increasingly demanding flexibility in terms of the delivery of content. In that regard, digital technologies were considered to be a means to meet customer requirements toward content (M5, M6). Digitized approaches in the distribution of media content were considered to hold merits for consumers, advertising partners and the company itself through increased revenues (M1, M2, M3, M4).

Value proposition. The representatives of the investigated companies indicated that they were driven by their media content and showed a tendency to choose content quality over actuality (M1, M3). Interview respondents recognized that, by publishing content via digital channels, their companies became more accessible and they potentially created additional value for customers. Examples that were collected for the generation of additional value through digitalization were the personalization of published content for advertising purposes (M1, M2, M3) and the use of real-time data (M3) (e.g. traffic information). Digital technologies were cited as being utilized to intensify customer contact, for example, to provide feedback options for customers on delivered products and services (M1, M2, M3, M5, M6).
Interview respondent M6 underlined the influence of customer groups. A challenge that was identified in that regard was to supply different customer groups with tailored content. Digital technologies enabled firms to offer customers the possibility to choose both the content itself and the way the content could be consumed (e.g. through publishing content on multiple platforms) and were subsequently able to address multiple customer groups. The main issue, according to interview respondent M6, was the interfaces within a company and to the customer. Another aspect that was mentioned by interview respondents M1 and M5 was the secure handling of personal data and the strict implementation of legal regulations (M1, M2, M5, M6).

5. Discussion
5.1 Influence of digitalization on BMs in the automotive and media industry
Results indicate that the value creation aspect is strongly influenced by digitalization in both the automotive and the media industry. Pressing issues are, thereby, the firms’ processes and their partner structures. Respondents saw an influence through altered requirements regarding employee qualifications. Furthermore, respondents perceived the positive effect of digitalization on the value proposition and value capture aspects, which resulted in improved and additional revenues. However, the degree of digitalization applied by each firm was determined by the customer demand. This result also resonates the findings of Linz et al. (2017) and Berman and Bell (2011), who said that the customer is the main driver behind digitalization. Moreover, respondents from both industries indicated that the influence of digitalization would challenge existing technologies, for example, through shorter technological innovation cycles. Based on their perceptions of the current effects of digitalization, our respondents anticipated that digitalization would have a major impact on their firms’ future value propositions. These findings are also supported by those of studies such as Arnold et al. (2016) and Kiel et al. (2017). In their studies, they identified that the value proposition was mainly influenced by changes in the offers. Companies increasingly added services to the physical products (e.g. predictive maintenance) or offered complete solutions. Matzler et al. (2016) and Berman (2012) also described changes in the offers and, thus, in the value propositions as being the first step taken toward a digital BM.

Data collected from representatives of the automotive industry indicated that the influence of digitalization on various aspects of value creation was perceived as the industry’s dominant theme. For example, production process optimizations were frequently cited by the interview respondents. This may be because the companies to which the interview respondents belonged are mainly engaged in B2B-markets. Furthermore, the automotive industry is mainly engaged in Industry 4.0 projects, placing a focus on the optimization of value creation (Bauernhansl et al., 2015; Kiel et al., 2017). Companies recognize that they need to manage the connection between the physical and the digital world in the context of Internet of Things before they offer digital services to customers (Fleisch et al., 2014). This aspect of the BM has been assigned a higher priority than other aspects, such as customer relations, in the value capture area. According to our respondents in the automotive industry, the influence of digitalization on their firms’ value propositions affects their products and services. In that regard, data-driven add-on BMs and new ways of customer contact were explicitly mentioned.

In the media industry, digitalization affected the value creation through adjusted processes for content generation as well as the need for technological reconfiguration. However, in contrast to the automotive industry, respondents thought that digitalization had a strong effect on value proposition and value capture aspects of the BM. Opportunities provided by digitalization were used to exploit aspects such as the personalization of
services offered, digital platforms and improved customer orientation. This may be because the media industry has a strong business to customer focus, causing the companies to place a greater emphasis on value proposition and value capture aspects. Another further reason is the early influence of digitalization on the media industry and the necessity to deal with that fact. These findings are also supported by Bourreau et al. (2012).

5.2 Similarities and differences in coping with digitalization between investigated industries

Respondents from both industries mentioned external and internal drivers for digitalization. External drivers such as available technologies or the shortening of technology lifecycles were cited as relevant for the media and automotive industries. These findings echo those of Bouwman et al. (2017), who concluded that “internal drivers related to innovative activities and strategy, as well as technology turbulence, play an important role when social media and Big Data are part of business model innovation” (Bouwman et al., 2017, p. NOS).

Mezger (2014) revealed that the businesses’ sensing capabilities are important for detecting technological and market developments, while analyzing BMs in other industries helps to learn about the problems and challenges to be faced. Seizing capabilities are reflected in transformative and exploitative learning processes by re-combining knowledge about customers, markets and technologies used to develop the new BM. Sensing and seizing capabilities are characterized by their high degree of interaction. The reconfiguration capability requires companies to change their activity system, structures and governance. Decisions about new resources must be made, and the replacement of existing ones is important. These points stress the need for capabilities to integrate partners into the BM.

The findings clearly underline the need for companies to have the sensing capabilities described by Mezger (2014). Furthermore, opportunities in areas such as process optimization were mentioned as internal triggers by members of both interview groups. The aspect of the add-on business can be identified in both the automotive and the media industry, as explained by Fleisch et al. (2014). This result is in line with those of Coupette (2015), Kaufmann (2015), Loebbecke and Picot (2015) and Ernst & Young (2011), who stated that the effect of digitalization can present itself in the form of a reconfiguration or extension of the established BMs.

Furthermore, representatives of both industries recognized the potential of digitalization to optimize their BMs, as described by Coupette (2015) and Kaufmann (2015). However, our results indicate that the influence of digitalization on BM elements and, therefore, the potential for optimization depends greatly on the company’s industry. Furthermore, in the automotive and media industries, the influence of digitalization questions the existing organization, interfaces, infrastructure and capabilities. While Mezger (2014) concluded from his findings that managers could facilitate BMI by focusing on the BM level rather than “addressing new technological possibilities and changing customer needs by well-known product and process innovation routines” (Mezger 2014, p. 445), our data did not allow us to clearly differentiate between the different organizational layers and respective innovations. From a capability perspective, however, the aspect of skills required by digitalization was evident to representatives of both industries. Interview respondents frequently pointed out challenges in the area of employee recruitment and qualification. The ability to build and create the know-how required to seize digitalization opportunities was seen as highly relevant. This was also revealed by the findings of the study conducted by Arnold et al. (2016) as well as Kiel et al. (2017). They highlighted the importance of businesses possessing additional competences and know-how in order to offer new services or solution packages, respectively. Saebi (2014) stated that companies need to develop dynamic capabilities to be prepared for changes in their BMs. She identified the preparedness to change BMs and overcome rigidities in the existing BM as “business model change capability” (Saebi, 2014, p. 17). If this idea is taken one step further, the BMI requires meta-capabilities in the form of innovative adaptive capabilities, as described by Collis (1994), since the way of doing business is altered and, subsequently, dynamic capabilities are also altered.
Table II provides an overview of the BM elements in investigated industries and the allocation of these elements to dynamic capabilities phases. Aspects regarding investigated companies’ BMs are structured according to the proposed framework in Figure 1.

<table>
<thead>
<tr>
<th>Business model elements (1)</th>
<th>Sensing</th>
<th>Seizing</th>
<th>Reconfiguring</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value proposition</td>
<td>Identify possible new/adapted products and services</td>
<td>Adapt toward digital products and services</td>
<td>Introduce new (digital) products or services</td>
</tr>
<tr>
<td></td>
<td>Investigate digital options to improve communication with customers</td>
<td>Realize possibilities to improve customer contact</td>
<td>Enhance the existing value proposition</td>
</tr>
<tr>
<td>Value creation</td>
<td>Identify necessary employee qualifications</td>
<td>Adapt employee competences</td>
<td>Use communication with customers to demonstrate added values</td>
</tr>
<tr>
<td></td>
<td>Investigate options to support product development processes</td>
<td>Support of product development processes</td>
<td>Use established business relations and interdisciplinary collaborations</td>
</tr>
<tr>
<td>Value capture</td>
<td>Identify digital possibilities to capture value</td>
<td>Change partner structure and scope of collaboration</td>
<td>Use digitalization to Improve product development processes</td>
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<td></td>
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<tr>
<td><strong>Automotive</strong></td>
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<tr>
<td><strong>Media</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Value proposition</td>
<td>Identify options to increase speed of generation and reach of media content</td>
<td>Personalize media content and channels</td>
<td>Introduce new (digital) products or services</td>
</tr>
<tr>
<td></td>
<td>Identify options to supply different customer groups with tailored content</td>
<td>Use of personalization for advertising purposes</td>
<td>Enhance the existing value proposition</td>
</tr>
<tr>
<td>Value creation</td>
<td>Identify necessary employee qualifications</td>
<td>Use digital technologies to ensure data security</td>
<td>Use of digital technologies to intensify customer contact</td>
</tr>
<tr>
<td></td>
<td>Identify the need for new/adapted media content formats</td>
<td>Use of digital channels to increase content accessibility</td>
<td>Use of digital technologies to constantly adapt to customer needs</td>
</tr>
<tr>
<td></td>
<td>Identify options to increase flexibility in content delivery</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Value capture</td>
<td>Identify possibilities to react to low profit margins</td>
<td>Adapt to content platforms and personalization to generate additional revenue</td>
<td>Constant collection of information on customers</td>
</tr>
</tbody>
</table>

**Table II.**

Influences of digitalization on BM elements and their associations with dynamic capabilities.
6. Conclusion

The findings of this research have contributed to the literature on BM and digitalization. Recent theoretical approaches were applied to explore digitalization and BMI. As a sample, representatives of the automotive and media industry in Austria and Hungary were chosen and took part in semi-structured interviews. By offering their practical examples and insights, these representatives outlined the influence of digitalization on BMs. The opportunities and challenges companies perceive when changing their BMs, for example, by using digital technologies was discussed. Furthermore, this discussion shed light on how the investigated industries have coped with the influence of digitalization, pointing out and comparing similarities and differences in their behavior toward BMI. This information, taken together, represents a valuable, highly relevant contribution to a field that lacks an empirical foundation.

As with any research, this study also has its limitations. The main limitation of this research was the restricted number of informants included in each case study. In this respect, more insights could be gained in the future by conducting a study with more respondents or diversifying the sample, taking more organizations into account. In general, further analyses are certainly needed to determine the importance and influence of digitalization concerning company strategies and BMs. This is a complex topic both from a theoretical and a practical point of view, and one requiring more detailed study.

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Customer expectation from Industrial Internet of Things (IIOT)

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Abstract

Purpose – The purpose of this paper is to discuss how the rush of technological change will consolidate the worldwide reach of the internet with more capacity, specifically to control the physical world, including the machines, industrial facilities and frameworks that characterize cutting-edge technology.

Design/methodology/approach – The data were collected from 203 respondents predominantly from emerging economies, specifically India and SEA. Most of the participants are working professionals. Structural equation modelling was used to analyze data, as it is a popular statistical technique because of its ability to model selected independent variables and take into account all possible forms of measurement error to test an entire theory.

Findings – The Industrial Internet of Things (IIOT) platform comprises four fundamental capabilities: connectivity, big data, advanced analytics and application development. The IIOT has the potential to provide a high level of synergies between the 4 Ms of manufacturing, namely, man, machine, material and method.

Research limitations/implications – The collected data are predominately from India and SEA (close to 75 per cent), while contributions from other regions are comparatively less, so the findings cannot be generalized to the global context.

Practical implications – It is in the interest of service providers to collaborate and provide a universal solution to retain legacy systems to minimize the investment and reduce the security threat, which could boost IIOT adoption while ensuring that manufacturers are able to leverage this new technology efficiently.

Originality/value – The framework obtained has good quality of validity and reliability indicators. Thus, an alternative framework has been added to customer expectation which is currently a popular topic in the technological changes.

Keywords Information technology, Digitization, Advanced manufacturing technology

Paper type Research paper

1. Introduction

The Industrial Internet of Things (IIOT) is a framework for enabling discrete machines to collaborate or a process for empowering them with computational capabilities. Isolated processes and machines are connected using open industrial communication protocols, and thus collected data are now available for processing in various ways to make possible more informed decisions than ever before (Tao et al., 2014). The IIOT is a new trend in manufacturing facilitated by physical and virtual connectivity. Newly connected enterprises are now ready to leverage the combined power of computer science, information technology (IT), communication and manufacturing knowledge, which may lead to the fourth industrial revolution.

The advancement in computer science has led to affordable and smaller computational devices (chips), which are incorporated into almost all modern industrial devices.
Computer-based design tools are available, and we are moving towards more sophisticated 3D design and modelling tools. IT has improved enterprise-level efficiencies by standardization and high-level visibility of business processes (Dehning et al., 2007). The advent of wireless communication and sensors can potentially connect all discrete and remote devices. In brief, all the ingredients to achieve smart manufacturing via the IIOT are already available and have been proven in silos; now it is time to integrate the existing capabilities to revolutionize the manufacturing sector (Dujovne et al., 2014).

Firms expect major productivity improvements, reductions in operating costs, agility and improved decision making from IIOT investments. The IIOT somewhat breaks with the conventional industrial control pyramid. In the new system, the monitoring and control of field devices are still managed by machine-level control (PLC) for better performance and the execution of some critical control loops, but a higher level of sequences can be decentralized (Monostori, 2014). Traditionally the communication protocols were also differentiated. The hierarchy in the system, like PLC, is connected to field instruments via Modbus, Profibus or DeviceNet, while the enterprise level is predominately the Ethernet. The IIOT concept encourages the use of a common open protocol, preferably the Ethernet, for all levels of communication to enable the seamless integration of operational technology (OT) and.

The impact of the IIOT can be seen as short term and long term. In the short term, the impact will occur in the form of monitoring, control (business process and manufacturing process), optimization and autonomy. In the long term, as industrial internet-based technology (the IIOT) becomes instilled in industry, it will construct a demand-based economy fuelled by the real-time demand and supply and supported by highly optimized, automated and flexible manufacturing systems.

This paper focuses on the short-term impacts of adopting the IIOT in manufacturing, and all the independent variables are constructed around the foreseen value creation by the IIOT as follows:

(1) Monitoring: digitalization of data (dashboard).
(2) Control:
   - business process: perpetual connectivity with customers; and
   - manufacturing process: reduction in unplanned downtime, network security (control of intellectual property).
(3) Optimization: improved assets and plant performance, informed business decisions.
(4) Autonomy: interoperability, advanced automatic analytics.

The main objective of this research is to measure the depth of understanding of the IIOT in developing economies and the expectations associated with this emerging technology. Although the IIOT is the most-talked-about topic in manufacturing, it is still in the boardroom. The primary focus of this research is to determine users' (customers') expectations from the IIOT, and the survey focuses only on matrices that can be achieved in the short term, that is, less than two years after implementation. The questions are framed around the following questions:

(1) What are the values that the IIOT can bring to manufacturing firms?
(2) What are the prerequisites for the journey towards IIOT adoption?
(3) Which factors can augment the adoption process?

2. Literature review
Numerous modern organizations today are seeking to undertake digital transformation activities. However, many lack a precise way to deal with this change across all their levels
2.1 Digitalization of data

Digitalization initially depicts the conversion of simple analogue data, such as current, voltage, temperature and other industrial measurements, into computerized data. Fundamentally, changes in operational processes can only be brought about by digital data, which propel the use of computational devices. These changes correspond to advancements in trivial methods of manufacturing. Among the different outcomes, digitization and enormous information investigation reshape plans of action and affect work among learning specialists—similar to industrialization accomplished for assembling a workforce (Ivezic et al., 2014). This research attempts to identify the benefits of digitalization for manufacturing industries.

Sustainability is the key criterion for any company’s current valuation, so all companies must have a clear strategy to sustain any kind of future challenge. Digitalization is one strategy that can effectively help corporations in the corporate waste area by implementing environmentally friendly approaches, finding the most effective and productive utilization of the existing assets (e.g., oil, gas, minerals and wood), and other vital factors to remain relevant and competitive in the future (Jianpeng et al., 2009). Manufacturers have come to recognize that digitization does not just involve patching up and showcasing IT. The demands of digitization will eventually constrain organizations to change each part of their business for all intents and purposes (Peters et al., 2015).

Typically in manufacturing industries the day-to-day operations are controlled by experts with minimal or no support from computational devices (Loebbecke and Picot, 2015). These activities and other operational issues during the execution follow some predefined rules, and these rules have been in existence for a few decades, while today’s need for flexible manufacturing cannot be framed in a very few existing predefined frameworks. In a very dynamic manufacturing environment, there may be a specific framework for every minute, and no single framework can be superior in every situation. Accordingly, it would be intriguing to utilize the most fitting and correct decision-making matrices for every situation supported by digital data, and, to accomplish this objective, manufacturing companies are inclining towards machine learning (Priore et al., 2001).

Although there are significant advantages of adopting machine learning, its implementation can be achieved in various ways, like implementing completely automated decision making by machines or taking inputs from learning followed by manual decision making. This selection will be made on the basis of the stage of the project, the criticality of decision making, the impact of a delay in decision making and other dynamics.

Agility is one of the most desirable capabilities of industrial manufacturers around the globe (Zhang and Sharifi, 2000). Opportunities for all manufacturers lie in value engineering, so for manufacturers such dynamic business conditions require a very high level of operational visibility, that is, the ability to monitor their execution and respond to various situations. Consequently, thorough data provisioning on all chains of importance levels is vital.

However, the existing IT frameworks, for example, MES or SAP, barely address the data needs of specialists on the shop floor level, which causes clumsy hold-up times, inflexibility and expensive correspondence. The operational process dashboard for manufacturing is a versatile dashboard for the shop floor that can be a solution for eliminating the existing bottlenecks (Gröger et al., 2013).

Business activity monitoring is an actual dashboard that focusses on real-time monitoring for continual improvement in various processes and the investigation of basic business procedures to recognize abnormalities progressively and respond immediately. These dashboards can be implemented at various levels with respective KPIs and control levels for any business purpose.

and capacities. This research on the IIOT system aims to understand the expectations that organizations may have of their version of a connected enterprise.
2.2 Perpetual connectivity
Perpetual connectivity occurs when organizations and associations remain constantly connected with their items, clients, procedures and conditions. This idea of connectivity offers various opportunities for organizations, from obtaining constant information on item use in a specific market to proactively improving products and services to protect the existing market and maximize the lifetime value of the existing customers. Additionally, continuous monitoring of sensors in various pieces of equipment brings significant value to organizations, as support staff can proactively perform the requisite corrections based on real-time conditions.

Servitization can be considered as a shift from product sales to an offering that is a coordinated blend of products with services that carries more value for consumers. A trend is developing towards customized products and services that can only be delivered if both the seller and the buyer are connected, mainly over the internet. Advanced administration permits effective and versatile business models (Baines et al., 2009). The service department of any firm is now seen as a profit centre, and the focus is on maximizing the revenue through services. The response to this study’s survey indicates that servitization is an inevitable change in manufacturing and that the connection between the buyer and the seller is the first step towards this, followed by organizational change that is required to alter the culture and obtain new capabilities (Neely, 2008).

The value proposition for any consumer is not based exclusively on the financial viewpoint but spreads to other social and psychological values too. A buyer normally derives value by evaluating the cost, input, usability and profit of the product or service bought (Geng and Wasinwasukul, 2012). Other value-added services, like educating clients on how to use the product and troubleshoot, can be delivered via connectivity. In the manufacturing sector, the acquisition cost of a product is normally much lower than its life cycle cost, including commissioning and maintenance, so connected services, like online remote support and condition monitoring, offer great benefit to their users (Doligalski, 2015).

As the paradigm of business is gradually shifting towards customer-centric solutions, providing continual value with the delivered product is the key (Uchihira et al., 2016). Organizations are now starting to see that the opportunity begins with the sale of the product, as the delivered product is now the basis for ongoing discussion. If the manufacturer can stay connected with the customer via the product, the product becomes a window through which the customer’s other needs can be understood. Thus, a smart connected product enhances the value of customers for the organization; the best example of such customer value is in the telecom industry, as, once companies are connected, they can sell new apps, data or other services. Similarly, in the industrial sector, when vendors are connected with customers, they will find numerous opportunities to satisfy customer needs (Gierej, 2017).

One of the key features of modern products is interoperability with other related products via connectivity. The survey results also indicate a strong relationship between connectivity (the independent variable) and customer value for organizations.

2.3 Advanced automatic analytics
As the pace of business decisions is already fast, future-looking organizations are starting to understand that it is insufficient only to investigate the generated data; rather, they should make some value out of it. To achieve this, these organizations are starting to use analytics to operationalize their data as a major aspect of a business procedure (Bose et al., 2008). Analytics can be an integral part of monitoring systems, databases, decision-making processes and so on. Advanced automatic analytics is part of the decision-making process to reduce any delays or human errors, and the outcome of analytics can also be used as additional knowledge or insights followed by any manual action.

Business decisions can be classified broadly into four perspectives: financial, internal process, customer related and R&D related (Groger et al., 2012). An analytical tool can
provide valuable insights for management, business owners or other employees who are well coordinated with their respective KPIs. The key advantage of analytical tools backed by actual data and scenario planning is that they can provide guidance on foreseen uncertainties to enable informed strategic decisions. All strategic decisions can be mapped with value-focused objectives at different levels to receive guidance in decision making that will work towards the common corporate goal.

The tools can help in determining the pros and cons behind each strategic decision. The investigators can then help their organizations by considering ways to plan alternatives, enhancing their shortcomings and surveying the value of such enhancements or by making better vital choices by consolidating the positive elements of different options. Another important aspect, specifically inconsistency due to isolated decision making without knowing all the vital alternative crossovers between situations, can be avoided (Laptev et al., 2012).

In manufacturing sectors, like pharma, chemicals and mining, some extraordinary swings in consistency are an unavoidable truth, although all process-related disciplines, like Six Sigma and others, have been implemented. For these industries advanced analytical tools can provide a solution to all complex procedures that enables micro analysis for problem diagnosis and resolution (Lechevalier et al., 2014). In manufacturing the available data can be used to determine the patterns and relationships between distributed systems, for which analytical tools can be useful. Even in best-in-class units the utilization of the cutting-edge technology of analytics can uncover opportunities to increase consistency in products. The maintenance of equipment ensures its availability and reliability; these are very important for any kind of manufacturing to avoid any unwanted loss in production. Previously suppliers ensured the faultless operation of a product for a specific guarantee period only, but since the life cycle benefit demand has picked up, condition-based monitoring has become important not only for users but also equally for suppliers. Reliability-centric maintenance evolved from the aircraft business. This methodology uses analytics to analyze machines systematically using a specific algorithm, called failure mode, and effect analysis to predetermine the possible failure of components based on their condition (Lechevalier et al., 2014).

Condition-based monitoring screens the condition of plant hardware through different analytical tools, which use the historical data for analysis and to project possible failure. In the setting of aggressive businesses, the advantage of cutting-edge maintenance procedures, like condition-based maintenance, ensures the availability and reliability of all the vital components; this message is replicated by the participants in this survey (Al-Najjar and Alsyouf, 2003).

2.4 Reduction in unplanned downtime

Unplanned downtime is the sum of all unwanted interruptions in any business. Machine failures, human errors and system failures cause nuisances. Some of the direct impacts of unplanned downtime cause harm to machines, humans, the environment and other performance indicators. Unplanned downtime contributes to a reduction in plant efficiency and profitability. Safety and environment-related failure can cause regulatory and reputational impacts. The monetary impact of unplanned downtime is different for different industries, and it can be up to $20,000 per minute. More than three-quarters of downtime is caused by human or process error.

Since a major cause of downtime pertains to errors that can be improved by proper planning and the correct use of technology, the impact can be very significant and easily measurable. The IIOT can potentially provide improved fault prevention by facilitating better visibility. The participants in the survey feel that the impact of the implementation of the IIOT on unplanned downtime will be very strong and reflected in strong positive relationships. Most manufacturing units lose productive capacity in the range of 5–20 per cent, and most firms cannot even...
estimate the total downtime cost to them correctly (Martínez, 2009). A reduction in unplanned
downtime is one of the key immediate benefits obtained from adopting IIOT technology.

Overall equipment effectiveness is a very effective universal tool for measuring the efficiency
of an entire plant or just one piece of equipment. Three major factors that have an impact on
OEE are the availability of the equipment/plant, the performance of the equipment/plant and the
quality of the outcome of the equipment/plant. OEE is one key KPI of the maintenance and
operation team inside any plant (Ahmad and Dhafr, 2002).

Real-time condition monitoring means continuously observing the state of a machine or
piece of equipment powered by IIOT technology, which enables the early detection of any
unwanted deviation to shift the failure category from unplanned to planned (Porter and
Heppelmann, 2015). This permits early detection and the execution of remedial action in
states of earlier instability, which will reduce the unwanted failure of the equipment or
machine. Real-time condition monitoring is possible in smart devices with computation
power, from which data are collected for statistical calculation and early prediction; over
time the accuracy of this system is continuing to improve.

Investments in manufacturing are very high, including individual equipment, so the
expectation of optimized usability of these resources is genuine. Optimized utilization is made
possible by maintaining the high availability of a unit or machine, which can be achieved by
adopting proactive maintenance powered by real-time condition monitoring. This is strongly
approved by the respondents to this survey (Lee and Lee, 2015).

2.5 Improvement of plant and asset management

To make continuous improvements, we must have clear metrics for their measurement.
IIOT-enabled devices will generate a large pool of data, and, with advanced analytical tools,
we can identify the key variables that to date have been either uncovered or unmeasurable.
Once we have identified the variables, we follow the cycle of learn → think → solve to attain
continuous improvement in the performance of individual assets or overall plants
(Sandengen et al., 2016).

IIOT-enabled remote accessibility is critical for any decision making, and the decision-making
cycle can be reduced from days to hours and from hours to real time. Connectivity will bring
mutual learning, and the implementation of best practice can easily be replicated among various
plants, departments, shifts or machines. Most manufacturing facilities today use preventive
maintenance procedures, smart devices with computational power can predict the equipment’s
condition and alert users to the actual maintenance requirements, saving valuable resources and
enabling the support team to prioritize its schedule easily (Zhou et al., 2012). In preventive
maintenance most of the time spares are replaced even before they are required, generating an
unnecessary cost for the organization, and if this costly mistake is augmented by poor
workmanship, it can cost the company very dearly.

With the power of the IIOT, all those behavioural inefficiencies can be seen and eliminated;
for example, patterns of energy usage can be monitored and the energy cost can be calculated
per unit of product produced. All the available data can be used for comparison with peers,
and inefficient units can take corrective measures to reduce wastage (Parry et al., 2016).
Organizations may not be ready for automated decision making, but the computer-based
algorithm can definitely provide valuable insights for an improved approach. Authentic
information and data mining used to find regularities are definitely valuable for organizations
(Witten et al., 2016). In spite of humans’ ability to utilize previous learning to make
decisions, there are various flaws for individuals when utilizing cases. Sometimes individuals
aimlessly utilize case-based thinking depending on past encounters without verifying it
in the new circumstance, which is where the computer-based algorithm can help to improve
decision making.
2.6 Improvement in business decisions

As an expansion of the internet, the IIOT could be beneficial beyond imagination for the entire business process. The IIOT can play a key role in setting firms’ strategic business decisions, which are vital in deciding their fate, as a correct strategy makes firms relevant and competitive in the market. Data that have mostly been localized (IT–OT still work in silos) to date have the potential to participate in business decisions; the integration of business software with OT data will unleash the possibility of real-time analysis to aid any business decision. The IIOT will not only help in making correct decisions but has the potential to bring agility to decision making and implementation.

The key to improvement lies in visibility, improved communication and real-time decisions followed by quick execution. It should be remembered not only that the IIOT provides internal information but also that perpetual connectivity with customers brings valuable information regarding demand shifts, customer behaviour, users’ perceived value, competition and so on. In the survey all three key variables – visibility, communication and real-time execution – show a significant impact on the business decision process (Uckelmann et al., 2011).

Visibility for businesses can be defined as an efficient system to map the actual demand from the market and plan the production accordingly. It has been proven in the OEM segment, in which the visibility of the actual demand–supply and the sharing of relevant data with partners have improved the business operation dramatically. Better visibility addresses numerous normal business and working difficulties, for example, increasing worldwide competition and rising manufacturing costs by allowing shorter production cycles that react rapidly to client requests. Other quantifiable variables that can be improved by visibility are a reduction in working capital, the production cycle time and a reduction in scrap (Waller and Fawcett, 2013).

A key element for the fruitful usage of IIOT frameworks requires a corporate culture that stresses the benefit of shared objectives over individual interests and furthermore the estimation of trust between accomplices, workers, directors and companies. The success of IIOT implementation lies in cross-functional collaboration across any departmental limits; non-participation and non-inclusion of stakeholders can potentially hamper the outcome (Gubbi et al., 2013). Internal or external communication is the key to understanding the dynamics of business and aligning firms’ strategic decisions. Moreover, established communication is the key to agility to implement the requisite change. This becomes even more important for global companies in which virtual teams work towards the same goal. Thus, IIOT-enabled data establish a method of clear correspondence to overcome space and time limitations that may cause process loss (Sung and Chiang, 2012).

Manufacturing is a time- and resource-consuming activity. Undoubtedly resources are scarce, and, in the current dynamic circumstances, they are even more valuable, so for the optimum utilization of resources managers should have accurate data and guidelines. The requisite data in this case would be clear matrices of current vs optimal production parameters. Normally the designed capacity is not an ideal benchmark for production, so value engineering is performed to achieve the optimal manufacturing procedure (Palattella et al., 2013).

2.7 Security and interoperability

The execution of the IIOT depends on a design comprising a few layers: from the field instruments’ data acquisition layer at the base to the application layer at the top. Layered engineering is to be outlined in a way that can meet the demands of various pieces of equipment and existing communication protocols. One opportunity for manufacturers is the possibility of improvement because they use a legacy system, but the same legacy system constitutes a heterogeneous mix of various systems working in silos. No proven solution is available for existing system interoperability. Similarly, various layers of the IT system need to be protected individually. The concept of defence in depth (CISCO) is one viable solution to IT security concerns, which advocates security in each layer. Some of the data
are sensitive to the organization and can be part of its intellectual property, so these must be protected. Apart from the threat of theft, the data must be protected from all kinds of noise or attack to avoid any unwanted shutdowns or other losses.

Several companies can offer solutions to data threats to make systems more robust and trusted. One of the concepts is defence in depth, which focuses not only on data security in the software but also on data security at the source, which may be a computational device or PLC itself. Some companies have already started their journey towards the implementation of the IIOT, and the respondents to this survey also think that the security is mature enough to proceed with implementation.

The cutting-edge manufacturing frameworks will be demand driven, so agility and timeliness are the most important criteria; to achieve such flexibility in manufacturing, the existing legacy system needs to be connected. This is again a new paradigm that is shifting from a proprietary protocol to a more open protocol and cooperation (Jardim-Goncalves et al., 2016). The Ethernet is emerging as one of the open protocols to enable interoperability between various systems, but today even the Ethernet has a few variants. This is one of the reasons why the IIOT demands more collaboration between various stakeholders and solution providers. Firms need to embark on a five-stage journey of interoperability from physical interoperability (equipment) to organizational interoperability (Lin et al., 2015).

3. Research methodology

Through the written audit and the extent of future research indicated in the survey articles, seven key natural factors were identified for investigation. These variables are: digitalization, perpetual connectivity, the use of advanced analytics, unplanned downtime, business decisions, asset and plant performance, and factors to boost IIOT implementation. The data used in this research are collected 203 respondents predominantly from emerging economies, specifically India and SEA. Most of the participants are working professionals and belong to vendors, OEMs, and manufacturing, EPC/consultancy or system integrators.

This research indicates that the reason for the adoption of the IIOT will be driven by opportunities to reduce the production cost or increase the revenue. A total of 89 per cent of the respondents agree that more informed decision making will eliminate the existing inefficiencies; 90 per cent of the respondents feel that a faster time to market is important in creating a new stream of revenue by launching new products and services.

3.1 Data analysis

An online survey is used to collect the data, and the structural equation modelling (SEM) tool is used for data analysis. SEM is a popular statistical technique because of its ability to model selected independent variables and take into account all possible forms of measurement error to test an entire theory.

3.2 Data reliability and validity

The reliability of the model can be evaluated utilizing the figures of Cronbach’s $\alpha$. This parameter acts as a lower-bound estimate of the reliability of the collected data. A Cronbach’s $\alpha$ value of more than 0.7 is viewed as reliable (Hair et al., 2014) (Table I).

Campbell and Fiske (1959) characterized “convergent validity” as the degree to which two measures that are thought to be connected are really related and prescribed an AVE value $> 0.5$ as necessary for each construct.

3.3 Discriminant validity

Campbell and Fiske (1959) presented discriminant validity. The level of separation between latent constructs is demonstrated utilizing ADANCO 2.0.1. It tests whether constructs are
irrelevant or in truth random. The square root of the AVE (normal difference) ought to exceed the estimation of different factors (Herz, 1996). The qualities demonstrate discriminant validity testing as shown in Table II.

3.4 Structural equation modelling
Path modelling is a special case of SEM, in which each indicator is used for the respective variable in the causal model. The correlation is the equation of the sum of the contribution of all the paths through which the variables are connected. The strength of each path is calculated as a product of the path coefficients along the path. The $R^2$ value of 0.667 supports the model (Table III).

4. Research findings
Ten hypotheses have been identified; based on their level of significance (using the $t$-value table for significance), all ten hypotheses are accepted, and their impacts are in the range from moderate to very high. The analyses of the individual hypotheses are presented below (Figure 1):

$H1$. Digitalization has a significant influence on the advanced analytics related to IIOT adoption in manufacturing.

$H2$. Digitalization has a significant effect on the expected outcome via the IIOT in manufacturing.

$H3$. Perpetual connectivity has a significant effect on the expected outcome via IIOT adoption.

$H4$. Advanced analytics has a significant effect on the expected outcome via the IIOT in manufacturing.

$H5$. Downtime has a significant influence on the business decisions enabled by IIOT technology.

$H6$. Unplanned downtime has a significant effect on the adoption of the IIOT in manufacturing.

$H7$. Improved plant and asset performance have a significant effect on the adoption of the IIOT in manufacturing.

$H8$. An improvement in business decisions has a significant effect on the adoption of the IIOT in manufacturing.

$H9$. The concern over security and interoperability has a significant influence on the business decisions related to IIOT adoption in manufacturing.

$H10$. The security and interoperability concern has a significant effect on the expected outcome from the IIOT in manufacturing.

<table>
<thead>
<tr>
<th>Construct</th>
<th>Dijkstra–Henseler’s $\rho_A$</th>
<th>Jöreskog’s $\rho_c$</th>
<th>Cronbach’s $\alpha$</th>
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<td>Digitalization</td>
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<td>0.7951</td>
<td>0.7366</td>
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<td>Connectivity</td>
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<td>Analytics</td>
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<td>0.8031</td>
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<tr>
<td>Asset performance</td>
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<td>0.8087</td>
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</tr>
<tr>
<td>Outcomes</td>
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<td>0.8834</td>
<td>0.8240</td>
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Table I. Values of the overall reliability of the constructs.
Table II: Discriminant validity

<table>
<thead>
<tr>
<th>Construct</th>
<th>Digitalization</th>
<th>Connectivity</th>
<th>Analytics</th>
<th>Downtime</th>
<th>Asset performance</th>
<th>Business decision</th>
<th>Security and interoperability</th>
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<td></td>
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<td>0.3648</td>
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<td></td>
<td></td>
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<tr>
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<td>0.4937</td>
<td>0.4316</td>
<td>0.3706</td>
<td>0.5890</td>
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<tr>
<td>Business decision</td>
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<td>0.4183</td>
<td>0.3888</td>
<td>0.4386</td>
<td>0.7079</td>
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<td>0.1737</td>
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<td>0.5009</td>
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<td>0.2331</td>
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*Notes:* Squared correlations; AVE in the diagonal.
<table>
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<tr>
<th>Effect</th>
<th>Original coefficient</th>
<th>Mean value</th>
<th>SE</th>
<th>$t$-value</th>
<th>$p$-value (2-sided)</th>
<th>$p$-value (1-sided)</th>
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<th>97.5%</th>
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<td>0.6079</td>
<td>0.0665</td>
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<td>0.0000</td>
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</tr>
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</table>
Digitalization has a strong influence on analytics ($t$-value $= 9.09$; CI $> 99\%$); thus, this hypothesis is accepted.

The second hypothesis examines the impact of digitalization on the desired outcome from the implementation of the IIOT. In this survey, the impact of digitalization on the IIOT is moderate ($t$-value $= 1.95$; CI $> 90\%$). With the advent of smart devices with embedded computational power, the digitalization of data is no challenge for firms but just a stepping stone in the IIOT adoption process.

The third hypothesis examines the impact of connectivity on the desired outcome via IIOT adoption. In this survey, the impact of connectivity is in the moderately acceptable range, as the $t$-value and CI are 2.21 and 95%, respectively.

The fourth hypothesis examines the impact of advanced analytics on the business process as a key building block in IIOT technology. Advanced analytics has a significantly strong influence on the desired outcome via the adoption of the IIOT, supported by the $t$-value and CI analysis with values of 2.77 and 99%, respectively. The fifth hypothesis examines the level of influence of the independent variable downtime on another independent variable, business decisions. Downtime has a strong influence on business decisions ($t$-value $= 6.93$; CI $> 99\%$); thus, this hypothesis is accepted.

The sixth hypothesis examines the variable unplanned downtime as a key improvement area via IIOT adoption. In this survey, the impact of uptime on the overall expectation from IIOT has a moderate impact, suggested by the $t$-value and CI of 2.45 and 95%, respectively. The seventh hypothesis examines the variable asset and plant performance as a key parameter to achieve via IIOT adoption and its impact on a bigger canvas. In this survey, the impact of asset and plant performance on the overall expectation from the IIOT has a moderate impact, as suggested by the $t$-value and CI of 2.57 and 95%, respectively. The eighth hypothesis examines the achievement of more informed business decisions as one of the outcomes from the
implementation of the IIOT and its alignment with other broader expectations. In this survey, the impact of business decisions on the key expectations from IIOT adoption is strong ($t$-value = 3.03; CI > 99%). In previous research the impact of the IIOT on business decisions is qualified in the three dimensions: operational, managerial and strategic (Shang and Seddon, 2002). The ninth hypothesis examines variables like security concern and lack of interoperability that cause bottlenecks in the adoption of the IIOT. In this survey, the impact of security and interoperability on the journey towards the IIOT is high, suggested by the $t$-value and CI of 3.15 and 99%, respectively. Several studies have been conducted on security challenges (Weber, 2010) and solutions to the challenges by different vendors. In this survey, the respondents think that the level of security is enough to proceed towards adoption. Finally, the tenth hypothesis examines the relationship between the obstacles and the expected outcome from the implementation of the IIOT. The $t$-value and CI between the two variables are 2.3 and 95%, respectively, which suggest a moderate impact of the variables. The existing research papers on interoperability have emphasized the requirement for a multi-communication translator service, and a security framework for the IIOT (Babar et al., 2011) has been suggested as possible prevention against any threats.

5. Implications for the manufacturing industry
The analysis of the results from this study indicates that various desirable results, such as digitalization, the advantages of advanced analytics, improved business decisions and asset performance, perpetual connectivity and other competitive advantages are the drivers of technology adoption. However, existing legacy systems, security concerns and the high investment cost are reasons for the comparatively slower adoption than anticipated by experts.

It is in the interest of service providers to collaborate and provide a universal solution to retain legacy systems to minimize the investment and reduce the security threat, which could boost IIOT adoption while ensuring that manufacturers are able to leverage this new technology efficiently.

6. Contributions of this research
One of the key expectations from IIOT technology is that it will empower people by supplying on-time and relevant information to identify the cause and effect relationship (Uckelmann et al., 2011). This will help in improved decision making regarding various aspects of manufacturing, like scheduling and resource optimization. Seamless communication between people, processes and machines enables better and faster decision making (Lee et al., 2014). In manufacturing plants, the resource management practice is less efficient due to either a lack of awareness or long-cultivated behaviours. However, with the advent of technology like the IIOT, such inefficiencies can be eliminated by real-time monitoring, and this brings significant savings to firms and can help in creating a balance between inventories and demand (Shrouf and Miragliotta, 2015).

IIOT technology enables perpetual connectivity with customers, so key factors for new product or design, like value proposition and a change in the demand/expectation, can be collected in no time, thus reducing the cycle time for new product launches (Mahmood and Hushairi, 2016). The reliability of machines or systems can be increased by improving the following key factors using the IIOT: breakdowns, waiting time, reduced speed operation, rework percentage, scrap percentage and so on (Rodseth et al., 2016).

7. Limitations and scope of further research
The learning is mainly built on the available secondary data to gain an understanding of the driving factors of IIOT technology adoption in manufacturing. The collected data are predominately from India and SEA (close to 75 per cent), while contributions from other
regions are comparatively less, so the findings cannot be generalized to the global context. Moreover, 46 per cent of the respondents are from solution providers (IT, automation vendors or EPC), while only 20 per cent of the respondents are actually from manufacturing. The construct is focused on the short- to mid-term gains of IIOT adoption.

Future research should consider opportunities not only in the short term but in the longer term too. Global insights will be able to provide a more generalized understanding of IIOT adoption in manufacturing. This study focuses only on the expectation from the technology, although the social, behavioural, economic and managerial aspects of it need to be studied to evaluate the actual impact of this technology.

8. Conclusions
The IOT has an anticipated economic impact of as much as $11.1 trillion per year in 2025. B2B uses can contribute 70 per cent of the estimated value. In the new era of smart manufacturing, the flow of information plays a pivotal role, since manufacturing plants are made up of several heterogeneous systems accumulated over time, so no single vendor can provide all the necessary services. Therefore, exclusive information and interfaces are no longer a reasonable choice to serve the life cycle and supply systems of complex and long-lived products.

IIOT-based engineering information services are still in their early stage. Legacy systems in manufacturing with proprietary data and protocols are seen as one of the major existing challenges. With the advent of open standards for data and interfaces, a new era of collaboration is emerging. This is particularly essential for small- and medium-sized organizations, because the concept of openness will reduce the acquisition cost and soon all firms will participate in this transformation.

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Further reading


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Building the hydrogen economy through niche experimentation and digitalisation

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Department of Engineering and Technology Management,
University of Pretoria – Groenkloof Campus, Pretoria, South Africa, and
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Rebel Group, Johannesburg, South Africa

Abstract
Purpose – Hydrogen fuel cells could play an important role in meeting the challenges of the Two Degrees Scenario. The purpose of this paper is to review the development of this technology in South Africa with the aim of understanding how the country can transform its existing socio-technical systems and act to support a hydrogen-based technological innovation system (TIS).

Design/methodology/approach – A mixed methods approach has been followed in this study. Secondary data analysis was used initially to build a profile of South Africa’s present energy system, followed by a stakeholder survey of the emerging hydrogen economy. Respondents were selected based on a convenience/snowball sampling approach and were interviewed using a semi-structured questionnaire, covering opportunities for South Africa in the global hydrogen economy; sources of competitive advantage; the present phase of development; the maturity of each function and the main weaknesses within the TIS; and finally the appropriate policy instrument to remedy the weakness and/or maximise opportunities for local companies.

Findings – The research has shown that the hydrogen economy is still at a pre-competitive level and requires ongoing government support to ensure an energy transition is realised. In particular, it is important that niche experimentation, a proven strategy in respect of successful sustainability transitions, is further pursued. Importantly, the net cost of hydrogen-based transportation, which is still several times larger than the cost of transport based on the internal combustion engine (ICE), must be reduced, especially in the key applications of public transport and underground vehicles. Furthermore, the development of digital technologies to manage supply fluctuations in energy grids must be accelerated.

Originality/value – The South Africa economy will be severely affected by the replacement of the ICES with battery electric vehicles due to the country’s reliance on ICES for platinum demand. Fuel cells represent a new market for platinum but the hydrogen TIS is still at a vulnerable point in its development; without policy support, it will not contribute to a successful socio-technical transformation, nor provide an alternative outlet for platinum.

Keywords Government policy, Digitization, Green manufacturing

Paper type Research paper

1. Introduction
Global energy systems continue to rely on the non-renewable resources of coal, oil and natural gas, as shown in Figure 1. Collectively these three feedstocks account for 87 per cent of the global carbon dioxide emissions, with the latter now exceeding 35 trillion metric tonnes per year (Decourt et al., 2014). Energy usage is spread over all economic sectors but the major emissions of carbon dioxide arise from electricity production (42 per cent), transport (23 per cent) and industry (19 per cent) (IEA Statistics, 2015).

It is widely acknowledged that unprecedented levels of carbon dioxide emissions are causing climate change. The existing concern and impending crisis for global ecosystems has led to the adoption of the Paris Agreement which requires all ratifying countries to contain and reduce their greenhouse gas emissions with the goal of peaking such emissions “as soon as possible” and continuing the reductions thereafter, thereby keeping global temperatures from rising no more than 2°C by 2100, referred to as the Two Degrees Scenario (2DS), with the ideal target being a rise of not more than 1.5°C (Robbins, 2016).
Meeting the 2DS goal will be impossible without the decarbonisation of the transport (liquid fuels) and electricity sectors; accordingly European Union targets on emissions for 2050 will require a 95 per cent decarbonisation of road transport (McKinsey & Company, 2010). Hydrogen fuel cells can play a vital role in the attainment of these targets, supporting the mitigation efforts related to minimising climate change and raising energy security (International Energy Agency, 2015). Furthermore hydrogen fuel cells, together with technologies for the transformation of power-to-gas and power-to-liquid fuels, can be used alongside wind and solar systems as a means of addressing the intermittency of these two technologies, storing surplus power and facilitating the decarbonisation of the chemical industry (Plessmann et al., 2014).

Apart from the potential role of hydrogen fuel cells in supporting the transition of energy systems to renewable resources, the technology can also be used to reduce the levels of dangerous pollutants in the urban environment which arise from the use of diesel in public transport. Following studies done in the 1980s on particulate emissions from diesel exhausts (McClellan, 1987), there has been growing pressure to phase out the use of diesel in buses and trains. For instance, in 2016 the Mayor of London, at the unveiling of the city’s first double-decker hydrogen bus, announced that all buses would become zero emission by 2020 (Greater London Authority, 2016). Other 11 major cities, including New York, Los Angeles, San Francisco, Amsterdam, Copenhagen and Cape Town, have similarly agreed to phase out their procurement of pure diesel buses by the end of 2020.

Although the market is actively looking for technological solutions to the environmental challenges, hydrogen fuel cells are still at an early stage of development and not yet economic in either of the abovementioned applications (intermittency and public transport). The difference between the technology’s present level of maturity and the required price points is substantial and significant support will be required across a range of functions in order to ensure that hydrogen can play a role in global energy systems. This paper reviews the hydrogen economy in South Africa in order to understand how the country can act to support a new hydrogen-based technological innovation system (TIS) that will be essential to meet the goals of 2DS.

In the first section, fuel cell technology is briefly described and proportioned, followed by description of the South African hydrogen economy and an introduction to the theory of TIS, as developed by Hekkert et al. (2011). This theory, together with a comparison of the techno-economic data for key applications of the existing technologies, is then applied to an analysis of the hydrogen economy leading to an identification of the main weaknesses within the South African system. Finally, the paper concludes with a set of recommendations on how niche experimentation could be used to facilitate the entry of hydrogen fuel cells into the transport and energy sectors.
2. Background material

2.1 Overview of hydrogen fuel cell technology and costs

The core technology of a hydrogen fuel cell is the use of a catalyst (often platinum) to convert gaseous hydrogen into electricity. The hydrogen, normally stored under pressure at 70 MPa, is delivered to the anode of the cell where it releases electrons in the presence of the catalyst and migrates across the electrolyte as protons. At the cathode, these protons combine with oxygen anions, arising from the reduction of oxygen in air, also in the presence of a catalyst, to form water (see Figure 2).

There are many different types of fuel cells including the Proton Exchange Membrane Fuel Cell (PEMFC), the Direct Methanol Fuel Cell, the Phosphoric Acid Fuel Cell (PAFC), the Alkaline Fuel Cell (AFC) and the Solid Oxide Fuel Cell (SOFC) (Edwards et al., 2008). The cells differ according to the type of electrolyte and the material of construction at the anode/cathode, as shown in Table I. The most dominant type for the smaller mobile (transport) applications is PEMFC, whereas PAFC is preferred for larger, stationary systems. Although SOFC systems were more popular relative to PEMFC in 2013/14 due to Japan’s large-scale programme for the use of SOFC in combined heat and power applications, this segment of the market has diminished significantly and PEMFC now has a majority market share at close to 80 per cent of global shipments of fuel cells.

<table>
<thead>
<tr>
<th>Fuel cell type</th>
<th>Typical capacity (kW)</th>
<th>Efficiency (%)</th>
<th>Investment cost ($/kW)</th>
<th>Lifetime (h)</th>
<th>Maturity</th>
</tr>
</thead>
<tbody>
<tr>
<td>PAFC</td>
<td>&lt; 11,000</td>
<td>30–40</td>
<td>4,000–5,000</td>
<td>30,000–60,000</td>
<td>Mature</td>
</tr>
<tr>
<td>PEMFC (transport)</td>
<td>80–100</td>
<td>45–50</td>
<td>500–750</td>
<td>&lt; 5,000</td>
<td>Early market</td>
</tr>
<tr>
<td>PEMFC (stationary)</td>
<td>200–2,000</td>
<td>50–55</td>
<td>3,000–4,000</td>
<td>&lt; 60,000</td>
<td>Early market</td>
</tr>
<tr>
<td>SOFC</td>
<td>&lt; 200</td>
<td>50–70</td>
<td>2,000–4,000</td>
<td>&lt; 90,000</td>
<td>Demonstration</td>
</tr>
<tr>
<td>AFC</td>
<td>&lt; 250</td>
<td>50</td>
<td>200–700</td>
<td>5,000–8,000</td>
<td>Demonstration</td>
</tr>
</tbody>
</table>

Capital and operating costs for fuel cells have declined over the last two decades, although the technology is still expensive relative to fossil fuels. The costs of electrical energy from various sources are often compared using the levelised cost of energy (LCOE), values for which are published by several agencies and companies including the US Department of Energy and Lazard. The latter’s reports are available on an annual basis, cover a wide range of technologies including solar photovoltaic (PV), solar thermal, fuel cells, geothermal, wind, biomass, diesel, gas, nuclear and coal (Lazard, 2016) and are mostly reported in terms of ranges given that the LCOE values are context specific, and depend on various assumptions. The latest LCOE values estimate PV costs at $49–$62/MWh and fuel cell costs at $106–$167/MWh (Lazard, 2016).

Within the various fuel cell technologies, PEMFC has become a leader within the transport sector, resulting in a growing demand for the technology, and the positive projections for fuel cells in general based on the demise of the internal combustion engine together with strong growth of either battery or fuel cell electric vehicles (Sassams and Leaton, 2017).

However, technology costs are critical for the future of the fuel cell electric vehicle. Although electrolysis (the splitting of water to hydrogen and oxygen) and the subsequent conversion of hydrogen to electrical power are well-proven technologies, the costs for each step are presently uneconomic in most applications even with a generous carbon tax. For instance, it is estimated that a tax of at least $82 per tonne CO₂ will be required for hydrogen fuel cells to be competitive against existing liquid fuels (see Table II). The carbon tax value has been calculated based on estimates for the efficiencies and specific carbon dioxide emissions of gasoline and hydrogen, as shown in the table.

### 2.2 Overview of hydrogen storage, compression and distribution

Hydrogen has a high energy content per unit weight but a low per unit volume, with the result that hydrogen storage in sufficient quantities to support its use as a chemical fuel is costly. Indeed, it has been noted that the safe and cost-effective storage of hydrogen is a major barrier to the widespread adoption of hydrogen as an energy carrier and the subsequent development of a hydrogen economy (Broom, 2011).

Typically, hydrogen is stored as a compressed gas under high pressure, although many other systems have been investigated including liquid hydrogen (cryogenic), microporous media (such as nanotubes), hydrides, metal organic frameworks and low pressure tanks (Barthelemy et al., 2017; Durbin and Malardier-Jugroot, 2013). However, this research has not yet yielded the desired outcomes in terms of cost and safety, with the estimated prices of on-board systems being about $12–$16/kg (Niaz et al., 2015), which is about an order of magnitude higher than the equivalent liquid fuel systems (Amos, 1998).

The most attractive approach to hydrogen distribution remains the use of a gas pipeline serving a network of refuelling stations. There are already 274 hydrogen refuelling stations, but Denmark is the only country which can offer a territorial base coverage; it is also the country with the highest density of hydrogen stations per inhabitant (FuelCellsWorks, 2017).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>Internal combustion engine</th>
<th>Fuel cell electric vehicle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy efficiency (fuel to mechanical)</td>
<td>%</td>
<td>20</td>
<td>47</td>
</tr>
<tr>
<td>Carbon emission</td>
<td>kg CO₂/MWh</td>
<td>2,728 (includes refinery)</td>
<td>140</td>
</tr>
<tr>
<td>Total cost of ownership</td>
<td>$/MWh delivered</td>
<td>134</td>
<td>346</td>
</tr>
<tr>
<td>Carbon tax required for equal cost</td>
<td>$/MT CO₂</td>
<td></td>
<td>82</td>
</tr>
</tbody>
</table>

#### Table II.
Efficiencies and emissions for fuel cell electric vehicles vs internal combustion engines
2.3 The South African hydrogen economy

The hydrogen economy in South Africa is a small group consisting of the platinum producers (Anglo Platinum, Impala Platinum, Lonmin and Sibanye), two government departments (Trade and Industry, and Science and Technology), a public research institution and a number of universities. The latter are mostly collected into an initiative known as the Hydrogen South Africa (HySA) Programme, which is a research and development (R&D) programme funded and managed by the Department of Science and Technology. Its goal is to develop technology for the local manufacture of hydrogen fuel cells and to create demand for the use of platinum group metals. Under the programme, three Centres of Competence have been established covering different parts of the hydrogen value chain. HySA Catalysis, based at the University of Cape Town, focusses on the development of innovative components for PEMFC stacks, including catalysts, electrodes and complete membrane electrode assemblies. HySA Infrastructure, located at North West University, develops innovative applications and solutions for hydrogen production, storage and distribution. It offers novel technology for electrochemical hydrogen compression, hydrogen storage, electrolysis linked to photovoltaic panels and methanation. Finally, HySA Systems, based at the University of the Western Cape, covers high temperature PEMFC for combined heat and power applications, and the development of complete systems including fuel cell electric vehicles and complete PEMFC stacks.

On overall representation of the hydrogen value chain in South Africa is shown in Figure 3. It is noted that with the exception of hydrogen transport and distribution (T&D), all components of the value chain are covered to some extent by HySA, and that there are several commercial companies active in hydrogen generation, hydrogen storage and hydrogen T&D.

2.4 Theory of technological innovation systems

A number of previous studies have analysed the rather complex problem of how new technologies in support of sustainability transitions can become more dominant within their respective market applications. Two approaches have been selected for this study, namely, the framework of TISs (Bergek et al., 2008; Hekkert et al., 2007, 2011; Markard and Truffer, 2008b) and the theoretical understanding of sustainability transitions (Markard et al., 2012), in particular the concept of niche management (Schot and Geels, 2008).

The frameworks share a set of common principles as follows:

- Sectors like energy and transport can be conceptualised as socio-technical systems. Such systems consist of actors, networks and institutions (rules and standards of the system), as well as material artefacts and knowledge. The systems concept emphasises that the components are tightly interrelated and dependent on each other.

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Figure 3. Components of the hydrogen value chain
A socio-technical transition is a set of processes that lead to a fundamental shift in socio-technical systems. Sustainability transitions are long-term, multi-dimensional, and fundamental transformation processes through which established socio-technical systems shift to more sustainable modes of production and consumption.

In terms of TIS theory, there are seven broad key areas that need to be addressed in the maturation of emerging innovation systems (Hekkert et al., 2011), namely, entrepreneurial experimentation and production (F1); knowledge development (F2); knowledge exchange and diffusion (F3); guidance of the search (F4); market formation (F5); resource mobilisation (F6); and legitimation or counteracting resistance to change (F7) (Hillman et al., 2011). F1 refers to the level of entrepreneurial activity; F2 to knowledge creation through R&D; F3 to technology transfer and diffusion; and F4 to the expectations of key actors and particularly government which will positively affect the visibility and clarity of specific needs among technology users. An example of the latter in the field of renewable energy is the long-term decarbonisation goal set by governments for their respective energy sectors. F7 refers to the creation of legitimacy for the new technology including active lobbying and advocacy by industry groups to promote the adoption of the new technology.

The role of government changes according to industry maturity, the phase of technology development and the type of technology (Wilson, 2012). For instance, in the formative phase government is required to pioneer changes in the political and regulatory context which will legitimate the industry including the removal of barriers to market acceptance. In the up-scaling phase, government support for market development through the appropriate demand-side incentives is important, whereas in the growth phase robust competition policy is more critical.

2.5 Niche experimentation

An additional and important role for government in the formative phase is its support for niche experiments. In the development of technologies which have significant potential to allow the preservation of public goods, as is the case of the hydrogen economy, governments are compelled to act in a way which mitigates the risk of the development. In this regard, there are a number of possible approaches of which experimentation is now the most widely used (Schot and Geels, 2008; Sengers et al., 2016).

The practice of “experimenting” or “experimentation” is central to the transformation of existing socio-technical regimes to more sustainable systems. The notion of socio-technical experimentation is that society itself can be considered as a laboratory within which a “variety of actors commit to an experimental process which results in the trial and possible introduction of alternative technologies, where the latter seek to purposively re-shape social and material realities” (Sengers et al., 2016).

A number of approaches have been followed in such experiments, with perhaps the most important being niche experimentation. Existing socio-technical regimes, characterised by entrenched networks of actors and institutions, form the core of present systems and are often a barrier to structural change towards sustainability. In niche experimentation, new technological niches, enabled initially by radical innovation, are created and protected from the competitive pressures of the existing socio-technical regimes. The environments within these niches allow the nurturing and co-evolution of technology, user practices and regulatory structures, and may develop into market segments. Within these spaces, co-evolution of technology, user practices and regulatory structured can take place in an experimental manner.

There are three processes which are considered to be critical for the initial protection of niche experimentation, namely, shielding (a process which holds off selection pressure);
nurturing (a process which supports the development of the path breaking innovation); and empowering (a process which makes niche innovation competitive against the existing regimes). Other important aspects are social learning (a process of knowledge diffusion, sharing and linking with associated or adjacent domains), scaling up (a balancing between providing support to niche players and engaging with existing actors who have the power and resources to bring about socio-technical change). In an area of experimentation broadly referred to as transition experiments, the key processes as labelled as broadening, deepening and scaling up (Van den Bosch and Rotmans, 2008).

In summary, this study draws on two theoretical frameworks which are complementary and mutually enhancing to the development of its conclusions. In the first case, it has employed the TIS structure to both profile and critique the South African hydrogen economy, following the approach of a previous study on stationary fuel cells (Markard and Truffer, 2008a); second, it uses the theory of sustainability transitions, and particularly the concept of niche experimentation to develop recommendations for government policy and programmes. The latter is highly relevant to the case of a formative TIS, which is the present situation for the hydrogen economy. Further details on how niche experimentation can be applied within the South African context have been given in the discussion section of this paper.

3. Methodology
A mixed methods approach has been followed in this study. In the first phase, secondary data were analysed to build a profile of South Africa’s present energy system. This phase was followed by a stakeholder survey of the emerging hydrogen economy. Respondents were selected based on a convenience/snowball sampling approach and were then interviewed using a semi-structured questionnaire, the contents of which had been previously outlined and covered a number of aspects including opportunities for South Africa in the global hydrogen economy; sources of competitive advantage; the present phase of development (pre-development, development, take-off, acceleration and stabilisation); the maturity of each function (F1–F7) of the TIS; the important gaps or weaknesses of the TIS; and finally, the appropriate policy instrument to remedy the weakness and/or maximise opportunities for local companies. The interviewees consisted of a mixture of researchers, government officials and employees of private companies.

The work was designed as an exploratory study with no attempt to be comprehensive in its approach. This method, which is broadly described as an exploratory, qualitative design using a limited number of industry experts as informants, has been followed in previously published TIS studies (Chen, 2018; Edsand, 2017; Jacobsson and Karlarp, 2013; Karlarp et al., 2017). It is acknowledged that this design limits the external validity of the results and particularly the extent to which the responses can be claimed as being representative of the sector, an outcome which could be claimed in the case of a quantitative, comprehensive approach. Nevertheless, the fuel cell community in South Africa, and indeed many emerging TISs in other countries, are small communities of researchers, lobbyists, government officials and market developers who share similar views about the prospects for fuel cell technologies and its market challenges. The results of the survey are therefore considered to be sufficient in being able to develop the theoretical insights of the case study, as reported in this paper.

4. Results
4.1 Analysis of the South African energy system
Present configuration. The Sankey diagram for the South African energy supply/demand is shown in Figure 4. There are several unique features about system which are
important to the overall discussion on sustainability transitions and niche experimentation, as follows:

- The system is relatively small, forming only 1 per cent of the global energy system.
- In terms of primary resources, the system is heavily dependent on coal, where the latter is 66 per cent of the total energy demand in South Africa vs 31 per cent for all countries (see Figure 1); such dependence is the consequence of both abundant local coal reserves and very limited local production of oil and gas, with more than 90 per cent of all oil, oil products and natural gas being imported.
- It has a large coal-to-liquid fuel facility which supplies about 30 per cent of the country’s overall needs for liquid fuel; the existence of this facility together with the associated expertise in gas-to-liquids technology (Meleloe and Walwyn, 2016) may assist the overall transition to a 100 per cent renewable energy system, as explained in the later sections of this paper.
- Biomass is still a relatively large component of local energy resources, mainly as a result of this material being a relatively inexpensive means of residential space heating and still widely available. However, biomass is a declining resource due to overharvesting and the pressures of urbanisation accompanied by the loss of suitable agricultural land (Niedertscheider et al., 2012). Biomass as a heating fuel is also highly inefficient, leading to significant carbon emissions, environmental degradation and increased disease burden (Fullerton et al., 2008; Norman et al., 2007).
- Solar and wind energy have historically been an insignificant proportion of total energy supply ( < 0.2 per cent), although this has changed since the introduction of the Renewable Energy Independent Power Producers Procurement Programme (Walwyn and Brent, 2015). Renewable resources now supply 10 per cent of the country’s electrical energy requirements (Obert and Pöller, 2017).

Revised configuration based on hydrogen fuel cells. South Africa has abundant resources of wind and solar, and other studies have already shown that given the diverse climatic conditions, a national grid which is almost completely dependent on renewable resources will be possible (Bofinger and Bischof-Niemz, 2016). In other words, very high levels of renewable energy penetration within the national grid could be accommodated without compromising energy security.
However, the cyclical nature of energy generation from wind and solar will require at least one and preferably several forms of cost-effective energy storage. The need for storage will provide the ideal opportunity for hydrogen, which could serve as an energy battery and distributor, depending on the cost and availability of the hydrogen infrastructure. In the first instance, excess power from wind and solar, which will become available as the installed capacity of photovoltaic cells and wind turbines increases, can be used to produce hydrogen via (fuel cell) electrolysis. This hydrogen can then be stored and used in fuel cells for energy generation as may be required, leading to the type of system architecture as shown in Figure 5.

The new structure proposes that infrastructure for wind and solar should be at least ten times the present levels and possibly higher, depending on the actual electrical efficiencies which will be obtained as the degree of dependency on renewable resources rises. This proposition clearly has an associated cost and although low carbon emissions are desirable from a climate perspective, the cost of the transition will need to be carefully managed in order to ensure that it does not reduce the competitiveness of the South African economy.

4.2 Analysis of the hydrogen technological innovation system in South Africa

The South African hydrogen TIS was analysed using the standard structure as presented earlier, supported by hydrogen roadmaps developed by the Industrial Development Corporation (2016), Impala Platinum (Smith, 2016), the Department of Science and Technology (2008) and Department of Trade and Industry (2016). The results of the analysis are summarised in Table II.

It is clear from the table that the overall system is still in a formative phase or pre-development phase, characterised by a strong focus on knowledge creation (R&D), supported by the resource mobilisation, guidance of the search and knowledge exchange. The system has the positive properties of high-intensity applied research, the presence of several small-scale companies and some installed hydrogen fuel cell capacity. In terms of the latter, a number of prototypes and demonstration units, including electrolysers for the conversion of solar energy to hydrogen, electrochemical hydrogen compressor, PEMFC components, stacks, fuel cell forklifts and stationary power supplies, have been built and are already operational. Other prototypes, such as a fuel cell load haul dumper, are in the planning or initial construction phase. This approach of prototypes and demonstration units, referred to as strategic niche management, is critical to growing the credibility of a new technology within a well-established sector such as energy, as discussed previously.
Commercial revenues within the sector are low, most of the resources are derived from public funds distributed by the Department of Science and Technology, and much of the activity is taking place at university-based research centres. Although some fuel cells have been installed, these are primarily demonstration facilities which are intended to explore niche applications within existing markets. Entrepreneurial activity, which is critical to the take-off phase, is located mostly around or within the research centres of HySA and outside of these networks there is little evidence of small firms engaged in product or service development.

Given the overall orientation of the fuel cell sector, namely, as a key technology to support decarbonisation and the enhancement or at least preservation of public goods, it is also evident that there is significant international collaboration and knowledge exchange within the local sector. Apart from the presence of international researchers within the research centres, drawn from a broad cross-section of countries, the study also revealed several cases of bilateral agreements with joint programmes in key areas of technology development. Although national programmes funded by public money tend to procure and work locally, in order to maximise any benefits as may be derived for domestic firms and industries, there are projects in which HySA has been able to link with international collaborations.

Table III also provides a useful summary of the key weaknesses within the fuel cell TIS. Although there are talks with a key investor (Chemours Company), these discussions are at an early stage and have not led to inward investment or technology transfer, both of which will be essential to the long-term sustainability of the TIS. Equally important is the observation that market formation remains weak with government not yet acting to develop or support local markets, as has been the case in South Korea (automobiles) and Japan (combined heat and power). On the positive side, it is noted that the aspect of “guidance of the search” has received attention with the publication of several roadmaps and innovation strategies, and the inclusion of fuel cells in departmental strategies. Further supportive steps in this regard, and particularly the implementation of strategy, will be important.

The issue of market formation links directly to the second focus of this study, namely, the concept of niche experimentation and how it can be deployed in order to stimulate the hydrogen TIS. There are several potential market applications for fuel cell technology which could be developed as market niches, including underground mining vehicles and inner city public transport, where in both cases air quality considerations limit the use of internal combustion engines, single-site electricity generation at chlor-alkali facilities, rural electrification and materials handling equipment, the latter including fork lift trucks (Industrial Development Corporation, 2016). Further discussion on these experiments and how they can be selected is presented in the next section.

5. Discussion
Applications of fuel cells are not competitive within the present socio-technical regimes and further progress in terms of the transformation of the energy generation/transport sectors, as required for 2DS, will not be possible without ongoing public funding and government support. However, South Africa (and other developing countries) cannot afford to establish experimental niches across the entire hydrogen value chain; the country will need to be highly selective and focussed in the allocation of its resources towards the enablement of the hydrogen economy.

In this regard, two important applications and one key intervention are now presented which could provide significant future opportunities for the country in addition to achieving the necessary changes in the transport and electricity sectors. It is noted that the selection of the two applications has been made on the basis of recommendations developed by Kim and Lee (2015) in their study of science and technology policy within middle-income countries, and particularly the differences between South-east Asia and Latin America. Their work
has suggested that it is important to select areas which have high capacity for the
development of technological rather than scientific knowledge, and second that these areas
should comprise of products or services with short-cycle times (Lee, 2016). The latter is
especially important in the case of South Africa which has been struggling over a significant
period with low economic growth and the classic symptoms of the middle-income trap
(Seekings and Nattrass, 2015).

South Africa has already attempted to develop its own electric vehicle, unfortunately not
with any success (Swart, 2015), with the main issue being the collapse of government
funding and the absence of commercial partners/venture capital funding. It is important to

<table>
<thead>
<tr>
<th>No.</th>
<th>Function</th>
<th>Status</th>
<th>Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1</td>
<td>Entrepreneurial experimentation and production</td>
<td>Very limited entrepreneurial activity; commercialisation driven by university spin-offs and mining firms (platinum)</td>
<td>Increase efforts by public-funded commercialisation agencies to identify and support entrepreneurs within all components of the hydrogen value chain. Establish fuel cell clusters within local science parks.</td>
</tr>
<tr>
<td>F2</td>
<td>Knowledge development</td>
<td>R&amp;D support focussed on the three Centres of Competence; limited firm-level R&amp;D HySA has clear targets in respect of human resource and new product development</td>
<td>Increase public-funded product development in support of fuel cell components manufacture. Develop fuel cell electric vehicles as a means of reducing pollution in underground and urban spaces. Increase overall research effort including work presently being undertaken at universities and firms.</td>
</tr>
<tr>
<td>F3</td>
<td>Knowledge exchange and diffusion</td>
<td>Engaging with international companies; talks at early stage only with the company Chemours Company, a Du Pont spin-off, for the local production of fuel cell components</td>
<td>Secure inward investments from international fuel cell companies resulting in foreign direct investment and technology transfer.</td>
</tr>
<tr>
<td>F4</td>
<td>Guidance of the search</td>
<td>The National Hydrogen and Fuel Cell Technologies Research, Development and Innovation Strategy has been published by the Department of Science and Technology; similarly, the Department of Trade and Industry has included fuel cells in its policy documents</td>
<td>Drive new regulations based on COP21 commitments and safety requirements, including a carbon tax. Implement more demonstration projects and improve legislative environment for distributed energy generation. Include fuel cell power plants in the Integrated Resource Plan.</td>
</tr>
<tr>
<td>F5</td>
<td>Market formation</td>
<td>Very limited activity; government has not acted significantly to develop local markets (the Department of Trade and Industry is considering a public transport project)</td>
<td>Implement more demand-side measures in support of underground mining, public transport, liquid fuels, rural electrification and materials handling.</td>
</tr>
<tr>
<td>F6</td>
<td>Resource mobilisation</td>
<td>The main investor at this stage is the Department of Science and Technology Limited firm-level interest except for the platinum industry</td>
<td>Extend human resource development at the universities. Expand public funding for fuel cell R&amp;D/innovation/commercialisation. Unlock barriers to distributed energy generation and heighten public awareness of the benefits of the hydrogen economy.</td>
</tr>
<tr>
<td>F7</td>
<td>Legitimation or countering resistance to change</td>
<td>Energy sector remains controlled by a powerful pro-nuclear and pro-coal lobby Some industry roadmaps in place (Impala Platinum and the Industrial Development Corporation)</td>
<td>Introduce awareness raising programmes within primary and secondary education. Support a fuel cell industry association.</td>
</tr>
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</table>

Table III. Status of the functions for the hydrogen TIS.
learn from this experience and avoid its repetition with the hydrogen TIS. As a result, the two examples have been proposed on the basis of strong local markets/commercial interest (public transport) and short-cycle times (digital technologies for grid management). In general, software-based products or services, broadly referred to here are software technologies, are characterised by short-cycle times, rapid changes in markets and underlying technological competencies and open innovation, all of which are highly relevant to the present context in South Africa. The recommendation of grid-management software is moreover closely aligned with the capability being developed within the Square Kilometre Array (Dewdney et al., 2009) and suggests that the country could apply a similar set of skills to the more widespread problem or application of integrating multiple energy sources within a national electricity grid.

5.1 Niche experimentation in the transport sector

Demand-side intervention as a means of changing the liquid fuels sector has a strong historical precedent in South Africa. In the 1950s, the government established Sasol as a local producer of liquid fuels based on the gasification of coal to produce syngas (a mixture of carbon monoxide and hydrogen) followed by the Fischer Tropsch process. The company has since expanded and continues to supply 30 per cent of the country’s liquid fuel needs. However, the coal-to-fuel technology is highly polluting and the company’s facility at Secunda is considered to be the single largest emitter of greenhouse gases in the world.

An alternative fuel system for the transport sector could be developed based on hydrogen. Although some of the industry analysts predict a strong growth in both battery and fuel cell electric vehicles (Sassams and Leaton, 2017), it is unlikely that this will happen based on the present cost and performance levels of the technology. In the initial (formative) phase niche experimentation, as outlined in the previous sector, will be essential. It is proposed that the use of fuel cells in the metropolitan public transport sector will be ideal in this respect. Buses operate on a round trip basis, which reduces the need for a distribution hydrogen infrastructure, and the present use of diesel in the inner city is considered to raise levels of dangerous particulates, as already mentioned.

5.2 Digital technologies and grid management

Although renewable technologies offer a viable alternative to energy generation in terms of costs and emissions, these technologies suffer from the intermittent nature of the resource. As a result, the transition to renewable energy has already presented, and will increasingly present, challenges for the stable management of national energy grids.

An example of the intermittent nature of wind and solar is shown in Figure 6, which presents the electricity generated in France from these two sources over the period 9 February to 15 February 2017. In many instances over this period the time constants for the fluctuations were too high for a compensating response from the base generators, particularly coal, lignite and nuclear. Although small changes happening over relatively long periods can be accommodated, this is not possible with large changes (> 5 GW) in periods of less than 2–3 h. Such fluctuations have to be addressed by increasing the output of gas turbines, where additional capacity can be brought on stream relatively quickly, or by imports from neighbouring countries.

Digital technologies will be critical to the management of supply fluctuations induced from an increasing dependence on renewable resources. Although integration of relatively low levels of renewables has not yet presented major concerns, this will not be the case at higher levels of penetration (Chudy et al., 2015), and the issue has already received widespread attention, becoming a subject of global research (Morales et al., 2013). Apart from the sudden changes in supply factors, the integration of renewables into national grids has been described as a change from deterministic to stochastic production facilities,
reflecting the perspective that renewable resources change more extensively and the changes are more random (less predictable). Solutions to this problem include the introduction of capacitance or storage, the use of energy markets, better forecasting of demand and real-time control based on stochastic algorithms.

The use of digital technologies is clearly central to all of these approaches. In addition to real-time data about the performance of multiple sources of energy, there is a need to control demand and integrate energy pricing into consumer choices. More detailed study of these requirements within the South African energy should be the subject of future research.

5.3 Awareness raising and absorptive capacity
Legitimation, which refers broadly to addressing the social acceptability and desirability of a technology, and thereby counteracting any public resistance to transformation, is a highly necessary component of establishing a successful TIS, particularly where it could lead to a long-term sustainability transition (Andersson et al., 2018; Edsand, 2017). Possible interventions addressing this aspect include both formal and informal lobbying, further details of which are now presented.

Formal lobbying includes the establishment of industry associations which actively promote the sector among the various stakeholder groups including government departments, research organisations, financiers and private companies, and where necessary, lobby for the introduction of regulatory or infrastructure systems to support the adoption of a new technology. Some recommendations in this regard have already been made in Table III.

Informal lobbying covers campaigns to raise public awareness of the technology and its potential benefits. Such campaigns can be introduced at various levels and by multiple actors, including government and industry associations. Examples of possible interventions

![Graph showing intermittency of wind and solar electricity generation](https://www.gridwatch.templar.co.uk/france/)

**Source:** Gridwatch (France), available at www.gridwatch.templar.co.uk/france/

**Figure 6.** Intermittency of wind and solar electricity generation
include the development of learning materials for use in primary and secondary educational institutions, the raising of public awareness through targeted information campaigns and the establishment of public fora where research and environmental groups can engage in debate on the relevant issues, including the unforeseen or unintended consequences of a new technology.

There are several examples where public opposition has resulted in delays to, or even the termination of, technologies for sustainability transitions (Devine-Wright, 2007). It is therefore important that governments should understand the risks of a new technology and engage with the public in an open and participative manner on its possible adverse effects. In the case of hydrogen fuel cells, it is also important that government agencies and departments should implement educational and awareness campaigns at all levels, but particularly within secondary educational institutions, in order to allow the public to make an informed decision on the technology.

Such an initiative will also have the benefit of increasing the absorptive capacity for hydrogen fuel cell technology. The importance of the latter in successful technology transfer and diffusion is well understood (Bell and Pavitt, 1992; Cohen and Levinthal, 2000), and links to an earlier recommendation from Table III which stresses the importance of facilitating technology transfer from international fuel cell companies. Such transfer is unsuccessful when local absorptive capabilities are weak; a public awareness campaign at secondary school level will assist in generating enthusiasm for further human resource development in the fuel cell sector, and directly increasing the capability of the hydrogen TIS to adopt new technology.

6. Conclusions and recommendations

South Africa’s energy system is well-suited to a sustainability transition which is based on high levels of wind and solar energy generation combined with a well-developed hydrogen economy, where the latter includes facilities for hydrogen generation via electrolysis, gas-to-liquids conversion and fuel cell electric transport. Many of these technologies are already in place and can be adapted to a more broad-based energy system which meets the targets of 2DS.

However, a review of the hydrogen economy in South Africa using the TIS framework has shown that it is still in a formative or pre-development phase and ongoing government support through funding of new product development. Niche experimentation is essential if the goals of the programme are to be realised. In particular, the application of PEMFC in public transport as a replacement to diesel-based buses in the metropolitan areas, and the development of digital technologies for the integration of various sources of energy (wind, solar, coal, nuclear, gas and fuel cell) are proposed as areas of more intense research. Although in many applications digital technologies can be considered as providing an opportunity, in this case the use of such technologies will be essential; indeed, it seems unlikely that the transformation of the energy sector will be possible without the use of digital technologies that will allow real-time control of what are in reality highly stochastic systems. This proposal as an area of focus for niche experimentation also aligns with recent policy recommendations of developing short-cycle products and focusing on technological rather than scientific knowledge (Lee, 2016).

In many respects, South Africa presents a less intractable energy transformation challenge since it has high-quality renewable resources and a more limited dependency on oil. However, as described in this paper, the cost barriers of hydrogen fuel cells make such a transition uneconomic in the short term and ongoing experimentation is required to achieve this goal. It is recommended that niche applications are supported in the key areas of public transport, and digital systems to facilitate the integration of dispatchable and non-dispatchable sources of energy. Other recommendations include establishing science
parks to support the local manufacture of fuel cells and fuel cell components, stimulating foreign direct investment from international fuel cell companies as a means of increasing technology transfer, and introducing regulatory or policy measures to favour the application of hydrogen fuel cells within the transport and energy sectors.

References


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Abstract

Purpose – The purpose of this paper is to analyze the concepts attributed to the use of technology in the digital environment and its relations with consumer behavior in Brazil and Spain.

Design/methodology/approach – This paper discusses the concepts that cover the use of technology in the relations between technological changes in e-commerce and consumer buying behavior in a digital world, using the Technical Availability Index (Techqual), by Parasuraman (2000), applied to Brazilian and Spanish consumers.

Findings – Correlations between the concepts attributed to the use of technology by consumers have been identified which, in turn, may allow small- and medium-sized companies to develop strategies to improve engagement with their target audiences.

Research limitations/implications – This study explains how the understanding of these concepts can be continuously improved, proposing a continuous strategic review by the digital companies. The proposed approach to identify and measure assigned concepts can be tested in different performance sectors.

Practical implications – This study is unique in presenting concepts that can allow digital companies new ways of approaching their target audience, relationship with customers and positioning strategies.

Social implications – This research promotes a different look at how consumer behavior is understood, not only by companies, but also by individuals themselves, which may provide a better understanding of their behavior.

Originality/value – This study presents a comparative study among countries that are references in the digital consumer market, and links theory and practice in studies of consumer behavior.

Keywords Competitive advantage, Customer relations, Marketing strategy

Paper type Research paper

1. Introduction

While it is clear that digital technology transforms most retail sectors, there are a number of challenges that need to be understood by managers, such as rapid change in customer expectations and digital companies’ difficulty in understanding consumers believes. These challenges need to be addressed by industry and government leaders to unlock substantial benefits for their consumers. Business leaders in every industry are struggling with the strategic implications of these transformations for their organizations, industry ecosystems and society. The economic and social consequences of technological innovations, such changes in the company’s technological infrastructure and the learning and qualification of employees must be evaluated carefully by the industry and retail, since the consumer behavior is also constantly changing.

According to Argyriou and Melewar (2011), there are two questions that surround the concept of consumer attitude: the first is, according to Fazio (1990), if the attitude is a stable
association related to an event and then evoked in consumer memory, or according to Feldman and Lynch (1988) and Schwarz and Bohner (2001), the consumer attitude is a temporary assessment of an object constructed at the time of a judgment. The second question is, according to Fishbein and Ajzen (1975), Fishbein and Middlestadt (1995, 1997), whether the attitude formation is a strictly cognitive process that stems from analytic, evaluative, deliberative or affective categorization. Ajzen (1991) has also shown that buying intentions are affected by motivational factors that influence consumer behavior.

For Mosavi and Ghaedi (2012), positive attitudes positively affect an individual’s behavioral intentions. Søndergaard et al. (2005) studied the formation of consumer attitudes, suggesting that the development of their attitudes follows a top-down approach. This means that before buying intentions are formed, consumers have specific attitude toward the particular product that they want or need to consume. According to Mir and Rehman (2013), the more positive these attitudes are, the more positive will be the purchasing intentions. The literature on the subject suggests that it is the pre-conceptional phase of the purchasing decision-making process that significantly determines the consumers’ intention to buy.

Technology has become an essential element in organizations, can both stimulate growth and create new business models. As a result, it is critical that Chief Executive Officers (CEOs) and management teams focus their attention on a single strategic question: How can technology change the business and how can it be turned into a competitive advantage? Instead of engaging in tactical debates about IT management, CEOs must focus on strategic threats and technology-driven opportunities that are directly affected by consumer behavior in the digital world.

Montgomery and Chester (2009) unpack the concepts of the digital world, and identify six distinct characteristics, which make it particularly attractive for young consumers, especially: ubiquitous connectivity, personalization, peer-to-peer networking, engagement, immersion and content creation. According to the authors, these characteristics make the digital world very different from traditional means of consumption, and are the main catalysts of new marketing techniques applied to the digital environment.

According to Confos and Davis (2016), the digital environment is continuous, engaging, interactive and immersive for individuals who consume online products. The online content created by companies creates an ideal environment which the messages can be sent directly to meet the needs of the target audience.

This paper discusses the concepts associated with the use of technology in the relations between technological changes in e-commerce and consumer buying behavior in a digital world. For this, it is necessary to highlight the challenges that managers face in order to achieve innovation success.

2. Challenges for innovation management

According to Kosmrlj et al. (2015), the evaluation of a manager, entrepreneur or executive director emerges from the creation and previous experiences that lead to a partial or incorrect evaluation of a problem to be sorted out. The authors have shown that there are two reasons a problem may be improperly assessed. First, an inadequate understanding of the problem and second, an incorrect specification of the problem.

Moreover, some of the key challenges to management innovation lie in subjective assessments, wrong assumptions and also in misrepresenting the information needed to solve problems.

2.1 Data, information and insufficient analysis

Another element that may represent a challenge in innovation management is intuition. According to Kosmrlj et al. (2015), relying only in intuition may lead to incorrect decisions, for three reasons. The first is insufficient information, which leads to incorrect conclusions.
Second, it could result in incorrectly processed, due to limitations of individuals analytical methods, which are not adequately considered. And the third reason refers to the usability of the “information age,” which the challenge is define the most relevant data from the results of data available.

2.2 The importance of focusing on the future
The innovation strategy must also ensure that research and development work is not always subject to the pressure of current business needs.

For Košmrlj et al. (2015), great innovators do not allow the needs and pressures of a given moment to nullify their vision for the future. It is worth mentioning, for example, IBM. The company has developed three teams to manage the company’s innovation program. This focused on three pillars: the company’s innovation strategy, technological trends and the operationalization of innovation. Thus, to ensure focus on present and future priorities, IBM has built its business opportunities in three different goals: key business opportunities (short term), growth prospects (medium term) and future opportunities (long term). IBM has consciously decided to allocate a relatively large portion of its funds (10–15 percent) for the development of long-term opportunities and they do not use those funds for any immediate priorities in the company.

2.3 Open innovation
Gassmann et al. (2010) noted that the phenomenon of open innovation has developed from a group of innovation professionals in high technology industries to a widely discussed and implemented innovation practice. This is reflected by several studies on open innovation, including Enkel et al. (2009) and Franke and Piller (2003). The literature on open innovation can be organized in nine different perspectives, described in Table I, which proposes a holistic vision to understand the possibilities of managing the innovation process.

The definitions presented in Table II can be considered as strategic matrices of innovation, since managers can develop the capacity to improve their management practices. However, it is important to understand the consumer’s view based on optimism, innovation, discomfort and insecurity when using a company’s products and services.

3. Consumer’s perceptions about optimism, innovation, discomfort and insecurity in digital environment
3.1 Optimism in consumption
When treating optimism in consumption, it is relevant to highlight its concept in the face of consumer behavior. According to Puri and Robinson (2007), optimism is considered as generalized positive expectations about future events. For Thaler and Sunstein (2008), optimism in human behavior defined as something inherent to the human being. For example, consumers expect to find the product or service they want for the best acquisition conditions, like a mix of product that meets the consumers need, competitive price and personalized customer service.

In two classic studies of Katona (1968, 1974) it was stated that desires are not static and when people are optimistic about their own and the prospects of the economy, new desires may arise. However, empirical studies have pointed to the opposite results of Katona. Rha et al. (2006) and Yuh and Hanna (2010) found that those who expect future income to rise are more likely to be savers than those who expect income to decline. This points to a direct relationship between the level of optimism and the consumer’s economic environment, and this relationship is also reflected in the digital environment. For example, marketing actions, such as coupons, prizes or cumulative discounts, can generate greater intent to buy than an isolated promotion, such as seasonal sales.
Perspective Definitions

The spatial perspective leads to research on the globalization of innovation Research, technology and product development have become more global, open innovation has become easier

The structural perspective shows that the division of labor increases innovation Hagedoorn and Duysters (2002) pointed out that there is a strong trend toward more outsourcing and R&D alliances. Open innovation approaches compensate the central R&D units, not only focusing on unit research activities business, but customer-oriented

The user perspective Users are integrated into the innovation process to use the freedom available in their early stages to understand the latent requirements of potential customers and to integrate user application knowledge. According to von Hippel (2005), user innovation is one of the most researched part fields of open innovation

The perspective of the supplier According to Hagedoorn, the initial suppliers’ integration into the innovation process can significantly increase innovation performance in most industries

The prospect of leverage Existing research skills and the multiplication of intellectual property in new market fields have often been neglected, despite their potential to create new revenue streams. According to Kim and Mauborgne (2004) and Chesbrough (2006, 2007), the creation of technology and the external commercialization of intellectual property is a future field with high potential

The process perspective Gassmann and Enkel (2004) point out three central processes in opening up the innovation process: “outside in,” “in out” and “coupled.” These processes may complement each other, although the predominance of the “in-out” process is generally more commonly used

The perspective of the tool Opening the innovation process requires a set of tools that enable customers to create or configure their own product with specific kits, or to enable companies to integrate external problem solvers or brainstorm through websites

The institutional perspective Open innovation can be considered a model of collective-private innovation. According to von Hippel and von Krogh (2003, 2006), free disclosure of inventions, discoveries and knowledge is a defining feature of the open innovation model

The cultural perspective Opening the process of innovation starts with a mindset. Creating a culture that values external competence and know-how is crucial to the practice of open innovation

**Sources:** Prepared by the authors, adapted from Gassmann et al. (2010) and Vo et al. (2011)
In addition, empirical studies on consumer optimism and investment behavior, such as Gervais et al. (2002), Puri and Robinson (2007), Jacobsen et al. (2008) and Balasuriya et al. (2010), consistently show that optimistic people are more likely to be risk takers, underestimating risk or investing more in stock. It is evident that optimism and consumer confidence are related concepts. According to the research conducted by Sammut-Bonnici (2007), there are five principles governing consumer confidence, namely: security (consumer privacy in the digital environment), information elements of the product or service marketing mix, (such as pricing policy), choice (treated exclusively as the access platforms used), repair (defined as obstacles to be overcome by the consumer during the buying process), and competition among digital markets.

Consumer perceptions of optimism, according to the literature, will always be related to their economic environment, either theoretically or regarding the impact of optimism on consumption. Regardless of the level of analysis, innovative products or services can also lead to innovative consumption.

3.2 Innovation in consumption

According to the World Economic Forum (2016), digital technologies not only empower consumers, but also offer companies a set of tools that can redefine the basis of competition in all industries. In the digital environment, there are three new fields of action where companies in the industry and digital retail can establish high standards of competitiveness in their markets and aggregate values for their consumers.

The first field consists of products and services that generate experiences. Pine and Gilmore (1999) presented a bold prediction: offering goods and services would no longer be enough to bring success to companies. Instead, companies needed to offer their customers unique and unforgettable experiences. Their view reflects the reality since the first years of the twenty-first century, where companies are seeing the customer experience as an increasingly important way to differentiate their offerings in addition to them.

According to the World Economic Forum (2016) report, the strategy a company adopts to create a winning customer experience around its product or service will depend to some extent on the specifics of its business and its industry. While traditional companies focused on products and services are more likely to use digital technologies and partnerships with technology companies to complement and broaden their existing brand positioning, they are constantly threatened by a wave of digital "disrupters" that redefine the base for excellent experiences. However, companies can provide unique buying experiences that are transformed into tangible aspects to improve their customer’s life and thereby deliver results that matter to them. A personalized and excellent customer service is an example of how this can happen. In the case of digital retail, personalized services and more interactive digital experiences in stores can help companies to offer a more integrated approach to managing customers’ travel in the physical and virtual contact points of a retail brand. This means that these marketing practices can provide an optimal balance between the brand at the physical point of sale and the brand in e-commerce. As an example, Burberry’s flagship store uses RFID technology to trigger relevant multimedia content for each of its items in its in-store exposures, resulting in a more personalized customer experience on its online store.

The second field consists of hyper-personalization. According to Capgemini Consulting (2016), hyper-personalization is an advanced, real-time customization of offerings, content and customer experience on an individual level. Designed to perfectly match a customer, hyper-personalization uses big data, for example, when a company uses survey data on social media to create and deliver products developed especially for its customers, to provide customized solutions in real time.
The study also demonstrated that hyper-personalization reflects a paradigm shift in marketing studies, from product-centered, to customer focused. Of course, companies need to understand better who their customers are and what exactly they want. Traditional targeting techniques are, therefore, not effective enough to allow organizations to offer customized solutions at a time when big data allows them to know and understand their customers individually and meet their expectations in a personalized way. So what is the benefit of continuing customer segmentation in the traditional way when technology has paved the way for individual targeting and hyper-personalization of customer experiences and offerings?

The third field consists of ownership over information access. According to Vision Critical (2015), the concept of access ownership is becoming the main critical success factor for companies, with more than 110m Americans participating in the collaborative economy, and approximately 140m in the Americas Latina. Consumers are drawn to the convenience of on-demand access, the prospect of financial savings and the potential to improve their quality of life. According to Vision Critical (2015), 82 percent of sharing transactions were driven by the desire to save money. In addition, with environmental concerns growing in importance, some users appreciate the efficient use of features that technology-based access platforms can provide. Others value the opportunity to avoid the risks of owning a good, such as a car, without losing access to the benefits it provides. Having said that, we can group the three new fields of innovation in consumption. Table II describes their concepts.

These three new fields, according to the authors’ view, may point to a paradigm shift that changes the companies’ understanding consumers’ behavior. Once companies in a specific market, clearly understand how their target audience behaves, new strategies of positioning and competitiveness emerge, enabling companies to plan their marketing strategies more effectively.

3.3 Influences of consumer discomfort
According to Rawson et al. (2013), organizations able to deftly manage the entire experience with their consumers get enormous rewards: greater customer satisfaction, reduced turnover, increased revenue and increased employee satisfaction. They also discover more effective ways of collaborating between functions and levels, a process that provides gains across the company. However, it is necessary to clearly observe the level of evolution (generation) of its products and services, so they are offered in a coherent way for its consumers.

The new generation of smart devices affects consumers’ buying behavior. The same research has shown that as consumers demonstrate an intention to bring these products to the digital environment of devices in their home, some categories are well positioned to move into mainstream use consumers’ everyday lives. These products include body health meters, smartwatches, home security systems, digital home entertainment systems, smart houses, 3D printers, virtual reality devices and personal drones.

The digital industry suffers growing pains, related to “out-of-the-box” experiences, and negative information published on social media. According to Schlosser (2005), a small amount of negative information about products and services can have an impact on the consumers’ behavior and attitudes.

Palmer (1996) stated that people fulfill an emotional need with the products they purchase. Thus, the relationship of the company brand with its consumers is a fundamental marketing action, so that the involvement between consumer and company in the digital environment can be strengthened.

Involvement affects the way customers process marketing communication. In the view of Petty et al. (1983) and Celsi and Olson (1988), since engagement is high, consumers pay more attention to commercials, exert more cognitive efforts to understand them, and focus more attention on product-related information. This may cause the medium-term sense of discomfort in digital consumption to be reduced to minimal levels. The Elaboration
Probability Model, presented by Chaiken (1980), describes that high involvement increases the likelihood of engagement between consumer and brand, resulting in a more lasting attitude change. In the midst of digital communication, it is believed that this process is even more evident. Figure 1 shows the operation of the ELM.

For new devices deemed “fit for use,” the digital marketplace must face the challenges of moving them from early adoption to the majority of the market and reach their full potential, and do so quickly. Otherwise, capturing the consumer’s imagination will not translate into a satisfactory purchase or a loyal customer.

Accenture’s (2014) survey also showed that the early adopters are key influencers for the wider market and their dissatisfaction is a significant barrier. Particularly in a digital marketplace where social media and classic advertising are strongly influence buying decisions, the early adopters must be satisfied for these products to move to conventional use.

3.4 Insecurity experiences in digital consumption
The digital environment, especially in retail, can increase consumer insecurity. In this way, it becomes relevant to identify the most common risks as well as the challenges for the consumer in the digital environment.

![Figure 1. Elaboration likelihood model](image)

**Source:** Elaborated by the authors, adapted from Sherman et al. (2014)
The study by Zimmerman and Baur (2016) identified the most common risks and challenges for the consumer in the digital market as they affect the experiences of insecurity in digital consumption. These risks to the consumer include: inability to transact because of a lack of network or adequacy of the digital service; complex user interfaces and insecure payment processes; poor consumer support; and potential user fraud.

The first risk, the inability to transact due to lack of network or inadequacy of the digital service, refers to the interrupted transactions that leave the payment orders unprocessed. According to El-Huni (2014), once the networks were completely disabled, it became common for users either to abandon the service to buy the product, or – in other cases – to leave their card and password with agents or merchants to complete the transaction at a later time, resulting in risks and reported experiences of inappropriate and even fraudulent behavior.

The second risk, complex user interfaces and suspicious payment processes, increases the likelihood of errors and transaction losses or timeout times due to limited transaction time. According to Zimmerman and Baur (2016), in addition to failures and repetitions of transactions, these issues degrade the buying experience of the consumer, which can increase in their dissatisfaction with the brand. These issues can significantly reduce trust and increase insecurity to the same extent, as this initial interaction with the digital market inconveniences the consumer, leading to a lower likelihood of wider use of digital retail services.

The third risk, poor consumer support, represents appeals mechanism, such as complaints, consultations and dispute resolution. According to Zimmerman et al. (2014), this risk represents another particularly weak point in digital market services. Consumers often do not understand or are confused about feature options and customer support, making it difficult to solve problems or get answers to questions about their payments. According to the authors, consumers of various digital services also worried that if they complained they could lose their transfers, a misperception that made them reluctant to report problems.

Even when customer service exists, consumers are not aware or have had negative buying experiences such as being held for a long time on automated waiting lines or having their call turned off before they could talk to any individual. This usually results in frustration and, in some cases, financial loss due to time spent. For Islam and Woodard (2014), there are studies that report that mobile consumers wanted to talk to support agents in a digital company, however, they often gave up thinking that it was not worth waiting to communicate a problem even if it could be solved.

The fourth risk, targets for user fraud of the digital service, refers to consumers in the digital market, who are particularly vulnerable to fraud, such as unauthorized charges, retail price increases and reduction of payments due, i.e. retention of a parcel. According to the Zimmerman and Baur (2016) survey, consumers are unaware of the actual rates associated with their payments in the digital environment, and are unaware of the exact amount and frequency of agreed charges, leaving them vulnerable to fraud or any unfair treatment. This can be summarized in a single term: lack of transparency.

The authors point out that password protection is another challenge for the services offered in the digital market, since many consumers share their password with third parties.

It is important to note that the protection of consumer information cannot be reduced in favor of the transaction’s efficiency. Both should be considered together so that the digital company can provide the best shopping experience to its consumer.

Thus, not only does the digital market have its share of responsibility for providing security on behalf to the consumer who provide services or selling products, but also the consumer must be aware of her actions such as sharing secret data for the sake of increasing efficiency. Table III summarizes the risks to the experiences of insecurity in digital consumption.

These four risks pointed out by the authors make it clear that the digital market, although prominent in the world, still lacks clear care and strategies toward its target audience. Any marketing strategy adopted by companies in the digital environment should consider not only
the factor of consumer insecurity, but also factors that generate discomfort in the process of buying a product or service in the digital environment and, at the same time, provide innovative actions that can guarantee confidence in the purchasing process.

3.5 Lifestyle variables in digital consumption
Contrary to surveys that relate consumer preferences to demographic variables, this research delineates areas of behavior and lifestyles that are theoretically linked to basic dimensions of value, price, social and emotional quality. These dimensions also apply to the digital market.

Orth et al. (2004) used the consumer lifestyle to predict consumer profiles and segments for a range of products and services. The authors point out that digital communication is increasingly common in the dissemination of products and services, and this affects the consumer’s lifestyle. In this way, companies can predict their consumers’ preferences to manage their positioning strategies. Orth et al. (2004) showed that the consumer’s lifestyle directs the marketing actions of digital companies. Using lifestyle information, companies can combine products and services that best meet a specific consumer need. According to research by Ernst & Young (2011), since the introduction of the first commercial sites commonly used in the 1990s, digital technology has brought a new level of convenience to customers. However, digital convenience came at the expense of meaningful engagement, as digital transactions replaced mostly physical interactions. The study also points out that digital channels develop in isolation, resulting in inconsistency and displacement between digital and physical channels.

The legacy is frustrating for consumers in the 2000s (also called digital natives) when they fail to complete an interaction in the digital environment, and feel compelled to physically visit the retail. Frustration is particularly felt by digital natives who grew accustomed to immediacy and convenience and expect to be known in all interactions with a company, regardless of the channel in which they choose to get involved. However, there are new technologies that make it easier for companies to bring together channels and deliver a consistent engagement model for their customers. Table IV demonstrates these new technologies.

Lima and Souza (2010) emphasize the position of Tristão (2008), who argues that just as the internet has evolved so have consumers, either by their use of networks and social media or by the relationship consumers want to have with a brand or company through the digital medium. The authors point out that by offering free and intuitive tools, consumers will behave as

<table>
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<th>Table III. Risks affecting experiences of insecurity in digital consumption</th>
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<tr>
<td>Risks</td>
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<tr>
<td>Inability to transact, lack of network or adequacy of digital service</td>
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<tr>
<td>Complex user interfaces and suspicious payment processes</td>
</tr>
<tr>
<td>Poor consumer support</td>
</tr>
<tr>
<td>Digital service user fraud</td>
</tr>
</tbody>
</table>

Source: Prepared by the authors
content producers. Lima and Souza (2010) emphasize that this evolution in consumer behavior requires a change of attitude and strategic thinking on the part of the managers.

A new definition for this new type of consumer may be called "prosumers." The term "prosumer" originated with Alvin Toffler, who used the term in his 1980 book *The Third Wave*. Toffler (1980) defined the "prosumer" as a consumer who participates in proactively creating products and services. The term came to mean a variety of things, but in this research define itself as an individual who makes little distinction between life at home or work. Being a "prosumer" involves engaging in any sphere of market action, regardless of time or location.

Lima and Souza (2010) corroborate the position of Firat et al. (1995), who define this category of consumers as those who, besides consuming products and services, also promote them. The authors emphasize that managers should have an understanding that consumers are actively engaged in creating value and benefits for their own consumption. An example of this engagement lies in a new Nike application concept in Los Angeles and Portland. Once the customer enters the store, the app recognizes their location and offers unique products available at that point of sale. The customer can check product availability at all nearby Nike stores and, if desired, can make payment through the application without waiting. And if the customer is not in the store, he/she can book the product through the application and keep it in a "personal cabinet" so that he can try it before buying.

This process of creating value, besides being part of the lifestyle of these consumers can also give rise to new strategies in companies for positioning their products and services in the digital environment.

According to Xie et al. (2008) and Lima and Souza (2010), prosumers are well-informed and constantly searching for knowledge and new skills and are involved in creating value and benefits for their own consumption. Table V highlights the main characteristics of prosumers.

The prosumer segment may be small, but its influence grows exponentially. The popularity of iPhone, iPad, YouTube, Facebook among other platforms and digital tools is evidence of this influence. Companies can develop strategies for the "prosumer" market and, according to Evans (2011), there are several approaches that companies can take when identifying their target audience in this market. For example, as early adopters, prosumers make use of solutions that keep them in touch with their families and friends, including connected life services such as social networking (personally and professionally). Instant messaging, which originated as a business tool, has become the prosumer’s preferred way to stay in touch with work colleagues and friends and family. According to Gerhardt (2008), the opportunity for industries lies in creating solutions that tightly integrate work and home life to attract the advantage of prosumers. Such solutions are hard to replicate, because changing providers also involves transporting and re-creating both personal and work data and services.

<table>
<thead>
<tr>
<th>Risks</th>
<th>Definitions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location-based services</td>
<td>Services to digitally identify a physical location of a person or object (e.g. the nearest ATM). Also used to replace coupons for advertising to customers based on their actual physical location</td>
</tr>
<tr>
<td>QR codes</td>
<td>It allows users to scan a physical object (product packaging) and access additional information digitally in their gadget</td>
</tr>
<tr>
<td>Increased reality</td>
<td>The real-world information surrounding the user becomes interactive when viewed through a digital screen. Often used to make the interactive sports show</td>
</tr>
<tr>
<td>Increased reality</td>
<td>A computer that feels and operates like a thin sheet of paper that can interpret the text written directly on it</td>
</tr>
</tbody>
</table>

*Source: Prepared by the authors, adapted from Ernst & Young (2014)*

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Prosumers are not hard to find or identify. However, capturing this desirable segment requires a systematic program of research, development and testing of targeted deals to them, as well as education about the value of the product or service.

3.6 Research’s theoretical framework
Before detailing the methodological procedures in the next section, it is important to highlight the theoretical framework developed in this research.

The research problem describes that there are several challenges in using digital technology that need to be understood. These include the accelerated pace of change in customer expectations, the cultural transformation in the use of technology in the early twentieth century, and the outdated regulation and identification of access to digital tools.

Thus, the objective of this research was delineated, which consists of analyzing the concepts associated with use of technology in the digital environment and its relations with consumer behavior in Latin American and European countries.

To meet this objective, the following research question was elaborated:

*RQ1. How can the use of technology improve the perception of the business by the consumer and how can it be transformed into a source of competitive advantage by the companies?*

The answer to this research question can be developed by analyzing the relevant literature and pointing out the state of the art on the subject. Table VI presents the main theoretical lines of this research.

The next segment describes the method and the technique used in this research to achieve the proposed objectives.

4. Method
The dimensions pointed out by Zimmerman and Baur (2016) described in item 3.4 will be used as reference for the development of the research analysis. Therefore, the dimensions: inability to transact due to lack of network or adequacy of the digital service, complex user interfaces and payment processes, poor consumer support and targets for user fraud of the digital service will be used to describe the relationships between optimism, innovation, discomfort and insecurity in digital consumption.
4.1 Methodological procedures

This item presents the methodological aspects as well its procedures that guide the analysis. This research is considered as a descriptive study. According to Silva and Schappo (2002), a descriptive study allows the description of the characteristics of a given population or the establishment of relationships among the variables that occur.

The approach to the research problem is of a quantitative nature, and a survey was used to collect the data. The survey is characterized by direct interrogation with the research subjects, and aims at describing the distribution of characteristics or phenomena, which occur naturally in population groups. Gil (2002) explains that the quantitative method searches for information from a significant group of people and then obtains the corresponding conclusions from the data collected.

The Technology Availability Index (Techqual) refers to the propensity of people to accept and use technologies to achieve their goals in life at home and at work. According to Parasuraman (2000), it consists of items that collectively determine a person’s predisposition to use technologies. Techqual has 36 items grouped in four dimensions: optimism, innovation, discomfort and insecurity. Each dimension is measured using a likert scale: 1 = totally disagree; 2 = partially disagree; 3 = neutral; 4 = partially agree; and 5 = I totally agree.

Scale development was a joint effort of Parasuraman and Rockbridge Associates in Virginia, USA. An iterative multiphase process was used involving discussion groups and reviewed by researchers from Marketing, and resulted in 44 items. Those were further reduced to 28 using a revision of the alpha coefficient estimates, correcting the total correlations point by point, and with the exploratory factorial analysis.

Further analysis on new data resulted in the final scale 36 items composed of four dimensions. The reliability estimates for these dimensions were as follows: optimism, 0.81; innovation, 0.80; discomfort, 0.75; and insecurity, 0.74. Confirmatory factorial analysis was used to verify its structure. According to Parasuraman (2000), the evidence of validity involved testing differences in means of various categories, including ownership of various services, the use of specific technology-based services, and the perceived convenience of engaging in a variety of technology-based services.

The sample used for this research was composed of 250 responses from students of postgraduate courses stricto sensu residing in Brazil and Spain, as detailed in Table V. The sample of 250 students was obtained by convenience and through a cross-section, and the marketing scale was applied through an online survey. The authors were careful to characterize the sample of 250 individuals considered as “prosumers.”

The research sample indicated that they may share cultural characteristics and consumption behaviors among themselves. According to Hair (2014), this is a procedure called...
“judgment sampling.” According to the author, in trial sampling (which is also called purposeful sampling), respondents are selected because the researcher(s) believe they meet the study requirements. Also, the author points out that since the evaluation of the researcher(s) is correct, the product of the sampling by judgment may be better than that of the sampling for convenience. The type of sampling was based on ease of access to consumers. However, the results cannot be generalized. The authors of this research believe that there will be no significant variation between consumer samples in Brazil and Spain.

It is important to emphasize that the Technology Availability Index (Techqual) with its four categories of analysis (optimism, innovation, discomfort and insecurity) can present the manager with relevant information on how to adopt different positions with its target audience by offering innovative products and services that meet the needs and perceptions of its consumers.

5. Findings
In this segment, the results and discussions about the survey data are presented. It begins with the characterization of the sample, according to Table VII.

Table VII shows that there was a balance between the responses obtained in Brazil and in Spain. From this information, the data presented the means of the scores for each dimension of analysis, which can be identified in Table VIII.

A balance is observed between the scores of the analysis dimensions of each country, which indicates a similarity of consumer behavior between both nations. It is important to describe an analysis of how each dimension behaves in Brazil and Spain. The scale used to extract the data from the survey was proposed by Parasuraman (2000), presenting a Cronbach's $\alpha$ of 0.890 in 36 constructs of the questionnaire, which can be verified in Table IX.

Thus, for the output generated, the value of 0.892 is significant as Hair et al. (2005) and Malhotra (2012) shows the consistency of the instrument used. According to the criteria of Hair et al. (2005), the result can be considered very good. For the analysis of the data from the survey, the statistical treatment was performed using SPSS software, version 23. Two techniques were chosen: the first one was the Simple Matching Analysis which, according to Fávero (2015), makes it possible to verify the association between two or more variables and

<table>
<thead>
<tr>
<th>Country</th>
<th>Brazil</th>
<th>Genre</th>
<th>Age range</th>
<th>Spain</th>
<th>Genre</th>
<th>Age range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>130</td>
<td>43% (M) and 57% (F)</td>
<td>23–29</td>
<td>120</td>
<td>48% (M) and 52% (F)</td>
<td>24–28</td>
</tr>
</tbody>
</table>

Source: Research data, from SPSS output

Table VIII. Dimension’s averages

<table>
<thead>
<tr>
<th>Average scores of the dimensions</th>
<th>Brazil</th>
<th>Country</th>
<th>Spain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimism (OTM)</td>
<td>3.82</td>
<td></td>
<td>3.91</td>
</tr>
<tr>
<td>Innovation (INV)</td>
<td>3.10</td>
<td></td>
<td>3.15</td>
</tr>
<tr>
<td>Discomfort (DSC)</td>
<td>3.43</td>
<td></td>
<td>3.53</td>
</tr>
<tr>
<td>Insecurity (INS)</td>
<td>3.63</td>
<td></td>
<td>3.65</td>
</tr>
</tbody>
</table>

Source: Research data, from SPSS output

Table IX. Statistical validity

<table>
<thead>
<tr>
<th>Cronbach’s $\alpha$</th>
<th>No. of items</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.890</td>
<td>36</td>
</tr>
</tbody>
</table>

Source: Output SPSS
their intensity from a cross-table of data, in order to identify if there are similarities or differences between countries and the dimensions of analysis.

Homogeneity Analysis (HOMALS) also known as Multiple Correspondence Analysis (MCA), which according to Fávero (2015) consists of a multivariate technique that allows the investigation of the existence of association between more than two analysis variables. According to Carvalho (2004), this method facilitates the study of the relationships between the several characteristics existing within a certain space of analysis. According to Malhotra (2012), this technique seeks to synthesize the observed relationships among a set of interrelated variables at the same time that identifies common factors, presenting a Kaiser-Meyer-Olkin (KMO measure of sampling adequacy) of 0.887 and a Bartlett sphericity of 8,214, which can be seen in Table X.

The values obtained showed that the factorial analysis is adequate (Malhotra, 2012), thus allowing the use of the following dimensions: optimism (OTM), innovation (INV), discomfort (DSC) and insecurity. For the scores, a five-level split was created based on the Likert scale to verify the association of variables, (1) totally disagree, (2) partially disagree, (3) neutral, (4) partially agree and (5) totally agree.

In order to fulfill the objective of this research, the relationship between OTM, INV, DSC and INS dimensions for Brazil and Spain was analyzed, generating the results as follows.

According to ANOVA data, the categories optimism, innovation, discomfort and insecurity in Brazil and Spain showed a few variations in the sample analyzed. It should be noted that, especially in the Innovation category (although there were variations in the sample), they were not significant when compared to the other categories, as shown in Table XI.

### 5.1 Results and discussion

The following discussion is based on a correlation analysis between consumers in Brazil and Spain, obtained from the results of the research using SPSS software. In the optimism category (OTM) there was a pre-provision of Brazilian and Spanish consumers to use the most advanced technology available on the market, since the products have it, have a significant level of convenience in its use.

For a group of consumers to be willing to use the most advanced technology available beyond optimism, it is necessary to have confidence in the digital environment and in the product brand that presents the level of technology desired by the consumer. The research carried out by

<table>
<thead>
<tr>
<th>Kaiser-Meyer-Olkin measure of sampling adequacy</th>
<th>0.885</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bartlett’s test of Sphericity</td>
<td></td>
</tr>
<tr>
<td>Approx. $\chi^2$</td>
<td>8,124.364</td>
</tr>
<tr>
<td>df</td>
<td>180</td>
</tr>
<tr>
<td>Sig.</td>
<td>0.000</td>
</tr>
<tr>
<td><strong>Source:</strong> SPSS output</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table X. KMO and Bartlett’s test</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>ANOVA tests</td>
<td></td>
</tr>
<tr>
<td>Brazil</td>
<td></td>
</tr>
<tr>
<td>$F$</td>
<td>19,813</td>
</tr>
<tr>
<td>$F$ critical</td>
<td>1,887</td>
</tr>
<tr>
<td>Spain</td>
<td></td>
</tr>
<tr>
<td>$F$</td>
<td>26,010</td>
</tr>
<tr>
<td>$F$ critical</td>
<td>1,887</td>
</tr>
<tr>
<td><strong>Source:</strong> Research data, from SPSS output</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table XI. ANOVA tests for Brazil and Spain samples</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimism (OTM)</td>
<td></td>
</tr>
<tr>
<td>$F$</td>
<td>19,813</td>
</tr>
<tr>
<td>Innovation (INV)</td>
<td></td>
</tr>
<tr>
<td>$F$</td>
<td>5,245</td>
</tr>
<tr>
<td>Discomfort (DSC)</td>
<td></td>
</tr>
<tr>
<td>$F$</td>
<td>26,010</td>
</tr>
<tr>
<td>Insecurity (INS)</td>
<td></td>
</tr>
<tr>
<td>$F$</td>
<td>28,439</td>
</tr>
<tr>
<td><strong>Source:</strong> Research data, from SPSS output</td>
<td></td>
</tr>
</tbody>
</table>
Sammut-Bonnici (2007), where the author presents the principles governing consumer confidence, distributed in five competitive forces: security (considering consumer privacy in the digital environment), information regarding the product or service (such as pricing policy), choice (treated exclusively as access platforms used), repair (defined as obstacles to be overcome by the consumer during the purchase process) and competition between markets.

In the innovation (INV) category, the results demonstrated that Brazilian consumers keep abreast of the most recent technological developments in their areas of interest, while seeking to discover new high technology products and services without the help of other people, whether they are from their social circle or not. The same has not been identified in Spanish consumers. According to the results, Spanish consumers are among the first in their social circle to acquire new technologies when they are available for consumption, and their social circle sees it as a source of invaluable information on whether or not to acquire new technologies.

Although, in consumer behavior in Brazil and Spain in the innovation category, consumers in both countries have a common characteristic in their profiles: preference for products and services that generate experiences. This is explained by Pine and Gilmore (1999): offering goods and services would not be enough to bring success to companies. Instead, companies needed to offer their customers unique and unforgettable experiences. The authors’ view reflects the reality since the first years of the twenty-first century, where companies are seeing customer experience as an increasingly important differential, along with the quality of their main offer.

In the discomfort (DSC) category, it was observed that for both Brazilian and Spanish consumers, they feel ashamed when they encounter a problem with a high-tech product or service while others are observing them, and believe that technology systems in use were not designed for use by ordinary people. The survey showed that this sense of discomfort can be linked to the level of engagement that consumers reach (or seek to achieve) when they consume a high-tech product or service of a particular company. The fact that consumers in both countries have this feeling of discomfort is reflected by the lack of engagement: the consumer simply has no reason to engage because of the difficulties and problems encountered during use or consumption. The study by Schlosser (2005) reveals that even a small amount of negative information about products and services can have an impact on consumers' attitudes. Similarly, Palmer (1996) stated that individuals have an underlying need for emotional attachment to the high-involvement products they buy. The development of the relationship between the brand and its consumers, as well as solutions that make feasible and facilitate the use of high technology digital products and services, are essential strategies for the engagement between consumer and brand to grow significantly.

In the insecurity (INS) category, it was found that the sharing of personal information in the digital environment persists as the main factor of insecurity. According to data from this research, Brazilian and Spanish consumers do not consider it safe to do any kind of financial business in the digital environment, and do not consider it safe to register their personal data for fast access by the company at future times. It is clear that this insecurity does not reflect in the act of buying online, but in the way in which the personal data of the consumers stored and managed by the companies that own this technology. Among the risks and the most common challenges for the consumer in the digital market that affect the experiences of insecurity in digital consumption identified in the study by Zimmerman and Baur (2016), are poor consumer support, and user fraud.

Poor consumer support, according to Zimmerman et al. (2014), represents a particularly weak point in digital market services. Consumers often do not understand or are confused about feature options and customer support, making it difficult to solve problems or get answers to questions about their payments. According to the authors, consumers of various digital services also worried that if they complained they could lose their transfers, a misperception that made them reluctant to report problems. Zimmerman and Baur’s survey also showed that for digital
service user fraud, consumers are unaware of the actual rates associated with their payments in the digital environment, and are unaware of the exact amount and frequency of agreed charges, leaving them vulnerable to cases of fraud or any unfair treatment, which significantly increases the level of insecurity in the digital environment.

6. Conclusion
The results about optimism, innovation, discomfort and consumer insecurity in the digital environment presented by this paper showed that consumers’ purchasing decisions are affected by their attitude, innovation, involvement and experience with the digital environment. According to the results, for the selected samples there is no significant difference on consumer behavior in Brazil and Spain. This can be explained by the Latin ancestry shared between the countries, and that is not restricted only in the language, but also of the culture in both countries. Although these results cannot be generalized to the entire population of these countries, the results demonstrated that consumer attitudes may reflect their real intentions at the time of purchase, and that can assume motivational factors that will influence their post-purchase behavior. The inversely proportional relationship between optimism and innovation presented by the results reflects the view of the authors, since it is not enough for a digital product or service to be innovative in its essence without the perceptions of consumers to be taken into account in the elaboration of a marketing strategy.

It is important to highlight the influence of consumer involvement. This research demonstrated that consumer involvement refers to a continuous commitment on the part of the consumer to thoughts, feelings and behavioral responses to products or services. In this way, the involvement with a product or service affects the consumer’s propensity to acquire it. This can be verified in the identical trajectories measured in the discomfort and insecurity dimensions through the results of the research.

This research aimed to point a new look at the study of variables that can affect consumer behavior, especially the consumer in the digital environment. By highlighting the variables “optimism,” “innovation,” “discomfort” and “insecurity” as an essential part of the understanding of consumer behavior, this study demonstrated that these variables are part of the new category of consumers called “prosumer,” and this new consumer can influence the way companies build relationships with their target audience. There is much more to discover on this topic.

As a marketing strategy, this signals that companies can invest in the level of engagement toward their specific audiences using the digital environment. By properly engaging their consumer, companies can create appropriate conditions for them to identify the real value that a brand has, whether through the tradition (history) that a brand has in the market, or through promotional actions like promoting a better shopping experience to the consumers. More accurate location-based services, enhancement of QR codes, access to augmented reality, and the use of digital paper are some elements that can enhance the consumer lifestyle of the twenty-first century.

The variables of online consumer, described in this study as digital natives, can be used as a filter when evaluating the dimensions of optimism, innovation, discomfort and insecurity, as analysis variables. These dimensions can be used as indicators of consumer buying behavior as well as the analysis of their actions in social media and lifestyle.

The results of this research can provide to managers, especially in the digital segment, understanding of how to fill in the gaps in their innovation processes, especially when using open innovation to fill them. Remembering the nine different perspectives of open innovation (as shown in Table I), managers can better lead their management practices, and seek results that can, in fact, deliver effective results in line with their overall strategies.

Companies operating in the digital environment must pay attention to consumer insights. They need to work constantly to better understand their consumers, and the data they get can lead companies to insights that generate richer and more relevant information for developing...
more efficient marketing strategies. And, if digital information shows that something is not connecting with consumers, the company can react appropriately and adapt its plans. More than ever, the data are fueling the marketing efforts of companies.

And the society can also benefit from receiving products and services tailored to their lifestyle. In the long term, consumer well-being and the shopping experience provided by the company can become an important asset within the range of benefits that a digital company can offer. Through design and other practices, it is possible to prototype totally new services and iterate existing ones quickly. Teams that work with digital services can test them with their users almost in real time. Insights that have taken years to emerge can now be discovered in days or weeks.

The effects of this trend can be seen everywhere. Shorter cycles are becoming more frequent in government services. For example, the UK Government Digital Service has created a 12-week e-petition service. The Peruvian Government has created a new digital provisional driver’s license in three months.

From the results of this research, it is possible to highlight three important components in which companies working in the digital environment can emphasize their marketing strategies. The first is the desire for convenience. The choice of the channel by consumers depends on factors such as convenience and security, and the creation of user experience. This can be achieved by increasing the consumption of digital services, improving the adoption of large-scale mobile payment and the adoption of biometrics for commercial use.

The second is to understand that consumers have the propensity to share data. The more loosely personal information is shared, the more susceptible consumers will be to data leaks and identity theft. Therefore, companies can increase their willingness to use personal information to detect fraud, improve responsiveness to re-use personal data between companies, and work on the quality of data sent.

And the third one is the perception of risk. Consumers who have experienced fraud – directly or indirectly – are more likely to stay away from unsecured transactions. To gain the confidence of their consumers, companies can protect personal data at risk, tolerance to the incidence of fraud and perception of the effectiveness of how organizations handle fraud.

It is a fact that these variables will affect directly the final price, customer service, product quality and other marketing services, however, they open significant opportunities to understand how consumers make in their decisions, especially in the digital environment. This research can be applied to future case studies in other segments, whether in industry or retail, and its results can be used for teaching and providing companies training programs on digital services, especially in digital retail.

References


Managing the digital consumer


**Further reading**


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What determines customers’ engagement in the digital service process?

Minna Saunila, Juhani Ukko and Tero Rantala
School of Engineering Science, Lappeenranta University of Technology, Lahti, Finland

Abstract

Purpose – The purpose of this paper is to examine customer engagement behavior (CEB) in digital environments. Specifically, the paper seeks to determine the factors that affect CEB in the different parts of the digital service process.

Design/methodology/approach – A longitudinal, qualitative, single-case study is used to examine CEB in digital environments. The selected case company is a provider of streaming TV services. Both primary data, gathered from interviews, focus groups and participant observations in meetings with a selected focus group, and secondary data, gathered from company websites sources, were used.

Findings – This study shows that CEB is determined by different factors in different phases of the digital service process. Moreover, the results show that engagement is highlighted during the front-end phase of the process. During the back-end phase, the role of engagement is realized by maintaining and updating solutions.

Originality/value – The originality of the research is based on the study of CEB in the context of the digital service process. The factors that affect CEB are classified as customer-based, firm-based and context-based factors.

Keywords Digitization, Service operations, Customer relations, E-commerce, Customer service management

Paper type Research paper

Introduction

Digitization has generated extensive changes for businesses. The complexity of the digital economy stems from its various functions. The digital economy provides global access to knowledge and information and thus affects the way in which people and organizations interact and behave. Furthermore, the continuous development of broadband and mobile technologies has transformed previous occasional connections to the internet into 24/7 interconnectivity (Bradley and Bartlett, 2011). As a result, the impact of the network has increased, and information, commerce and entertainment have converged (Fudurić et al., 2018; Shankar and Balasubramanian, 2009). According to Fudurić et al. (2018), we are currently living in the age of the connected customer: a customer who accesses content on multiple devices and whose use of the internet may soon surpass that of traditional media, such as TV, which have typically dominated media consumption. Thus, with the increasing development of wireless communication and multimedia technologies, streaming TV systems have become widespread in daily life (Deng et al., 2018).

One of the current challenges facing businesses in the digitized world is building deep, long-lasting connections with customers (Wiersema, 2013; Saunila et al., 2017). In contemporary, digitalized environments, customers can use different digital solutions and services that supersede traditional solutions. For example, customers use mobile devices to use banking services, to purchase goods from e-stores, and to watch TV. Moreover, customers can easily and quickly change their service provider. Thus, service providers must understand customers’ behavior toward and engagement with the services they provide. Previous studies have highlighted the need for service providers to understand the value customers derive from products and services, which is based on the products’ and...
services' value-in-use (Vargo and Lusch, 2008). The importance of the value-in-use of products and services is even more important in digital contexts.

The ongoing changes in traditional products and service processes, along with the increasing digitization of the media ecosystem, have led to changes in customer behavior and customer engagement that have and will continue to raise concerns among different industries across the world. To address this challenge, during the last decade researchers and scholars have increasingly recognized and sought to understand the concept of customer engagement behavior (CEB). CEB refers to customers’ behavior, besides purchasing behavior, toward a brand or firm, which results from motivational factors (Van Doorn et al., 2010). Customer engagement can increase customers’ loyalty to and satisfaction with a brand or firm (Jaakkola and Alexander, 2014), which may result in the brand or firm gaining a competitive advantage (Kumar and Pansari, 2016) or increasing its revenue (Straker and Wrigley, 2016). However, while the importance of CEB has been widely acknowledged, few studies have focused on customer engagement in a digital context (Marbach et al., 2016).

This paper addresses this research gap by determining the factors that affect CEB in different parts of the digital service process. By using a streaming TV service as an example of the digital service process, the paper builds on a longitudinal, qualitative, single-case study (Yin, 2003) due to its suitability to holistically analyze previously unexplored phenomena (Eisenhardt, 1989). A large company providing streaming TV services is used as a descriptive case study to explore CEB. A wide variety of primary data, gathered from interviews, focus groups and participant observations, and a wide variety of secondary data were used. This study contributes to previous studies of digital services processes and customer behavior by investigating CEB in the context of the digital service process. It contributes to the literature by clarifying the factors that determine CEB in the digital context and the factors of engagement that are pronounced in different phases of the digital service process. Due to the growing challenge to develop and maintain long-lasting customer relationships in digital business environments, the results of the study can also be used by many different practitioners operating in digital business environments.

The digital service process

Because digital technologies can be used to deliver value to customers in ways that extend customers’ conscious experiences in the contexts of time and space (Watson et al., 2002), digital technologies are important sources of competitive advantage and customer value. Digital business is changing the existing business world in a holistic and customer-driven way by renewing processes through, for example, digitization and the development of electrical services. Williams et al. (2010) define digital services as services that are obtained and/or arranged through a digital transaction over the internet. They highlight that although such services may start digitally, the interactions between customers and providers of these services may occur outside a digital context (Williams et al., 2010). Digital systems can be linked with product service bundles to create new digitized product service systems (Lerch and Gotsch, 2015). Lerch and Gotsch (2015) define this type of product service system as "an integrated bundle of physical products, intangible services, and digital architectures designed to fulfill individual customer needs via automated, independent operation, with the goal to significantly improve customer outcomes."

The provision of digital products and services, the use of digital resources to transform business processes and the use of digital resources to transform business strategies are the three categories of digitality (Bharadwaj et al., 2013). Digital business refers to how goods and services are produced and designed (process), the types of goods and services that are
offered (market offering) and how goods and services are brought to the market (business model) (Brynjolfsson and Kahin, 2000).

These three categories of digitality use similar methods of creating customer value, and they are not exclusive, so they can exist simultaneously. The digital service process to which we refer in this research can involve all three categories of digitality. If the market offering is digital, then the main benefit of digitality for the customer is the product or service. One benefit of business processes involving digitality is a simulation system for product development. Additionally, the use of digital resources to interact with customers allows for the possibility of a digital platform on which customers can order products that will be delivered to them in a digital form. In other words, ordering, payment and delivery occur in a digital form, which changes the way in which companies do business in terms of both time and space.

Digital services differ from traditional services in several ways. For example, they differ in terms of tangibility, although the extent of this difference depends upon the definition of tangibility, as pointed out by Williams et al. (2010). In addition, digital services differ from non-digital services in terms of ownership. Possession, which is usually equated with ownership, is often unclear in the context of digital services, as physical possession may not imply full control (Williams et al., 2010; Saanila et al., 2017). In addition, digital services must provide a rich user experience that can be measured in terms of usability, aesthetics and engagement (Nylén and Holmström, 2015). Thus, companies that provide digital services must consider the potential needs of their users, because meeting these needs is more crucial than the relational interactions between parties. Non-digital services are often based on personal relationships, which are more important than the provided service (Williams et al., 2010). Overall, the proper management of customer processes creates opportunities to strengthen a company’s engagement with customers. Customers’ subjective perceptions of the company’s identity, branding, advertising and channel engagement are powerful motivators that affect customers’ purchasing decisions (Straker and Wrigley, 2016). Thus, it is crucial to understand how CEB changes throughout the digital service process in order to meet customers’ requirements effectively and comprehensively.

Customer engagement behavior (CEB)

The definition of CEB

It has been acknowledged that effective value creation requires companies to engage customers’ knowledge in the service process (e.g. Vargo and Lusch, 2008; Grönroos and Voima, 2013; Wiersema, 2013; Zhang et al., 2015; Marcos-Cuevas et al., 2016; Petri and Jacob, 2016). Therefore, being aware of an organization’s engagement activities and future research requires guidelines for the engagement of different actors and stakeholder groups that are transferable across different contexts, as well as those that are more context specific (Kumar et al., 2010; Hollebeek et al., 2016; Alexander et al., 2018). Especially for digital business, customer relationships are in a crossroads, as new technologies are more often used to empower and engage customers (Straker and Wrigley, 2016). According to Marbach et al. (2016), customer engagement differs from customer involvement and participation because involvement and participation are not interactive, co-creative experiences.

There are many definitions of CEB. Thakur (2016) defines CEB as “a psychological state that occurs by virtue of interactive customer experiences with a focal object (e.g. mobile medium). Further, customer engagement goes beyond specific purchase transactions resulting from emotional and utilitarian motivational drivers.” Hollebeek (2011) uses the term “customer brand engagement” to describe “the level of a customer’s motivational, brand-related, and context-dependent state of mind characterized by specific levels of cognitive, emotional, and behavioral activity in brand interactions.”

Prior research has also discussed the different types of CEB. Demangeot and Broderick (2016) identify four dimensions of customer engagement: interaction engagement, activity engagement, behavioral engagement and communication engagement. Jaakkola and Alexander (2014) define
four types of CEB: augmenting behavior, co-developer behavior, influencing behavior and mobilizing behavior. Mobilizing behavior refers to the resources given by customers, such as relationships and time, in order to mobilize other stakeholders’ actions toward the focal firm, whereas influencing behavior refers to resources such as knowledge, experience and time given by customers to affect other actors’ perceptions, preferences or knowledge regarding the focal firm. Co-developer behavior involves customers’ contributions to help the focal firm develop its offerings. Finally, when engaging in augmenting behavior, the customer directly augments the focal firm’s offering beyond what is fundamental to the transaction.

Braun et al. (2016) identify three types of CEB: value creation, customer-to-customer interaction and online activities. The first type of CEB includes behaviors that enhance a firm’s product or service offerings. The second type includes behaviors that focus on other customers. While the first two types refer to engagement in an offline context and predominantly involve social interactions, the third type refers to engagement in an online context. This type of CEB takes place without any direct personal interaction; however, it may involve firm and social interactions.

This study uses Van Doorn et al.’s (2010) definition of CEB, which explains that CEB is a state that arises due to interactive customer experiences with a company and results from motivational factors. This definition includes all three types of CEB (value creation, customer-to-customer interaction and online activities) identified by Braun et al. (2016).

The factors that affect CEB
Van Doorn et al. (2010) categorize the factors that affect CEB as customer-based factors, firm-based factors and context-based factors. Customer-based factors include attitudinal antecedents, such as customer satisfaction, perceived usefulness, service quality and trust (Li et al., 2013). Customers’ goals also affect CEB (Chen et al., 2017). These goals may include maximizing customers’ benefits or relational benefits. In many cases, the goals themselves can influence how the brand is used and, consequently, how customers engage with the brand (Van Doorn et al., 2010).

Moreover, personality traits affect the likelihood and level of customer engagement (Van Doorn et al., 2010; Marbach et al., 2016). Marbach et al. (2016) studied CEB in online brand communities and found seven personality traits that were related to CEB: introversion/extroversion, agreeableness, conscientiousness, openness to experience, need for activity, need for learning and altruism. Thakur (2016) studied CEB in the context of mobile devices for shopping and found that CEB arises from six different customer experiences: social facilitation, self-connection, intrinsic enjoyment, time-filling, utilitarian and monetary evaluation experiences. So et al. (2016) divided CEB into five dimensions that collectively reflect the psychological and behavioral aspects of engagement: enthusiasm, attention, absorption, interaction and identification. Enthusiasm refers to a customer’s interest in a brand; attention refers to a customer’s focus on a brand; absorption refers to a customer’s strong concentration on engagement; interaction refers to a customer’s online and offline participation with the brand; and identification refers to a customer’s perceived belongingness to a brand (So et al., 2016). Many of these characteristics can influence customers’ cognitive processes and decision making in predictable ways and affect their behaviors (Van Doorn et al., 2010). Customer resources such as time, effort and money can also affect the level of CEB.

The most important firm-based factors that affect CEB are the company’s brand (actual and perceived) and rewards and other incentives provided to the customers (Hollebeek, 2011; Braun et al., 2016). Many studies have also addressed the role and inclusion of the social dimension of CEB (Calder et al., 2009; Vivek et al., 2012; Braun et al., 2016). The social benefits of CEB include recognition by others and kindness experienced while dealing with others, whereas relationship benefits include the ability to stay in contact with others and intensify relationships (Braun et al., 2016). Firms can also influence CEB by developing and providing...
processes and platforms to support specific customer actions (Van Doorn et al., 2010). For example, the findings of Blasco-Arcas et al. (2016) verify that building an engagement platform that enables customer-to-customer interactions and personalization empowers customers and improves their relationship with the firm and the brand. This requires that the firms encourage customers’ positive emotions during their interactions on such platforms to improve their level of engagement with the firm and perception of the firm’s brand. Providing environments that make customers feel empowered can cause customers to feel that they are relevant actors in the relationship, thus, improving their engagement with the firm. In addition, Rossmann et al. (2016) suggest that prior experience with a firm positively affects engagement (through word of mouth), especially for digital business.

Finally, the context-based factors that affect CEB include political, economic, environmental, social and technological aspects of the society in which the firm and customers operate. CEB is also affected by firms’ competitors and their actions (Van Doorn et al., 2010).

Methodology

Case description

The paper builds on a longitudinal, qualitative, single-case study (Yin, 2003) due to its suitability to holistically analyze previously unexplored phenomena (Eisenhardt, 1989). As a research methodology, case studies can be used to explore and understand contemporary and emerging phenomena in real contexts (Meredith, 1998). As discussed in the introduction section of this paper, streaming TV can be considered a contemporary and emerging phenomenon that is superseding traditional analogue TV. Dyer and Wilkins (1991) and Voss et al. (2002) further argue that single cases allow for researchers to draw in-depth observations and capture the context of the phenomenon in question in much more detail.

A company that provides streaming TV services is used as a descriptive case study to explain a phenomenon and the real-life context in which it occurred (Yin, 2003). The selected case company is one of the three market leaders in Finland, with hundreds of millions in revenue and tens of thousands of customers utilizing the streaming TV service. The studied digital service includes a platform that allows customers to watch live broadcasts on a mobile device, computer and TV. The platform also allows on demand broadcasts from channel packages. As for the case study method, it is common for researchers to select cases to explore different phenomenon in real-life contexts. The researchers’ motivation was to execute a longitudinal study with one of the leading companies in the field. When using single-case studies as a methodological background for research, leading companies can be used for benchmarking purposes to ensure the usefulness of the results (Choi and Hong, 2002; Fisher, 2007). For businesses with a high customer turnover rate, it is crucial to understand the factors that affect CEB in order to increase customer loyalty and satisfaction. The case study approach was chosen because there has been little research on customer engagement in digital business environments, and there is even less research on customer engagement in the context of streaming TV services.

The digital service process for streaming TV in the case company involves five phases: impulse for purchasing, purchasing, implementation, use and maintenance and termination. In the study, the factors that affect CEB at different phases of the digital service process have been examined and compared with the value-creating factors at different phases of the digital service process (Figure 1).

Data collection and analysis

According to Barratt et al. (2011) a qualitative case study can be considered an empirical study that primarily uses contextually rich data from bounded real-world settings to investigate a specific phenomenon. To conduct the empirical study and gain an in-depth view of the empirical environment, we used a broad repertoire of secondary data. The data
collection took place from 2015 to 2016. In the first phase of research, the main body of data consisted of various secondary data, which were accessed, analyzed and synthesized in order to gain an accurate understanding of the digital service process in the case company. The main data source was company websites. To ensure the quality of the secondary data, we relied primarily on official reports written by company insiders. Based on the first phase, we specified the digital service process in the context under investigation.

The secondary data had some limitations. In the second phase of the research, these limitations were overcome by using primary data, which were gathered through interviews, focus groups and participant observations during meetings with a selected focus group (Table I). Six semi-structured interviews were conducted with employees who had various roles at different levels in the firm’s hierarchy. In these interviews, open-ended questions were used to track the different factors that affected CEB throughout the digital service process (the factors were adopted from Calder et al., 2009; Van Doorn et al., 2010; Hollebeek, 2011; Vivek et al., 2012; Li et al., 2013; Chen et al., 2017; Marbach et al., 2016; So et al., 2016; Thakur, 2016). To acquire a comprehensive view of the patterns of CEB at each level, an observational method was used to collect the data. In addition, documentation related to the focus groups was analyzed. All data underwent content analysis. Based on the second phase, common and unusual CEB patterns in different phases of the digital service process were analyzed and discussed in light of prior literature.

<table>
<thead>
<tr>
<th>Data gathering</th>
<th>Study participants</th>
<th>Constructs addressed</th>
<th>Type of data</th>
<th>Data analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semi-structured</td>
<td>Director, online business</td>
<td>Customer participation in the digital service process</td>
<td>Recorded and transcribed</td>
<td>Content analysis of transcribed</td>
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<tr>
<td>interviews (6 pcs)</td>
<td>Director, customer relations</td>
<td>Customer motivation in the digital service process</td>
<td>interview data</td>
<td>interview data</td>
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<td></td>
<td>Director, entertainment business</td>
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<td></td>
<td>Head of customer experience and online services</td>
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<td>Head of market intelligence</td>
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<td></td>
<td>Customer experience expert</td>
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<tr>
<td>Focus groups (3 pcs)</td>
<td>Chief information officer</td>
<td>Value generated by the service</td>
<td>Three written reports about</td>
<td>Content analysis of written reports</td>
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<td></td>
<td>Customer experience expert</td>
<td>Value generated by different phases of the digital service process</td>
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<td>Director, online business</td>
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<td>Head of customer experience and online services</td>
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<td>Head of market intelligence</td>
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</table>

Table I. Primary data
Results
Here, the results of the empirical analysis are presented. The results are divided into those related to customer-based factors, firm-based factors and context-based factors.

Customer-based factors
The results of the study showed that the most important customer-based factors during the impulse phase of the digital service process were related to consumption goals and personality traits. During the impulse phase, the consumption goals were mainly related to the price and availability of the service. At a general level, service providers could be categorized based on their pricing strategies, which reflected customers’ behavior when their impulses were affected by the environment. The availability and possibility of utilizing services (in this case study, anytime and anywhere) were related to personal consumption goals. On the other hand, personality traits were related to both the image of the service provider and the personality of the customer:

Some people just want to get iPhone. When we are asking them about the reasons to purchase one, they just mentioned that there is no rational reason, it just suits well with their personal traits.

The most important customer-based factors related to the purchase/implementation of digital services were customer resources and attitudinal antecedents related to the service/product. Customer resources include customers’ financial resources as well as the knowledge/skills to utilize services. If a customer lacks these resources, he/she may not want to be engaged in the digital service process. However, if a customer has the financial and knowledge resources to purchase more comprehensive services, then he/she is more willing to engage in the purchasing/implementation phase, for example, by customizing the services. Attitudinal antecedents related to the service/product were also important customer-based factors during the purchasing/implementation phase. Some customers are very “tradition-minded” and thus do not want to engage in new or additional service processes, regardless of whether they have resources. However, curious customers (with the necessary resources) with openness to new solutions are willing to engage in the service process during this phase:

Basically, we have two kinds of customers. The ones that know very well what they need and only want to purchase it. They want a fast and simple delivery process and nothing extra. Then there are customers who want to utilize the services and ease their life or at least make it smoother. These group is also more and more engaged in the service processes.

During the use and maintenance phase of the digital service process, the most important customer-based factors were customers’ resources/skills and attitudinal antecedents related to the service. Customers’ resources/skills refer to a customer’s history of using services. The more services the customer has used in the past, the more capable he/she is to use additional services and the more willing he/she is to be engaged in, for example, product development during this phase. Resources/skills and attitudinal antecedents were also related to customers’ utilization of services and willingness to be engaged with the service. The more skills or resources the customer can use to take advantage of services, the more willing he/she is to be engaged with the service. Again, customers with openness to new solutions are more willing to be engaged with the service during this phase:

If the customers are engaged, for example for new service testing or development, it seem no more to be question of how we can find volunteers. It is more of how we can facilitate them. It seems that the customers are continuously developing their digital skills and capabilities and they are willing to be engaged. That causes challenges for service producers to handle the facilitation.

During the termination phase of the process, the most important customer-based factors were attitudinal antecedents related to the service/product. The willingness to be engaged with the
service and attitudinal antecedents (experience of personal treatment and trust) determine whether a customer relationship is terminated or if the use of a digital service is stopped. Such decisions depend on whether those factors were positive or negative. Customers who stop using the service for negative reasons or because of a negative customer experience are usually not willing to be engaged with the service, while those who stop using the service but did not have negative experiences are more willing to be engaged with the service. Usually, the latter customers also provide valuable feedback and development suggestions:

We are following terminating/leaving customers and asking reasons for these activities. It is quite soon clear, if the reasons behind the leaving are negative or something else. That has an effect to customer’s willingness to be engaged to this phase of the process.

Regarding value creation at the impulse phase and (in particular) the purchasing phase, it was considered important that the customer understood the entire service portfolio, including additional services (e.g. recording). This requires opening all value-creating factors for streaming TV to maximize the customers’ benefits. It is also important to ensure that the customer understands to what he/she is committing. Considering the value related to usability and user experience, it is essential that the implementation and use of all services are effortless, which requires solving customers’ problems and turning them into a positive experience regardless of the customers’ attitudinal antecedents or skills related to the service. Regarding the termination phase, it must be easy for the customer to stop the service because this enhances the customer’s trust in the provider. However, it is also important to provide incentives for customers to extend their contract so that the customers have a positive overall experience, in line with the results of the focus group sessions, which examined the value of the streaming TV services. The main value-creating factors were broadcasting quality, content portfolio comprehensiveness, the opportunity to watch on all types of devices, the opportunity to watch anytime and anywhere and the ease of purchasing and implementation. Customer experience was an important factor that affected CEB, especially in the use and maintenance phase.

**Firm-based factors**

This study showed that the most important firm-based factors during the impulse phase of the digital service process were related to brand and rewards and other incentives. The service provider’s brand positively or negatively affects the customers’ image of that provider, thus, affecting the customers’ personality traits. Rewards and other incentives are especially important for special campaigns, such as those occurring during the holidays:

Traditionally rewards and other incentives are commonly used to lure and engage customers to utilize digital service. However, lately these rewards and incentives have turned to be hardly to use as competitive advantages. It seem to be that currently the brand makes customer to want to be engaged.

The most important firm-based factors related to the purchase and implementation of the digital service were the social dimension and processes and platforms. Even though customers are purchasing digital services or products, they still want to engage in the social dimension of purchasing. Some customers have little understanding of the services they want to purchase and thus require support. Those with better understanding and skills appreciate the social dimension and may, for example, want to confirm hypotheses with professionals and customize their services. In addition to the social dimension, proper processes and platforms for purchasing were found to be important. These platforms can be physical or digital as long as the customers understand them well and the platforms include a social dimension:

Main part of the digital services are still bought physically. Even though the number of digitally purchased services is raising, there still have to be social dimension included in the digital purchasing. Customers want to have a possibility to be engaged, in case it is needed.
During the use and maintenance phase of the digital service process, the most important firm-based factors were processes and platforms, rewards/other incentives and the social dimension. If the customer wants to engage in, for example, service development or customer activation processes, proper processes and platforms must be available. For some customers, rewards and other incentives motivate engagement. The social dimension is also important, whether social engagement occurs physically or digitally.

During the termination phase of the process, the most important firm-based factors were reputation/brand, the social dimension and rewards/other incentives. The engagement factors related to reputation and brand can be motivated by either positive or negative reasons and may lead to termination of the service. If termination is due to a bad customer experience, then the reason for engagement may be to hurt the reputation of the brand. The social dimension is also important during the termination phase. Rewards and other incentives are provided mainly to encourage customers to continue rather than terminate the digital service.

During the impulse and purchasing phases, value creation was perceived as important for promoting the uniqueness of the service, especially regarding the content’s comprehensiveness (e.g. its sports offering). Combined with the proper incentives, this was perceived to affect customers’ brand awareness. Regarding the implementation and use of a service, the firm personally contacts customers (through customer service and user activation) in order to highlight the importance of customers and their own skills regarding the service and to ensure that customers have access to the correct services. This was perceived as the proper way to enhance the social dimensions that affect CEB.

Context-based factors
This study showed that the most important context-based factors during the impulse and purchasing phases were technological factors and competitors. Technological factors include new possibilities or requirements created by the development of technology. Technological possibilities may, for example, offer new platforms or social media solutions/services that customers can purchase or engage in. On the other hand, technological factors may force the customers to be engaged in digital services if, for example, some traditional physical services are terminated or replaced. Competitors’ activities also affect CEB; for example, new services or offerings may cause customers to change service providers.

During the purchasing phase, technological factors were of primary importance. As mentioned above, these factors may refer to new possibilities or requirements created by the development of technology. As customers become more aware, environmental and social factors also affect their engagement behavior. These factors are mainly related to manufacturing and ethical issues regarding services and products. Competitors’ activities and technological possibilities and requirements may affect CEB during the termination phase of the digital service process.

Regarding value creation in the impulse and purchasing phases, customers must perceive a company’s content comprehensiveness as superior to that of competitors if they are to continue using the service or offering. Promotion of this was considered a crucial factor that affected CEB. Furthermore, highlighting the opportunity for customers to watch a variety of content on any device, anytime and anywhere, was perceived as a technological and social factor that affected CEB. The technology can be considered social because it enables all members of a family to watch different content on their own devices and link their user experience to their own social relations (e.g. friends, colleagues, neighbors).

Discussion
In this study, the digital service process for streaming TV, which included the customer’s entire lifecycle, was examined in terms of CEB. Specifically, the study focused on what customer engagement factors were emphasized in the different phases of the customer’s
lifecycle in the digital service process. Afterward, the results were discussed in terms of Van Doorn et al.’s (2010) categorization of CEB factors, including customer-based factors, firm-based factors and context-based factors. The results highlighted customer engagement during the front-end phase of the digital service process while considering all three categories of CEB. The customer-based factors, including consumption goals, personality traits, customer resources and attitudinal antecedents, were emphasized. The findings showed that the consumption goals during the impulse phase were mainly related to the price and availability of the service. The possibility of utilizing services anytime and anywhere was also related to personal consumption goals. Furthermore, if the customer had the financial and knowledge resources to purchase more comprehensive services, then he/she were more willing to engage in the implementation phase, for example, by customizing the services. Thus, it was determined that elements such as customer satisfaction, the maximization of customers’ benefits, social facilitation, time-fulfilment and monetary evaluation experiences were important for customer engagement, especially during the front-end phase of the digital service process (c.f. Marbach et al., 2016).

Regarding the firm-based factors, the brand and variety of incentives were considered essential to the customer’s purchasing decision, which was reflected in the customer’s CEB during the front-end phase of the process. Based on the findings, the special campaigns, including rewards and other incentives, were perceived as especially important during the impulse phase of the digital service process, even though they were not considered competitive advantages. In addition, all types of customers seemed to value social interaction during the purchasing and implementation phases, for example, to confirm their own expectations with professionals and to customize their services. Thus, this result strongly supports the findings of Hollebeek (2011) and Braun et al. (2016). Additionally, the context-based factors were emphasized in the front-end phase because technological competitiveness and marketing campaigns were considered essential to customer engagement. Based on the findings, context-based technological factors that included new possibilities or requirements created by the development of technology were perceived as important during the impulse and purchasing phases. For example, the opportunity for customers to watch a variety of content on any device, anytime and anywhere, was considered as a technological factor that affected CEB. Thus, service providers must focus on these factors in order to manage the business better than competitors (Van Doorn et al., 2010).

During the back-end phase, the customer-based factors and context-based factors were highlighted. For example, attitudinal antecedents, such as experience of personal treatment, perceived usefulness, service quality and trust (Li et al., 2013), are important when you want to keep a customer or get a customer back. The findings of the termination phase of the process suggested that these attitudinal antecedents determined whether a customer relationship was terminated or if the use of a digital service is stopped, and such decisions depended on whether those factors were positive or negative. The context-based factors, especially offers, marketing campaigns and technological development, are critical to customer engagement during the back-end phase because they help firms overcome their competitors (c.f. Van Doorn et al., 2010). The company’s brand and reputation (Hollebeek, 2011; Braun et al., 2016) were not perceived as important factors during the back-end phase because they were considered more meaningful when the service was acquired for the first time.

Last, the study presented an application of Van Doorn et al.’s (2010) framework in the context of the digital service process for streaming TV. Based on this study, the framework seems to be a valuable tool that allows for the comprehensive description of the factors of CEB when aiming to manage digital service process. Thus, the study has attempted to validate the framework through a case study concerning CEB throughout the digital service process (Table II).
Conclusions
This study contributes to the results of previous studies on CEB and investigates CEB in the digital context. It contributes to the literature by identifying the factors that affect CEB in different parts of the digital service process (Figure 2). This study suggests that the factors that affect customer engagement differ among different phases of the digital service process and highlights the importance of engagement during the front-end phase.

### Table II.
The results of factors that affect CEB

<table>
<thead>
<tr>
<th>Factors affecting CEB</th>
<th>Description</th>
<th>Phase of the digital service process</th>
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<tbody>
<tr>
<td><strong>Customer-based factors</strong></td>
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<tr>
<td>Consumption goals</td>
<td>Way of using the product/service (how, what, how often)</td>
<td>Purchase/implementation</td>
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<td></td>
<td>Perceived effortlessness (price and availability of the service)</td>
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<tr>
<td>Resources</td>
<td>Financial resources</td>
<td>Purchase/implementation</td>
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<tr>
<td></td>
<td>Knowledge/skills to use service</td>
<td>use/maintenance</td>
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<td></td>
<td>Own experience/history of using the service</td>
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<tr>
<td>Personality</td>
<td>Reactiveness</td>
<td>Impulse</td>
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<td></td>
<td>Possibility to be in the forefront of development</td>
<td>Purchase/implementation</td>
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<td></td>
<td></td>
<td>Termination</td>
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<td>Attitudes</td>
<td>Usability of the service</td>
<td>Use/maintenance</td>
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<td></td>
<td>Perceived usefulness</td>
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<td></td>
<td>Perceived service/customer experience</td>
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<td>Perceived value added</td>
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<td>Possibility to influence</td>
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<td></td>
<td>Experience of personal treatment</td>
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<td></td>
<td>Trust</td>
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<td>Firm-based factors</td>
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<tr>
<td>Proactiveness</td>
<td>Involve customer in the development of products/services</td>
<td>Impulse</td>
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<td></td>
<td>Time and resources put to CEB</td>
<td>Purchase/implementation</td>
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<td></td>
<td>Processes of involving customers</td>
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<tr>
<td>Social dimension</td>
<td>Possibility to purchase services physically</td>
<td>Purchase/implementation</td>
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<tr>
<td>Processes/platforms</td>
<td>Possibility to purchase services digitally</td>
<td>Use/maintenance</td>
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<tr>
<td></td>
<td>Possibility to communicate with experts both physically and digitally</td>
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<tr>
<td>Understanding</td>
<td>Responding to customers wills and usability traits</td>
<td>Use/maintenance</td>
</tr>
<tr>
<td></td>
<td>Making it easy for customers to use</td>
<td></td>
</tr>
<tr>
<td>Brand</td>
<td>Emotions stirred within the customers</td>
<td>Impulse</td>
</tr>
<tr>
<td></td>
<td>Technical competitiveness</td>
<td>Purchase/implementation</td>
</tr>
<tr>
<td>Value creation</td>
<td>Interaction between producer and customer</td>
<td>Impulse</td>
</tr>
<tr>
<td></td>
<td>Communication toward customer (promotion of the services)</td>
<td>Purchase/implementation</td>
</tr>
<tr>
<td>Incentives</td>
<td>Offers</td>
<td>Impulse</td>
</tr>
<tr>
<td></td>
<td>Marketing campaigns</td>
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</tr>
<tr>
<td>Context-based factors</td>
<td></td>
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</tr>
<tr>
<td>Competitors</td>
<td>Offers</td>
<td>Impulse</td>
</tr>
<tr>
<td></td>
<td>Marketing campaigns</td>
<td>Purchase/implementation termination</td>
</tr>
<tr>
<td>Technology</td>
<td>Possibilities or requirements created by technology development</td>
<td>Impulse</td>
</tr>
<tr>
<td></td>
<td>Environmental concerns caused by the service provider</td>
<td>Purchase/implementation termination</td>
</tr>
<tr>
<td>Environment</td>
<td>Environmental concerns caused by the service provider</td>
<td>Termination</td>
</tr>
<tr>
<td>Social</td>
<td>Social recognition of the service provider</td>
<td>Impulse</td>
</tr>
<tr>
<td></td>
<td>Social concerns caused by the service provider</td>
<td>Termination</td>
</tr>
</tbody>
</table>

**Note:** The most accentuated factors are in italic
of the process. During this phase, customer-based factors are emphasized. During the back-end phase, complete services and solutions are provided in a digital format; thus, the role of engagement in value creation is shaped by maintaining and updating provided solutions. In these phases, the customer-based and context-based factors of CEB are emphasized, while firm-based factors are of less importance.

As a practical implication, these findings increase the understanding of CEB in streaming TV and therefore can assist practitioners in constructing value propositions. In addition, the division of factors that affect CEB assists in managing the phenomenon because they are more easily manageable than the whole phenomenon.

The results of this paper are based on a case study, which limits the generalizability of the findings. However, due to the nature of the research subject, the use of an in-depth case study is an appropriate research strategy for gaining a deeper understanding of the factors that affect CEB in the digital environment. More in-depth action research and case studies are needed to validate the results’ suitability, usefulness and acceptability.

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Digital services governance: IT4IT™ for management of technology

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Abstract

Purpose – The purpose of this paper is to present, analyse and demonstrate the impact and potentials of a pragmatically derived information technology (IT) governance framework, IT4IT™, for the discipline of management of technology (MoT) especially within the IT industry.

Design/methodology/approach – This paper is based on an extensive literature study working with the limitations of the relatively recent publication of IT4IT™ and the normative character of IT4IT™. A mixed-method case study is presented based on an IT service provider organisation. Both a qualitative method and a systems and design oriented method are being used.

Findings – IT4IT™ can provide value and a clearer understanding of the service delivery framework if the technological core of the focal organisation is adapted to a value stream thinking. This suggests a more operational character of all IT processes and analogue to general MoT frameworks and corporate governance models.

Research limitations/implications – Given the recent publication of the IT4IT™ framework, this study is primarily ex ante and suggests further full-scale ex post research in the future.

Practical implications – Validation and successful implementation of the IT4IT™ framework will give companies better opportunities for safe and controlled value creation using IT. Control connects with risk reduction and less risk can encourage innovation and “tame” development complexity. Using value streams will align IT better with manufacturing and services.

Originality/value – Companies are striving to seek governance and risk minimisation in IT development and operations. This paper is discussing the applicability of the IT4IT™ framework for finding a better understanding of the value creation and value proposition delivered by introducing controlled processes minimising risk.

Keywords IT4IT, IT service management, Management of technology, Digital business creation, SIAM

Paper type Research paper

1. Introduction

The digital transformation is central in most industries as an established or perceived game changer for business models and as the most strategically technological priority (Ba and Nault, 2017; Westkämper and Walter, 2014; Kodama, 2014). Information technology (IT) is a locomotive for many new industries and business models with technology penetrating areas of business hitherto not affecting by technological innovations (Rossignoli et al., 2016; Candi, 2016). Digital business models and disruptive innovations have become synonymous at least in a popular perception (Song, 2017; Tongur and Engwall, 2014).

Proper outcome of development, implementation and service orientation of digital initiatives is strategically determining in existing and emerging industries (Park et al., 2014; Lepmets et al., 2012). Despite the criticality of IT, IT development projects are generally regarded to be high-risk (Standish Group, 2016) pertaining to cost overrun, lack of quality and delays. In a management of technology (MOT) perspective, transition from development to operations of digital solutions is especially complicated as it involves a non-transparent fabric of technological and organisational processes across multiple or
numerous organisational entities (Cetindamar et al., 2009; Sarkis et al., 1995). Life-cycle management is unclear, and generally being difficult to measure (McNaughton et al., 2010; Berman et al., 1994). As a core technology of modern business, MoT approaches seem obvious to harness and guide processes of IT (Gaimon, 2008).

IT, as a technology, has largely, to this day, been controlled by “soft” governance frameworks such as project management systems and service management systems more being pragmatic normative constructs than actual business model foundations for IT organisations (Mesquida et al., 2012; Kumbakara, 2008; Lee and Om, 1994). IT has until now, in many ways, been regarded as exempted from the structuration and automation represented by IT itself. Several frameworks suggest that IT governance is critical in obtaining predictable positive outcomes of investments and cost, such as COSO, ITIL, COBIT, BiSL, ISO27000, MOF, CMMI and TOGAF (Ali et al., 2013; Lucio-Nieto et al., 2012; Melendez et al., 2016; Berrahal and Marghoubi, 2016; Tsunoda et al., 2017).

The IT4IT™ framework released by The Open Group in October 2015 suggests to a major change (Josey, 2015; Moore, 2016; Morlitz, 2016; Ng, 2016). IT has to be governed and structured along defined processes of value chains, life-cycles, service propositions, customer interaction and cost control as any other area of the organisation. In simple terms, IT4IT™ propose to think IT services produced like well-defined products in a modern factory (Westkämper and Walter, 2014; Schrader and Droegehorn, 2016).

The purpose of this paper is to review IT4IT™ as a practical implementation of a MoT framework and to review its perspectives and implications to the MoT society as well as the contributions it has to IT professionals, innovators and MoT practitioners.

Motivated by IT as a key transformational technological force in most organisations, and motivated by IT4IT™ as a suggestion for re-thinking corporate IT services, the research question of this paper is:

**RQ1.** How should the IT4IT™ framework be interpreted as an MoT framework, with respect to the dualism of IT as both innovation driver of the business, but also IT as focal in development and operational resources spend in the organisation?

Furthermore, this paper emphasises that with IT4IT™ as a suggestion for introduction of value chain processes in the IT value chain reaching from idea to operations, whereas earlier frameworks (e.g. PRINCE2 vs ITIL) have focussed on either development or operational processes. Thereby, the research lens of this paper is the assessment of IT4IT™ as an unbroken chain of value creation bringing IT closer to manufacturing theory and practice.

2. Literature study

This literature study is first presents the foundations of MoT in order to establish the referential relationship to the technological framework. Second, this section presents IT service perspectives in order to define IT as a broader and more complex technology than computing. Lastly, this section is presenting the IT4IT™ framework. The underlying claim of the literature study is to support and pinpoint a research gap in the perception of MOT being unrelated to industrial frameworks for design, development and operations of technology. Furthermore, the literature study is aimed at finding support for a general split of IS (read:technology) frameworks in development and operations. This split is a risk for failure of innovation. The research gap to address in the literature study is henceforth, why development and operations remains split, and what characteristics and success criteria an empirically driven framework IT4IT™ would need to meet to fulfil to offer an end-to-end framework for technology.

2.1 Management of technology

MoT predominantly addresses strategic considerations of technological systems of the enterprise (Shalley and Gilson, 2017; Kerr et al., 2013; Phaal et al., 2004, 2006).
However, MoT must be as a broad discipline to manage technologies also at a tactical and operational level, or at least design tactical and operational systems (Lucio-Nieto et al., 2012; Alter, 2014b). MoT typically addresses the life-cycle of technologies in the line going from early innovation up to the implementation, operations and end-life matters (Kim, 2013), although MoT just a frequently stops before manufacturing. Complementary to MoT life-cycle orientation, operations management address the cycle of value creation in the operational longevity of technology expressed by value chain management and discussions of business model creation (Kattenstroth and Heise, 2011; Tongur and Engwall, 2014). Kim (2013) moreover discusses the phenomenology of technologies using the Gartner Hype Cycle that describes technologies out of public professional interest and current perceptions on solving future anticipated problems. Hype constitutes both a driver and a bias in MoT (Berg et al., 2015) where the governance structures must deal with a more system fact-finding and decision-making process.

Enterprises must act in distinctive elements of design and engineering to ensure meaningfulness in the relation between organisation and technology (Mesquida and Mas, 2015; Sarkis et al., 1995), hereby emphasising MoT importance in the practice. Shalley and Gilson (2017) pinpoint MoT as the discipline of balancing creativity and innovation towards operations and standardisation. This is followed by Gaimon (2008) in a more general introduction to MoT and operations management as tightly connected and mutually dependent in aspects such as technological acceptance and diffusion, adoption of new manufacturing technologies, and technologies affected by and affecting innovation capability and knowledge management (Kirkman, 2016; Skaggs et al., 2012). Noh et al. (2017) suggest a data-driven model for technology evaluation and MoT.

Lindén (2013) suggests a model for MoT of IT/ICT encompassing the breadth of disciplines within corporate practice such as considerations for strategic directives, purchasing and a technological assessment of a range of elements constituting IT, such as hardware, software, integration and operations.

Information systems (IS) make up a strong load within the investment budget of many organisations, and return-of-investments is often overly difficult to calculate (Shrestha et al., 2013); MoT must be organised to ensure balance between the economic dimension of IT investment and the organisations ability to embrace new and promising technologies (Ba and Nault, 2017). Berman et al. (1994) express MoT as operating a set of strategic levers within the enterprise to ensure technology–strategy integration and alignment, especially activities of planning, organisation and control.

Thinking “frameworks” is deeply integrated in MoT research (Beard, 2002; van Wyk, 1988) with an MoT framework aiming at technological function, performance, principle and general features. People, task, technology, structure and strategy are connecting points in the analogue framework (Lee and Om, 1994). Kerr et al. (2013) highlight MoT as processes of identification, selection, acquisition, exploitation and protection vs strategy, innovation and operations. Furthermore, Kerr et al. (2013) suggest practical toolkits for governance and inclusion consisting of elements of human-centric approaches, workshop-based, neutrally facilitated, modular, scalable and visual. Many classical framework approaches have suffered from overemphasis on tangible technologies. Services connected to tangible technologies and service-based technologies are somewhat overlooked (Martin and Daim, 2012); services are related to a broad range of technologies from telecommunication, information exchange, digital businesses, advanced industrial services, as well as typical manual services with elements of technology like care, teaching, cleaning, gardening, etc. (Chang et al., 2014).

As exemplary of one specific technology that penetrates more sectors and attracts more interest than most other technologies is IT. IT is regarded by most a key innovation driver, often expressed as “digital transformation”, but, at the same time, a highly persistent and
static part of the corporate infrastructure (Gardner et al., 2016; Iden and Eikebrokk, 2013). This leads to a position of IT as both being of innovation and development and, at the same time, operation and maintenance. Often, this has been formulated as an ambidextrous capability (Chang et al., 2014). MoT and MoT frameworks must support research and practice in safely coordinating the two positions in an economic way, emphasising risk reduction and process performance.

2.2 IT and services
Services are identifiable abstractions of, mostly, human work and human intervention using a relatively broad set of skills and competencies (Tapandjieva et al., 2017; McBride, 2009; Kans, 2013). Services are closely related to human work that both rely on services but also produce services in work-systems (Alter, 2014a, b). In this context, work and services will be closely linked to technology and service creation on the basis of technology (Ulbrich and Schulz, 2014; Rennung et al., 2014; Mora et al., 2015). In IT and IT-based business development, the concept of service has several meanings often with a transcendence between professionally defined concepts and colloquialism, a.o.:

1. human advice and intervention, like a service desk (Kekkonen and Arasmo, 2016);
2. the perceived quality of interaction, like “a polite service”, or “bad service” (Mesquida and Mas, 2015);
3. technical features and available utilities, like a network connection (Mesquida et al., 2012); and
4. information, information exchange, information provision, like the weather report (Warfield, 2016).

ITIL and the IT service management philosophy define a services hierarchy as (Kasulke and Bensch, 2017; Cruz-Hinojosa and Gutiérrez-de-Mesa, 2016; Lucio-Nieto et al., 2012; Wulf et al., 2015; Andenmatten, 2016b; Cots et al., 2016):

1. service strategy;
2. service design;
3. service transition;
4. service operation; and
5. continual service improvement.

Service design and service operations are typically translated into ITIL core services (Ali et al., 2013), where ITIL has gone from a pragmatic framework into a global standard. Core services are:

1. incident management;
2. problem management;
3. change management;
4. release management; and
5. configuration management.

As services constitute the configuration of tangible as well as intangible assets, the services have to be registered in a configuration management database (CMDB) (Wu, 2014). The CMDB is useful as a reference for services and portfolios making up the architecture. However, CMDBs are demanding to maintain, and may be imprecise.
CMDB might, in the future, be more precise and interesting as they can be machine-generated, and rightfully designed, and can provide the reference architecture blueprint for automated service definitions.

IT is commonly organised as development activities vs operational activities. TOGAF and more frameworks describe and govern development (Tambo et al., 2016; Betz and Jahn, 2016). Development activities are often emphasised along with general corporate innovation priorities, and IT investments must be reviewed as both innovation and maintenance of existing capabilities to keep up with change (Peters et al., 2016; Candi, 2016; Jaw et al., 2010; Kießling et al., 2010; Lusch and Nambisan, 2015). An over-arching management system pinpoints project and portfolio management focussing on resource allocation and management of time and money invested (Vesterinen, 2015; Wang, 2016; Jolly, 2003). Operations are, in professionalised environments, often organised as services unrelated to development following the mindset of the ITIL framework (Cruz-Hinojosa and Gutiérrez-de-Mesa, 2016; Keel and Hodges, 2016); however, the literature also questions separating operations and development.

IT operations, over the last 15 years, generally adopted a service-thinking in concepts like “service oriented architecture” and “IT service management” (Berrahal and Marghoubi, 2016; Cots et al., 2016). However, the actual meaning of service is highly different from context to context, and it does not provide a specific rationale to state that existing IT delivery models are fully service-enabled (Curry, 2014; Jia and Reich, 2013). Service might though provide a useful level of abstraction for standardisation and structuration, and, within this, also useful services as building blocks in establishing corporate systems architectures (Keel and Hodges, 2016). Archimate® is an example of a modelling language supported by several vendors that can represent a service portfolio adding to the enterprise architecture (Band et al., 2015).

A fundamental of IT services is measurability. Services must be defined for expected outcome with associated relevant systems for measuring the performance or quality of the service (Betz and Jahn, 2016; McNaughton et al., 2010; Lepmets et al., 2012). Operational and transitional IT processes are connected by appropriate management practices generally known as IT governance focussing on best practices, corporate strategic alignment and standard operations procedures (Schrader and Droegehorn, 2016; Vlietland et al., 2016; Bin-Abbas and Bakry, 2014; Bañuls and Salmeron, 2008). This must hold against IT as complex, risk-based and with difficulties in holding technology static without losing competitive momentum.

### 2.3 IT4IT™

IT4IT™ is a standard developed and managed by The Open Group (Daniel, 2016; Styles, 2016; Bañuls and Salmeron, 2008; Josey, 2015). The first edition was released in October 2015. The Open Group is a standardisation organisation mainly supported by a range of the largest IT companies. The Open Group has developed a range of technology standards within foundations of IT, e.g. UNIX, IT interoperability, e.g. ODBC, and processual guides such as TOGAF (Tambo et al., 2016). IT4IT™ introduces a new style of thinking IT with specific aim of presenting IT as being fundamentally a tight knit combination of development and operations: like the process of developing and manufacturing a car; like an airline company; or like a chain of restaurants. The IT4IT™ position is making distance from the previous hard line of separating development and operations activities (Akershoek, 2016), represented by frameworks like PRINCE2 and ITIL, respectively. Moore (2016) states: “The IT4IT™ Reference Architecture allows the IT function to operate as a business in its own right. It recognizes IT as a production-oriented business, a manufacturer of code. Consider this in the light of the software development function making or breaking a business […]”.
More fundamentally, IT4IT™ is suggesting a position of representing IT from a value chain perspective (Walser et al., 2017; Kattenstroth and Heise, 2011). A value chain that ranges from strategic requirements up until successful and ongoing operations is a value chain, and a value chain that ranges from detailed business requirements and opportunities to benefit realisation, like any other technology in the company.

The basic concept of the IT4IT™-defined value chain is illustrated in Figure 1. Moore (2016) phrase IT4IT™ as an inevitable consequence of digital transformation of companies. When digital services become the foundation for the productive technologies of the companies, IT must be used to manage IT, such as IT can be used in management of a building or a vehicle. Andenmatten (2016a, b) emphasise that improvement in the development organisation and higher and faster precision of the service organisation is necessitating a common reference architecture with a joint information, functional and data model as suggested in IT4IT™ and illustrated in Table I.

Speed, reduced risk and cost efficiency are also suggested by Marimuthu and Venkatesan (2016). Even for legacy system architectures, IT4IT™ is proposing a "reinvention" of a high level of transparency, expressed as “Just as cloud is a disruptive force in technology platforms, the IT4IT™ Reference Architecture […] is a disruption of existing operating models” (Morlitz, 2016).

![Figure 1. The IT value chain](image)

**Table I.** General approach to the IT4IT™ reference architecture

<table>
<thead>
<tr>
<th>Component</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Functional model</td>
<td>High-level definition of all functional areas for IT</td>
</tr>
<tr>
<td></td>
<td>Based on customer use case analysis</td>
</tr>
<tr>
<td>Service model</td>
<td>Based on ITIL, service life-cycle and high-level grouping of: continuous</td>
</tr>
<tr>
<td></td>
<td>assessment, continuous integration and continuous delivery – and later into</td>
</tr>
<tr>
<td></td>
<td>value streams</td>
</tr>
<tr>
<td>Information model</td>
<td>Identification of key controlling IT artifacts</td>
</tr>
<tr>
<td></td>
<td>Definition of artifact life-cycles according to life-cycle model</td>
</tr>
<tr>
<td>Foundational integration layer</td>
<td>Defines key control points for integration, based on artifact</td>
</tr>
<tr>
<td></td>
<td>Link Information model with life-cycle model</td>
</tr>
</tbody>
</table>

**Source:** Josey (2015)
2.4 Theoretical model and research gap

The three theoretical foundations of this study are presented above: MOT, IS/services and IT4IT™. As set out in the research question, IT4IT™ is reviewed from its ability to provide meaningful interconnect between development and operations in the IS field alongside contrast itself with MoT, thereby understanding MoT as guiding for the overall efforts and initiatives of the company. To this end, industrial and empirical frameworks like IT4IT™ are then interesting to review from their ability to provide a meaningful and sufficient explanatory basis for transformation activities of the company. The assumed research gap is this field is hence the receptiveness in theory and practice of new introductions of end-to-end technology management frameworks IT4IT™.

3. Methodology

This paper is based on a qualitative, interpretistic and sociologically-inspired methodology in the tradition of IS studies (Walsham, 1995). Practice of relevance is underscored in the case study with an IT/IS providing organisation and its stakeholders (Benbasat and Zmud, 1999). Action research not only plays a significant role as the organisation and sociotechnical systems are affected by the study practices, but also reacts upon the imposed changes (Baskerville and Wood-Harper, 1996). The main case relies on a major case study with five months of in-depth, daily effort to observe, collect and structure data (Yin, 2013). The data collection approach consisted of daily observations in the work environment, participation in internal project meetings, interviews with customers or customer representatives, system design and modelling, model creation in BPML, UML and ARCHIMATE/TOGAF. The tradition of studying technology from its constituting structures is followed (Orlikowski, 2000).

Empirically, this paper is based on an extensive case study of a large IT service provider (Tambo et al., 2016; Aramand, 2008). The IT service provider used the framework, along with other frameworks, to introduce larger degree of homogeneity of its own service “catalogues” (Kumbakara, 2008), improved processes for navigating in the heterogeneous of its customers, and to ensure uniform processes of performance management and reporting (Lepmets et al., 2012). The empirical data collection was conducted during February–May 2016, and consisted of one co-author’s full-time presence in the organisation. During this period, three or four key stakeholders of the three main clients (banking, food and transportation industries) of the service provider were interviewed two or three times. The key stakeholder from the service provider’s side was the customer service manager (CSM). The CSM had core team of approx. four persons for designing, coordinating, delivering and measuring the services. The clients had likewise a team of one senior manager with specialists in e.g. network and security, service requirements specification, and legal advisors. For the implementation of the service architecture, a team of around six persons worked in service design, architecture development, metrics specification, metrics (business intelligence) implementation. All stakeholders and participants were interviewed or their roles and positions were recorded along the technical specifications and designs. As some team associates had minor roles and some had multiple roles; the overall team followed by this project had around 20 persons. Along with interviews, meetings, communication, relationships, knowledge positions and technical efforts were used as data sources. Technical efforts are to be understood as technical skills, insights in the service providers’ infrastructure and capabilities, insights in the customers’ infrastructure and service requirement, and actual models and systems developed and put into production.

Methodologically, this paper has been challenged by the novelty of the topic of IT4IT™ as few peer-reviewed materials are available. A broad range of analogue communication channels therefore had to be reviewed. This included among others standards, whitepapers, blog postings, student works, professional presentations, webinars, online training materials
and Youtube videos. Methodologically, new topics initiated phenomenologically or, as in this case, as a new standard, must fight the weakness of absence of prior work that is challenging the precision of the findings and outcomes. This effort has brought a range of materials that positively has supported the knowledge collection process. The main criticism within this approach includes: unsubstantiated commentaries (blogs), vendor bias and absence of scientific foundations. These three issues have all been taken into account and, eventually, the reference base of this paper is predominantly scientific materials.

A limitation of this study is that IT4IT™ is seen from the service provider’s side, and not from the focal organisations side. The service provider has earlier been integrated in a consuming organisation, and has first recently more visible role in the general market. The former role of the service provider improves the likeliness of outcome to focal organisations in general. The service provider is engaged with a range of larger enterprises in Northern Europe. In this role, the service provider is exposed to trends and operating styles in many different industries, thereby suggesting a higher validity of the findings. Representatives of three larger customers were interviewed as a part of the study: a food production company, a company in public transportation and a financial institution. These interviews approved the changes in the service offerings of the company described below. The three companies therefore provided a triangulation of the results in assurance of the practical and theoretical reproducibility and viability of the presented data, analysis and results.

4. Case study
Pollux is a major Northern European IT services provider that employs approx. 2,500 IT professionals. Pollux was spun-off from a larger research and manufacturing organisation in the life-science industry and was introduced at the stock market around 2015. The IT services are mainly in the field of IT infrastructure operations, software systems operations and management, help- and service desks, standard software implementation, application management, cloud services, clients and database management. Industries of focus are larger industrial enterprises, governmental services, healthcare and life science, and the financial industry.

Pollux have had a process of departing from its originating organisation and aimed at taking new, larger, professional customers on board. A customer engagement could start at US$1m pa and go up to US$20m pa. A customer engagement is normally viewed over several years and thus the total contract amount ranges from 5m USD to some hundred million USD.

In the process of getting new customers, Pollux has been highly oriented towards documenting and measuring its performance at a very detailed level adapted to the customer’s specific requests. These requests have been developed in the initial customer dialogue based on the specific focal services of the CSM and the customer’s purchasers and decision makers. The combination and configuration of services have been adapted to customer requirement or perceived customer requirements at a very detailed and somewhat unsystematic level. The unevenness of service configurations for each customer has had consequences. Pollux’s ability to deliver well-identified services has developed with the customer, and it has been difficult to utilise services and learning of services quality from one customer case to the next.

Pollux started in late 2015 an initiative towards harmonising services. Following the ITIL framework, the pool of services within the individual customer service contracts was tentatively merged into more standardised services. The purpose of the standardisation effort was expressed within the CSM forum as:

- establish patterns of activity as services entailing people, skill, technology and capability;
- standardisation as professionalization;
• present and describe standardised services in a service catalogue along with a CMDB definition process;
• develop customer expectations and (produced) service level on the standardised services of the service catalogue;
• promote reporting and business intelligence offerings to customers according to standardised services rather than customised services, where this was not necessary; and
• simplify reporting and tentatively make reporting real-time and customer-driven.

The ideal outline of the operational model of services delivery of Pollux is illustrated in Figure 2.

Pollux is pursuing a major change is its way of producing IT services. The change will aim connecting delivered services to the established and agreed service catalogue. To each service in the service catalogue, there is a defined reporting approach in line with a general effort of performance management. The management control in the form of standardised reporting is indicated at top level in Figure 2 and in a more detailed and process-oriented level in Figure 3. In this approach, Pollux ensures that processes in between have to transform to support the end-to-end reporting.

The transformation within Pollux is thus to change customer specific services into generic and standardised services. These services are supported in the service management catalogue. The service management catalogue specifies the KPI of the service level agreement that might be customer specific. The real-time monitoring collects data on ongoing service performance. The recording of the monitoring process can be used to generate standardised reports to the clients. Pollux is overall using its organisational experience going from one to many customers to approach IT services to a production process.

Pollux used the IT4IT™ mindset in the reorganisation of its services. As an infrastructure and application service provider, Pollux is neutral to both infrastructures and application vendors. The key value Pollux can provide to customers is problem-free operations and problem-free test and implementation of applications. In changes and transitions, Pollux might have an economic risk, if services fail or exceed cost. In having

![Figure 2.](image-url)
Figure 3.
BPMN diagram of process flow from requirement to service reporting
standardised services, and in inviting customers of better organisation of IT development and services, the customers are also urged to streamline the value justification suggested by development activities, in having a value creation mindset that connects the key elements of the IT process chain is subsequent better for both Pollux and its customers.

5. Discussion

In studying MoT frameworks, a number of criteria must be defined to establish meaningfulness for management, technology and the concept of frameworks as processual blueprints for both academia and practitioners (Kim, 2013; Lee and Om, 1994; Tambo et al., 2016; van Wyk, 1988). Fundamental to a framework, in general, and MoT frameworks specifically, is the ability to guide the governance process of technology up to a level of practical relevance. At best, MoT frameworks are to be considered as a reference model or a reference architecture in domain-specific technological processes (Lepmets et al., 2012; Bolisani and Scarso, 1999). Frameworks must provide navigation in corporate practices (Beard, 2002), and navigation is found between static structures and institutions and the dynamics of change (Martin and Daim, 2012; Pardo et al., 2013).

5.1 Case analysis and learning points

Key findings related to the case entail the desire of structure and value. The company was, for years, split between consultancy and classic “machine room” operations. The services sought by the market relate to highly professionalised, knowledge-intensive operational services. The transformation described in the case is seeking an amalgamation of the knowledge-based design efforts with the technology-driven operational performance.

On basis of the theoretical review in Section 2, the following key points are suggested as essential elements of research related to MoT frameworks:

1. the concept and implications of management must be defined;
2. technology must be definable and characterised in sufficiently generic terms, although technology must also be sufficiently concrete to be manageable;
3. life-cycles must be defined, from early innovation at idea and concept level and to safe and stable operations;
4. the framework must be communicable, scalable and teachable;
5. it should have practical applicability with relevant connection points to established operational frameworks such as the aforementioned COSO, ITIL, MOF, COBIT, etc.; and
6. assessment tools and efficiency metrics should be integrated.

With Beard’s (2002) framework, IT4IT™ is shifting “unorganised” IT services from the subjective to the objective, where the micro-level perception of IT services is changed to a macro level in using common reference architecture, and technology is used on technology rather than the “story” of technology is told and retold by stakeholders.

As Pollux changed from customised services to standardised services and defined itself more into the customer’s value chain, IT4IT™ presented itself as a blueprint for the actions taken. A number of outcomes came forward coherent between Pollux’ points of action and IT4IT™. Key takeaways followed by the observations leading to these findings are as follows:

1. More well-defined services including issues of less duplicates or almost-duplicates of the same services: this is derived from the introduction of a service architecture and a service catalogue (Kumbakara, 2008).
Better alignment between competencies and services often with distinct competency mapping included in the service definition: this is following a defined service (product) ownership regarding senior management and technical competencies in Pollux’ organisation; often, there is stated a “matrix” style of competencies for advanced and/or cross-cutting competencies, e.g. certified network engineers (Tapandjieva et al., 2017; McBride, 2009; Kans, 2013).

Better and more flexible use of competencies across customer engagements as competencies were explicitly defined, e.g. “Certified Information Systems Security Professional”: any service is defined from technological and human resources required. The first is defined in the CMDB. The second is defined intrinsic in the service definition (Wu, 2014).

Lower learning barrier on individual customer engagement and service level agreements: the service catalogue is identical across customer engagement and IT4IT™ is uniform (Kasulke and Bensch, 2017; Cruz-Hinojosa and Gutiérrez-de-Mesa, 2016).

More professionalised image to customers who actually were asking for standardised services to obtain operational efficiency: the ad hoc style of bespoke service configurations of early days’ customer engagements are on the long term regarded as “unprofessional” as customers must insist in transparency and efficiency from organisational learning within the service provider’s organisation (Morlitz, 2016).

A cross-organisational service catalogue: this artefact is inevitable of the establishment of the full life-cycle management of the deliverables (Josey, 2015).

Simplified and more efficient reporting on customer services – both to the customers and internally: the projects, among others, originated from complex reporting to customers. IT service management tools representing the service portfolio is the operational context (Vesterinen, 2015).

A deliberate reorientation towards more advanced customer services and relief in organisational load from simplification of “simple” services: moving from ad hoc services to standardised services do offload high specialised staff and creates more transparency and less dependency of individual staff members (Ulbrich and Schulz, 2014).

A preparedness to create an overall service delivery architecture where internal IT services were directed towards the value chain support (Kattenstroth and Heise, 2011).

A more manageable business: ad hoc solutions are converted to a configuration of standardised services reflecting the undesired characteristic of services being agreed directly between a service delivery manager and the client without improved buy-in from the whole organisation of Pollux (Curry, 2014; Jia and Reich, 2013).

The case of Pollux covers a range of service delivery methodologies from a large service provider to selected industrial clients based. The services delivery palette is developed over time out of the clients’ needs more than the service providers’ formal capabilities. The above list is pinpointing transitional opportunities for the service delivery activity.

5.2 IT4IT™ and management of technology frameworks

IT service management frameworks, such as ITIL, have inspired broad ranges of non-IT service management studies and governance models more generally discussed as business
service management (Gardner et al., 2016). Most theoretical positions see IT development as disjoint from IT services. IT4IT™ is suggesting a closer relationship. Up to 2015–2017, this was generally disregarded and found contradicting with best practices. Several methodologies now suggest such a closer interconnect in the delivery chain predominantly related to agile systems development methods (Vlietland et al., 2016). DevOps has gotten significant attention but is not a service-operational framework. Andenmatten (2016a) do however suggest potentials in linking IT4IT™ and DevOps.

In having a systematic approach to activities of the organisation as standardised services, it was furthermore easier and more straightforward to identify the organisation as a producer or provider (contrary to consultant) within the value chain. Here, again, emphasising the value of IT4IT™ as a frame of discussion of general IT services being a manufacturing process in contrast to classic perceptions of IT services, especially development, as being a craft or an art. IT4IT™ adds to state of art in the sense that it connects design, development and operations in a single life-cycle, and it considers transitional stages in the life-cycle as a value chain.

Getting back to the MoT Framework consideration, and given the reflections on the outcome of Pollux, the relationship between MoT frameworks and IT4IT™ contrasted as shown in Table II.

IT4IT™ suggests itself to be a practical implementation of MoT frameworks especially in conversion from of relatively mature innovations to operational environments and life-cycle management. A critical position to this is the low level of maturity coming from IT4IT™s relatively recent launch. Moreover, it is a discussion point if innovation processes of the enterprise are so precise and well-described that they can be transferred into a joint development-operations framework or needs further maturing. In discussing IT4IT™, there seems to be a dependency of relevance related to the complexity of the development processes, “Requirement to deploy”. Highly experimental and risk-based development activities seems less fitting to the framework than “low complexity” development processes. Moreover, as IT4IT™ contains elements of commoditisation of IT services and IT development deliveries, it is not clear how IT4IT™ can embrace shadow systems, non-IT IT-development, bring-your-own-device, sporadic business-driven Software-as-a-Service and likewise other commoditisation trends in the technology industry. IT4IT™ is driving IT further in the direction of commoditisation and consumerisation, reducing uncertainty in IT implementation and operations, and giving business stakeholders better opportunities for innovation. The better opportunities are coming more well-specified development activities stressing risk reduction. Several contributors comment on this relationship. Warfield (2016) pinpoints that IT4IT™ will ease the job of system architects as higher level of

<table>
<thead>
<tr>
<th>MoT</th>
<th>IT4IT™</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The concept of management must be defined</td>
<td>Reference architecture for management of IT technologies</td>
</tr>
<tr>
<td>2. Technology must be definable and characterised in sufficiently generic terms</td>
<td>Neutral to specific IT technologies</td>
</tr>
<tr>
<td>3. Life-cycles must be defined. From early innovation at purely conceptual level and to pure steady operations</td>
<td>Defines the cycle from inception to end-of-life</td>
</tr>
<tr>
<td>4. The framework must be communicable and teachable</td>
<td>Several MOOC’s have been created and seminars and teaching sessions are made</td>
</tr>
<tr>
<td>5. It should have practical applicability</td>
<td>Contesting other frameworks like TOGAF, ITIL, COBIT. Time has to show</td>
</tr>
<tr>
<td>6. Assessment tools and efficiency metrics should be integrated</td>
<td>Metrics miss still some clarity, but SLA KPI reporting is well demonstrated</td>
</tr>
</tbody>
</table>

Table II. Contrasting MoT and IT4IT™
standardisation is a target in itself. Andenmatten (2016a) suggests IT4IT™ as a tool adoption of the DevOps development model. Likewise do several other authors pinpoint advantages in adopting IT4IT™ as structure, standards and a possibility for converging the general business operations and IT. This discussion is furthermore underpinning the general business trends of digital transformation thereby creating coherence between digital transformation as an ubiquitous trend of MoT in most industries and IT4IT™ offering itself as guiding for precision in the technological dimension of digital transformation.

On the comparative position between MoT and IT4IT™, Table III suggests selected highlights of interesting fits between the four value chain elements of IT4IT™ and broad MoT areas of interest. Critical is to project this fit into proposals for organising operational practices and ensure analogy between IT services and e.g. general business services or physical manufacturing.

In critically discussing IT4IT™ several positions exist: Can we predict if IT4IT™ will get sufficient momentum in the industry? Is it duly reflecting the needs of the companies? Is it in the interests of IT departments and professionals? Can a relevant interaction between industry and academia actually gain momentum to emphasise the IT4IT™ – MoT dualism and ensure relevance to practice?

(1) The viability of IT4IT™ is decided upon companies’ willingness to invest, implement and operate. Shortly after the release of the standard came a range of e-learning providers. As of mid-2018, there are still few hits in job search databases and career profile networks, e.g. 1,800 hits in LinkedIn. Critical success factors would entail a job market, broad vendor support and implementations in larger scale with recognised benefits. The Open Group state 18 accredited training course providers in mid-2018 with more than 50 course providers found on the internet for both online and in-class training.

(2) IT4IT™ is largely augmenting ITIL with innovation and development considerations. ITIL has gained a status a global de facto standard. This has taken almost 20 years. IT4IT™ is more complex so a relatively longer and more modest proliferation might be expected. A momentum for successful implementation would again require quantitative studies.

(3) Pollux is a service provider of certain background services in the IT landscape. Pollux is neutral on the actual implementation in the customers’ organisations. So far, IT departments have received IT4IT™ positively although hesitant.

(4) IT4IT™ is useful in demonstrating an MoT practice in the form of managing technology life-cycles from idea to operations closely connected to a relevant value chain and also connecting the development cycle value chain with the operational value chain. A connection mainly overlooked by other frameworks focussing on either development or operations.

<table>
<thead>
<tr>
<th>IT4IT™ process</th>
<th>General MoT process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strategy-to-portfolio</td>
<td>Early innovation initiatives. Technology intelligence. Fuzzy front end. Open innovation (Song, 2017; Demirkan et al., 2008)</td>
</tr>
<tr>
<td>Requirement-to-deploy</td>
<td>Innovation management. Early supplier involvement. Portfolio management (Kießling et al., 2010; Lee and Om, 1994)</td>
</tr>
<tr>
<td>Detect-to-correct</td>
<td>Operations and life-cycle management (Tsunoda et al., 2017; Ng, 2016)</td>
</tr>
</tbody>
</table>

Table III. IT4IT™ vs MoT
To summarise, IT4IT™ proves itself academically interesting in the sense of suggesting a different and more embracing approach for business reorganisation for a more streamlined innovation-to-operations connection. Likewise is IT4IT™ worth practically to consider as a novel framework connecting value, development and operations in the line of general MoT frameworks.

5.3 Implications to theory, society and manufacturing

The introduction of IT4IT™ is envisioned to offer several implications to theory and practice. Theory of digital services is augmented with the aspect of a framework going from business incentive (idea) to operations where many other theories and frameworks are addressing development and operations as separate activities. The end-to-end or full life-cycle approach is affecting MoT theory in the sense that companies are getting a more specific solution with a set of more well-defined services, but might not be able to exploit innovations developed for similar companies in a different context. MoT theory must address the necessary openness of the implemented solution, the ability to incite and support innovation and the actual pace and robustness of the transition from development and into operations.

In this sense, IT4IT™ might lower the societal “threshold” for new services in the sense that the combined cycle of IT develop and operations should get simpler and likely cheaper when using standardised life-cycle methodologies. This can also be translated into a scenario of commoditisation with depletion of professional esteem and value as consequence and as a long-term projection.

A key learning of IT4IT™ in the above suggested context of using a life-cycle approach to IT, and a well-orchestrated application of measureable services is a convergence of IT and general manufacturing in most of its facets of innovation, development, transition and operations. This is supported in the trend of considering manufacturing as cyber-physical systems (Peters et al., 2016) and trends of “Industry 4.0” and similar phenomena adding to convergence of information life-cycles and physical manufacturing life-cycles. Likewise are the potential implications to manufacturing of the stipulated service management approach entailing defined services based on defined systems configurations with standardised metrics.

6. Conclusion

Suggestions for further studies include seeing the impact of full value chain implementations of IT4IT™ and associated empirical studies. The Open Group is a forum for large influencers within technology and most standards have impacted industries positively over time. The Pollux case started at the end-points of the value chain in form of standardising the service catalogue, service level agreement KPI definitions and the reporting of the SLA KPIs. A number of suggestions are presented for an actual IT-based underpinning of IT4IT™, e.g. IT4IT™-based knowledge management systems, dedicated management IS, better connections between portfolio management, enterprise architecture, project execution, delivery management and continuous transformation processes. Not one system exists so far for supporting the full IT4IT™ value chain, but the reference architecture is preparing solid grounds for this. Further projections for research in IT4IT™ could address the modern-day strongly heterogeneous service landscape of IT, where the Service Integration And Management (SIAM™) reference model has been proposed to manage multi-vendor environments; SIAM indicates a potential for augmenting IT4IT™ and control inter-organisational complexities (Andenmatten, 2016b; Armes et al., 2015).

Conclusively, IT4IT™ is taking IT a step further in being a more manageable technology with more specific definitions of services, customer expectations, relationships between innovation and operations, and transparency of processes. IT4IT™ suggests a highly...
specific and novel interpretation of innovation and operations value chains that can inspire other MoT processes. Scholarly, IT4IT™ is new and lacks scale implementations; thus, this paper has an *ex ante* perspective, and longitudinal studies must be initiated. Furthermore, there are discrepancies and inadequacies that must be subject for further studies. The IT4IT™ framework is an interesting suggestion to the MoT society for a professional framework that has gone further in governance models and provides a more holistically approach than probably any earlier framework.

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A mind model for intelligent machine innovation using future thinking principles

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Abstract

Purpose – The purpose of this paper is to address the possible future evolution of innovation from a human-only initiative, to human–machine co-innovation, to autonomous machine innovation and to arrive at a conceptual mind model that outlines the role of innovation regimes and innovation agents.

Design/methodology/approach – This is a concept paper where a theoretical "thought experiment" is done, using future thinking principles and data that originate from the literature.

Findings – A conceptual mind model is developed to facilitate a better understanding of complexity at the edge of innovation where intelligent machines will emerge as innovators of the cyber world. It was found that innovation will gradually evolve from a human-only activity, to human–machine co-innovation, to incidences of autonomous machine innovation, based on the growth of machine intelligence and the adoption of human–machine partnership management models in future.

Research limitations/implications – Very little information is available in the literature on intelligent machines doing innovation. The work is based on a theoretical approach that presents new concepts to be debated, but have not been tested in engineering and technology management practice, except for a conference presentation and academic discussion.

Practical implications – The current world view is that future "smartness" is only possible through the creative abilities that humans have, but as machines are entering the workplace and our daily lives, not only as static robots on a manufacturing line, but as intelligent systems with the potential to replace lawyers and accountants, doctors and teachers, companions and partners, their role in innovation in complex environments needs to be explored.

Social implications – Human–machine interaction is often an emotional social issue of concern in terms of the replacement of human intelligence with machine intelligence. It should be asked whether humans will or should remain in control of innovation? Artificial intelligence (AI) may complement and even substitute human intelligence, but huge value is embedded in the new goods, services and innovations AI will enable, especially in manufacturing, where value embedded in the project becomes complex and dynamic.

Originality/value – The thinking presented in this paper is original and should lead to debate to question the way innovation systems will work in future and inspires thinking about AI and innovation.

Keywords Innovation, Automation, Robotics, Complexity, Artificial intelligence, Industry 4.0

Paper type Conceptual paper

1. Introduction

As part of the 2018 World Economic Forum Annual Meeting in Davos, Switzerland (WEF, 2018), the role of artificial intelligence (AI) was yet again at the forefront and the relationship between people and machines is high on the agenda. McDermott (2018) wrote a preparatory paper on machine intelligence. He also states that "instead of putting man and machine against each other, we can work together to create something called ‘augmented humanity’". In the manufacturing world, intelligent machines are largely still viewed as robots only. These robots often take the place of human labour, hence the fixation with "technology against labour" and the socio-political fear of job losses. Leading industrial manufacturers have adopted the philosophy of robot–human collaboration in the context of "cobots" (Moniz and Krings, 2016). Robots are seen as consistent, reliable,
non-tiring, but not as “thinking”. AI is recognised as a cost saver, productivity enhancer and stimulant for economic development. McDermott (2018) states that the benefits of AI for companies relate to much more than cost savings. Implementing AI must also mean more innovation, improved forecasting, optimised operations and more customisation.

This leads to the research question:

**RQ1.** Will intelligent machines in future have the capability to innovate?

This notion was generically addressed in a conference paper (Botha, 2017) but the thinking in the current paper is now extended to include the edge of innovation in future where Industry 4.0 will revolutionise manufacturing, products and services and lifestyles of humans.

The objective is to develop a mind model on machine innovation. This model contributes to the understanding of the role of intelligent machines in innovation and provides a landscape for debate and application of different innovation regimes and their application to human innovation, human–machine co-innovation and autonomous machine innovation.

This paper is of a conceptual nature; the intention of the research approach is to present a thought leader and a mind model to aid the understanding of possible future machine innovation. A literature scan on the issue of machine innovation yields information on innovation to develop intelligent machines, but virtually nothing about intelligent machines that do innovation. Yet, initial hints are there that machines that become increasingly intelligent will be able to innovate. In approaching the “research” question: “Will intelligent machines in future have the capability to innovate?” one can find enough evidence in the progress of AI application trends, the technologies employed and the way people innovate to reach a conclusion.

In theoretical physics, a process is often applied called a “Gedanken” experiment, a thought experiment made famous by Albert Einstein (Perkowitz, 2010). In such an experiment one imagines to be in a position where phenomena that are currently unmeasurable can be experienced. The research question on machine innovation can best be addressed by doing future thinking that is evidence based. In looking at the future, a future thinking space and a future thinking lens (Botha, 2016) that consists of a spinning triangle with the corners being future-shaping influences of technologies, human behaviour and events can be used. A discussion about machine innovation should be based on existing human innovation processes and systems of innovation and how they are applied to support innovation. The question is then extended to whether human innovative capabilities can be transferred to machines and whether intelligent machines will be able to independently innovate or whether it will be a human–machine partnership where co-innovation takes place.

### Discussion outline

This paper will first report on a background understanding of the major trends impacting on innovation supported by views from the literature on the status of intelligent machines in context of innovation, innovation futures and disruption and complexity at the edge of innovation. It will then apply the future thinking lens to intelligent machines and their potential ability to support different forms of innovation as part of the thought experiment. This will be followed by the suggestion of a mind model for machine innovation. This model links different innovation regimes and applies them to human innovation, human–machine co-innovation and autonomous machine innovation. The paper ends with conclusions on the outcomes and contribution made.

### 2. Background understanding of intelligent machines and innovation

In this section, several new trends impacting on innovation are discussed to provide a background and understanding to the mind model development in this paper. The purpose is to juxtapose innovation in a rapidly changing future. Innovation is placed against the state of AI and intelligent machines; the world view of intelligent machines; intelligent
machines and humans; the learning machine; machine consciousness and conscience; the innovating machine; inventing machines; how humans innovate; the edge of innovation; manufacturing and innovation; a smart future; and human–machine co-innovation.

The state of artificial intelligence and intelligent machines

AI is not a new unique technology, but the combination of sensing, comprehending and acting in machines (Purdy and Daugherty, 2016). Its theoretic and technological basis has been developed over a long time. What is unique to AI is that all three of its basic capabilities are underpinned by the ability to learn from experience and to adapt over time. The term “artificial intelligence” was established in 1956, but the roots go back to Alan Turing’s ground-breaking paper in 1950 in which he poses the question “Can machines think?” (Turing, 1950). Carbonell et al. (2016) write that the aim of AI is to imitate human behaviour and that it has been present in many ancient mythologies and most religions.

The interest of people to create devices that replicate human behaviour fits the metaphor that man is the new creator. Another metaphor that emerged since the 1950s with the advent of the electronic computer is that computational systems are brains. This has led to similar views that the brain is a computer. Mental processes are now equated to computer algorithms. This merging of metaphors has led to the development of science that emulates the human brain (neural networks) and understanding of the human brain to build better computers.

Fear has always existed in debates of technology vs labour that humans will be replaced by machines in the workplace. This fear is now extended from blue-collar workers who may lose their labour-intensive jobs to robots in factories to white-collar workers who may be replaced by a higher form of creative power. One should rather be speaking of human–machine partnerships in the workplace. The paradigm should shift from total task take-over as in automation to co-thinking, co-learning and co-working in a partnership. In future, machines will increasingly work and behave like humans. This means that creativity, intuition, motivation and ethics may be common to both people and machines. Will machines have a conscience? Human–machine algorithms will be developed and human–machine relationships will be challenging human resource management experts. Autonomous machine decision making will have to be trusted by humans.

Nordström (2016) writes “an increasing number of artificial intelligence applications are being developed that make machines more sophisticated in how they learn and make decisions […] By gathering and synthesizing vast volumes of data from multiple sources, these intelligent machines can automate complete processes or workflows, learning and adapting along the way. This rapid development of intelligent automation is bringing about a new era of productivity and innovation on an astounding scale, setting new standards for quality, efficiency, speed and functionality”.

Humans innovate with a consciousness of the impact of their innovations. Will intelligent machines ever have consciousness? The question relates to whether there is a relationship between intelligence and consciousness. Consciousness is the state or quality of awareness, intelligence is the ability to acquire and apply knowledge. To answer this question, one has to look at the dissociation of consciousness and attention in humans. Haladjian and Montemayor (2016) are of the opinion that one can programme ethical behaviour based on rules and machine learning, but not reproduce emotions or empathy, but at the same time admit that this may be possible through simulations. There is a deep relation between emotion and cognition in human intelligence. Emotions in machines will thus not be able to be programmed through control systems, but will have to be acquired through learning and simulation. Haladjian further argues that machines may develop access consciousness, but not phenomenal consciousness. Block, as quoted by Kriegel (2006), makes a distinction by defining phenomenal consciousness as what it feels like to be conscious, whilst access consciousness deals with readiness (availability) to
reason and control of action and speech. The current state of AI is that it will act on the basis of rationality, but not empathy. Is there a relationship between consciousness and conscience? Conscience generally deals with an inner feeling or awareness of rightness or wrongness of behaviour, based on morality or value systems. Consciousness relates to an awareness of the environment. Machines can be very aware of where they are and in what context. The open question is whether they can distinguish between right and wrong? Does this mean that intelligent machines may be corruptible?

As digitalisation and machine intelligence are rapidly emerging towards disruptive status, the question should be asked whether humans will or should remain in control of innovation? The Fourth Industrial Revolution, the Internet of Things, smart everything, from wearables to cities and AI are future techno-economic waves that will change forever the way humans work, play, live and transact. Humans tend to think that future “smartness” is hidden only in the creative and innovative abilities that they have. Innovation is dependent on the ability to recognise patterns, combine and integrate existing properties and knowledge to represent something that is perceived as new by the user, seeing the gap in the market and intuition. This is exactly what AI and intelligent machines do. David Autor is quoted in Purdy and Daugherty (2016): “Often people only think of AI boosting growth by substituting humans, but actually huge value is going to come from the new goods, services and innovations AI will enable”.

Inventing machines have been demonstrated (Hantos, 2016). Already, governments are considering introducing new systems for protecting intellectual property that is generated by a non-human entity.

How humans innovate
Innovation has been classified in many ways (Lee and Trimi, 2018) and (Leitner, 2013) some of these are summarised in Table I.

The evolution of innovation includes phases of closed (or proprietary) innovation, collaborative innovation and open innovation. Most of these innovation types are aimed at value creation for individuals, organisations or societies.

<table>
<thead>
<tr>
<th>Type of innovation</th>
<th>Way of innovation</th>
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<tbody>
<tr>
<td>Incremental innovation</td>
<td>Step-wise innovation, the one improvement followed by another</td>
</tr>
<tr>
<td>Radical innovation</td>
<td>Abrupt innovation, taking a major jump from the one state of product or functionality to another</td>
</tr>
<tr>
<td>Ambidextrous innovation</td>
<td>Innovation coupling systematic problem solving and ideation</td>
</tr>
<tr>
<td>Disruptive innovation</td>
<td>Game-changing innovation, causing new markets or eliminating existing markets</td>
</tr>
<tr>
<td>Frugal innovation</td>
<td>Removing non-essential features from products or solutions for developing environments</td>
</tr>
<tr>
<td>User innovation</td>
<td>Customised and personalised solutions of products</td>
</tr>
<tr>
<td>Open innovation</td>
<td>Pre-competitive co-innovation; crowdsourcing</td>
</tr>
<tr>
<td>Market innovation</td>
<td>Improvement of the mix of target markets and the creation of new markets</td>
</tr>
<tr>
<td>Sustainable innovation</td>
<td>The creation of new market space, products and services or processes driven by social, environmental or sustainability issues</td>
</tr>
<tr>
<td>Technological innovation</td>
<td>New technologies are envisaged that will support innovative products and services</td>
</tr>
<tr>
<td>Integration innovation</td>
<td>Finding ways of integrating existing solutions in such a way that they address new challenges</td>
</tr>
<tr>
<td>Value innovation</td>
<td>Adding value along the value chain, accelerating ideas into the marketplace that are perceived to have enhanced properties</td>
</tr>
<tr>
<td>Soft innovation</td>
<td>Considering aesthetics, design, creativity and the creative industries</td>
</tr>
<tr>
<td>Social innovation</td>
<td>The generation and implementation of new ideas about social relationships and social organisation, the value accrues primarily to society rather than to individuals</td>
</tr>
<tr>
<td>Business model innovation</td>
<td>Agility in business model dynamics to rapidly add value to the value chain</td>
</tr>
</tbody>
</table>

A mind model for intelligent machine innovation
The boundary between the present and the future is called the edge of disruption (Botha et al., 2017). This edge is dynamic, chaotic, evolving, energetic and mostly complex. Hagel (2008) states that edges matter since they take many forms – the edge of markets, industries, emerging economies, demography or knowledge domains. He states “edges are powerful sources of business innovation because they are places of potential and friction, where traditional products and practices are no longer adequate to address unmet needs or unexploited potential”. Ito (2018) states that interaction with disruptive things is what is required today. Disruptive innovation does not happen in the large R&D labs anymore; it happens on the edges of systems and networks.

Traditional views on innovation in manufacturing revolve around the right innovation strategy, balancing the innovation portfolio, looking beyond products and focusing on a strong culture to attract the best talent, enhancing collaboration and adopting innovation success measurement (Misthal and Eddy, 2013). The future of manufacturing is undoubtedly being shaped and guided by Industry 4.0 (Norbury, 2016). Supported by digitalisation, the Industrial Internet of Things, cyber-physical systems, hyper-connectivity and using big data and big data analytics, new demands for innovation in manufacturing are rapidly emerging. The challenges facing production are greater and manufacturers have to think ahead to remain competitive. Most likely Industry 4.0 will culminate in so-called factories of the future (Von Heynitz and Bremicker, 2016). Factories of the future will result in radically new manufacturing philosophies, addressing digitalisation, redesign of the organisational and operational structures, new skills and talent in human resources, alignment of production and logistics, restructuring and agility on the value chain, new business and revenue models, extreme cyber-security and compliance with legal requirements, still to be developed. Although most of the innovation types discussed above will still be relevant, their alignment with these new demands for production in the Industry 4.0 context will change drastically.

Humans and machines innovating towards a smart future
Innovation approaches should be extended to assist in creating a smart future (Lee and Trimi, 2018). Smartness includes intelligent environments, hence the role of intelligent machines. A smart future is more than preparing for the future by visualising it, it is setting up the future with the right technology choices, living conditions, connectivity and business endeavour. A smart future requires smart people; smart leadership; smart governments; smart infrastructure; smart industries; smart healthcare and education systems; smart transport and residences; matching human talent and jobs; creating business opportunity and work, utilising both the youth and elderly; sustainability and designing, beyond our current thinking horizons. The question arises whether humans can maintain their superiority in innovation, whether they can innovate alone or whether they need assistance from a higher form of intelligence? These levels of future smartness reach a complexity that can best be addressed by employing machine intelligence and with that machine innovation, taking the vast number of variables into account to create our tomorrows. This innovation is not limited to the smart factory of the future (Von Heynitz and Bremicker, 2016), but to the environment in which these factories will operate and the people who will do the innovation and those who benefit from the innovation. It is not only about the manufacturing of physical products or the establishment of services, but also about “manufacturing” the environment in which these will be consumed. To a large extent, new innovation styles in a complex environment will be influencing the way the human race lives and conducts itself, so the notion of the factory of the future may be extended to creating the world of the future and shaping humanity for that world.

Game-changing innovation is emerging from online human collaboration and crowdsourcing (Nesim, 2016). With crowdsourcing and open innovation, the mere volume of ideas can grow so large, that they represent the complexity of social networks. Finding adoptable ideas from the proliferation of ideas from innovators and linking them to each
other to form an innovation ecosystem can represent complexity large enough where human cognition fails and it will be necessary to employ AI. Swarm optimisation has been applied to this level of innovation (Martinez-Torres and Olmedilla, 2016). Swarm optimisation was inspired by the social behaviour and movement patterns of bird flocking and fish schooling. It is based on the swarm intelligence concept, which refers to AI systems where the collective behaviour of individual elements that are interacting locally with their environment creates coherent holistic patterns.

This means that well-connected communities and human relationships will remain at the roots of innovation, with the exception that intelligent machines will be added to the mix. Innovation in virtual space will be used to design new products and services. Communication is a primary engine for innovation. However, the larger the participant set, the more selectivity is required for new ideas that lead to new solutions and the more complex the interaction becomes. Thus, there is a need for AI. Machine cognition will assist human cognition. New ideas and new designs have to be compared with a vast range of existing ones and user requirements need to be dynamically addressed in product and service development. Innovation addresses the synchronisation of product offering and user preference. Given the dynamism of the user market and the fact that the user or customer becomes more selective, sophisticated and customisation oriented, machine intelligence could be a major aid to the innovation process, logging and matching the user requirements, the innovative ideas, the patterns they form and the cross-impact they have on each other (competitiveness) and the market (fulfilling and creating needs).

3. Thought experiment on machine innovation

This section addresses the future thinking lens process used to do the thought experiment on the cross-impacts of future-changing factors on innovation. The innovation types that emerge are then used to inform the mind model on machine innovation.

The future thinking space (Botha, 2016) is defined by a triangle where the corners represent technology, behaviour and events, the so-called future-shaping factors (refer to Figure 1). By “spinning” the triangle to simulate inter-factor influences, a continuum is created that makes up the future thinking lens. As the technology, behaviour and events are moved through space and time, they influence each other through cross-impacts that are dependent on the direction of spin. For example, a clockwise spin leads to technology influencing events, events influencing behaviour and behaviour influencing technology. An anti-clockwise spin results in technology influencing behaviour, behaviour influencing events and events influencing technology. Future strategic views now emerge in a clockwise spin of the lens or in an anti-clockwise spin, based on narratives for the particular future in consideration.

This future thinking lens is now applied to machine innovation. The technologies considered in AI are: complex adaptive systems (intelligent machines interact with and autonomously adapt to their environment); predictive systems (intelligent machines use knowledge gained through experience and machine learning to anticipate effects of different factors); consciousness (intelligent machines can do rational simulation); understanding people (human–machine interfaces and interaction); machine vision (using sensing systems that conduct pattern recognition); and self-programming (the ability to change operating algorithms based on learning and desired outcomes).

The human behaviour in the marketplace that will drive machine innovation are: product/service customisation expectations; need for rapid solutions; need for connected products/services; involvement in product/service specification; the need for simplified user interfaces for complex and knowledge-rich products/services; high usability features; and highly intelligent support.

Human behaviour among innovators inside the enterprise include: the need for contribution to open innovation; competitive benefits from proprietary innovation; financial
and social value creation; empowerment to create a smart future; making sense of complex environments; and the desire to remain in control.

Major events that will drive machine innovation are: power balance shifts as a result of renewed nationalism and localisation and the end of globalisation leading to global vulnerability (geopolitical); global recession, currency value stability, failing economic alliances, wealth-poverty divide (economic); climate change and resulting food security, water scarcity, nutrition and health issues (natural); interconnectedness, harmony, cohesion and well-being (social); and migration and cultural shifts (demographic).

These future-shaping technologies, behaviour and events now yield specific innovation impacts when the lens is spun clockwise or anti-clockwise or when it is put in oscillation.

**Spinning the future thinking space anti-clockwise**

In this exercise the influences are considered when technology impacts on behaviour; behaviour impacts on events; and events impact on technology.

Market innovation will result from AI technology in machine innovation influencing human and market behaviour. The application of AI technologies will have a large impact on improvement of the mix of target markets and the creation of new markets. Intelligent machines that can suggest innovation improvements will enable products and services much better tailored for the market. These innovating machines will support market innovation through analysis and learning and modelling that will result in supporting human innovators. Innovating machines will operate either as assistants for human innovators, or independently. They may be customised for innovation from a support system point of view, or may be on the production line, in the environment that is being sensed, part of the control system, integral to life support and safety systems or mobile as part of transport and logistics environments.
Human behaviour in markets or inside the organisation can influence events through sustainable innovation in the creation of new market space, products and services or processes that are driven by social, environmental or sustainability issues. The quest for creating new market space because of the user revolution dictating new demands can lead to economic renewal. Innovative processes on how political choices are made, economies are evolving, social benefit is derived and on the movement of people to find new opportunities are required for sustainability and peace. Intelligent machines will be ideal in supporting sustainable innovation, to take market dynamics into account, and to match the innovations with the complexity of geopolitical, economic, natural, social and demographic events that unfold. Sustainable innovation includes frugal innovation and intelligent machines could contribute to understanding essential products and services in a development context.

When events determine technology, it usually results in integration innovation to include existing solutions in such a way that they address new challenges. Emerging events will require the application of existing AI technology to assist with innovative solutions. In addition, the emerging events may stimulate the development of new AI technologies. Warfare and power balance, as part of the geopolitical sphere, for example, has always driven advanced technology development. Peacekeeping, economic prediction and innovative ways of addressing poverty, climate change mitigation and adaptation, well-being of people and human migrations will eventually all have a major impact on what AI technologies are integrated for the complex solutions required.

Spinning the future thinking space clockwise
In this exercise the influences are considered when behaviour impacts on technology; technology impacts on events; and events impact on behaviour.

Technological innovation takes place when behaviour in the marketplace or by human innovators demands new technology. The emerging market behaviour identified will lead to the need for new intelligent machines with the ability to support innovation or do it autonomously. Highly dynamic environments ask for more intelligent technologies in supporting machine innovation. Emerging AI technologies will be stimulated and new technology domains such as genetic engineering, neuro-engineering, the Internet of Things, virtual simulation and augmented reality will be integrated with AI to support better technological innovation processes.

Disruptive innovation may take place when technology influences events. Disruption can be positive or negative. When intelligent machines have the ability to suggest or effect innovation that will solve the global challenges represented by geopolitical, economic, natural, social and demographic events, they can make a major positive contribution to the state of the world. These positive innovations will become possible because intelligent machines will deal with large complex data sets much faster; see emergent patterns easier than humans; apply their acquired consciousness to consider a multitude of cross-impacts, good and bad; present objective support to humans through humanitarian conflict solution; and improve themselves through algorithm adjustment to be more effective. On the other hand, machines that are intelligent and autonomous may make the wrong decisions or get out of control when they reject the sense of consciousness and even a conscience they simulate themselves. Concern has been expressed about the proliferation of AI, mainly in smart weapons systems. Such technologies could have a negative disruptive effect on the world and initiate new emerging events that may get out of control (nuclear war, biological warfare, climate disruption, human injustice, etc.).

Social innovation takes place when events determine the behaviour of people. Social innovation primarily accrues value to the collective (society) rather than the individual (human or organisation). The emerging events identified will shape market behaviour and the way people innovate for new solutions and value. In the neo-liberal world order, openness has led to globalisation. Sharing of information, the right to be informed and participate, ownership of
capital and the right to create an own future are accepted benefits of neo-liberalism. Global conflict and interference over these rights, however, remain to exist and ideological, religious and commercial drivers perpetuate the conflict and human suffering in some parts of the world. The use of human–machine co-innovation or autonomous innovation by machines could resolve many of the issues that humans have found so difficult to address over the past century and more. Machines are apolitical, unbiased, have no need for greed (yet) and could apply their advanced technologies and fast learning to impartially address so many of the social innovation needs that have emerged. It is often said that you cannot innovate for someone, but you can only innovate with someone. In social innovation, co-innovation between humans and machines may just be the right approach.

4. Mind model for machine innovation

In this section, innovation regimes are defined, consisting of innovation modes and domains. These are then described for humans in innovation and machines in innovation. The latter part of the section addresses how these innovation regimes are divided among three innovation agents: humans-only, human–machine co-innovation and autonomous machine innovation to make up the mind model.

It was argued that intelligent machines, utilising AI technology that is available or emerging today, can most definitely contribute to a broad base of innovation. This implies the existence of three innovation agents: humans innovating on their own; intelligent machines assisting humans to innovate (human–machine co-innovation); and intelligent machines innovating autonomously.

Innovation regimes for humans are defined (Botha, 2017) as a combination of innovation modes (grassroots innovation; systematic innovation) and innovation domains (open innovation; closed or proprietary innovation). Figure 2 shows the characteristics of the innovation regimes for humans.

Grassroots innovation refers to innovation by individuals who normally do not have any formal training in innovation. Human beings use their natural capacity to innovate. The term is often used in context with bottom-up solutions for developing communities, but does include any defined society, also focus groups in modern marketing. Systematic innovation refers to innovation processes that have been studied, documented and can be transferred...
and adopted. Open innovation involves the sharing of ideas at a pre-competitive phase in a highly participative way and closed innovation is that innovation which is considered as leading to proprietary solutions. Moving from grassroots innovation to systematic innovation, knowledge is normally formalised, and captured (codified) in a retrievable form. The interface between grassroots innovation and systematic innovation represents the fusion of specialist and generalist knowledge systems. Moving from open innovation to closed innovation normally refers to business creation and ownership. Each of the innovation regimes is characterised by the information that feeds innovation, working with knowledge, learning, its primary driver and the main outcome of the innovation.

In open grassroots innovation, information emerges from tradition. Knowledge is embedded in metaphors, typically found in storytelling. Learning takes place through storytelling and knowledge is passed from person to person in narrative form over very long time periods. The driver to make innovation work is trust among people. The main outcome is the development of social capital, defined as the networks of relationships among people who live and work in a society, enabling that society to function effectively.

Information in the open systematic innovation regime normally originates from research done on specific topics. Knowledge is embedded in explicit processes. Learning is based on formal education and training in innovation systems. The driver for this innovation is the sharing of knowledge at a pre-competitive level. The outcome is intellectual capital that includes the people who innovate, their networks and the potential for proprietary gains.

In proprietary grassroots innovation, information to use in innovation originates from folklore and practice that has been demonstrated in successful application of the innovation, usually without a sound base of scientific proof or understanding. Knowledge is embedded in individuals and is normally tacit and uncodified. Learning is through inheritance and normally passes from the practitioner to a very close relative or from one small specialist group to another. The knowledge is often deemed as a spiritual gift. The driver for this type of innovation is protection of practices that are not formally described and codified. The outcome is most likely value-addition to natural capital, since the knowledge is often linked to natural resources.

In closed (proprietary) systematic innovation, the best known in the business environment and normally includes intellectual property protection such as the registration of a patent. The information feeding the innovation is based on invention. The knowledge lies in discovery and is of an explicit nature. Learning on how to do this type of innovation takes place through a formal education and training process. The driver is secrecy until disclosure after intellectual property protection has been secured. The outcome is intellectual property that has monetary value.

The same landscape can now be used to describe innovation regimes for machines (Botha, 2017). The innovation modes and domains used for describing human innovation are maintained and the envisaged characteristics when machines are applied to innovation are discussed with reference to Figure 3.

When intelligent machines are employed to assist with innovation in open grassroots innovation, information will now be obtained from a database built from community inputs or machine sensing and surveillance. The knowledge that the intelligent machine works with will originate from data mining and synthesis processes. Machine learning will include audio-visual recording and sensing of the environment. The driver will be privacy, which may encourage individuals to share their knowledge, thus addressing the trust issue when humans innovate in this innovation regime. The outcome will be social capital as part of innovation for inclusive development ensuring that all marginalised and excluded groups are stakeholders in development processes.

In open systematic innovation, information will originate from big data and social networking. Knowledge will be extracted through pattern recognition and applying...
complexity algorithms. Machine learning will be through simulation and modelling and result in complex data visualisation to communicate results with humans. The driver is access to humans and other intelligent machines and objects connected to the Internet of Things. The outcome is intellectual capital that could be further developed into proprietary intellectual property.

For closed grassroots innovation, information available to machines could be in the form of processes, operating procedures, models and maps that have been acquired from humans or other machines. Knowledge extracted from this information would lead to prediction and iteration of, say how an indigenous product will do in a specific global market. Machine learning will be through adaptive systems approaches shaped by the awareness through sensing of the predicted impact of innovations under development. The driver may be prospecting for new applications or new markets and optimising community offerings in a business context. The outcome will be adding value to natural capital, since products are often related to indigenous knowledge of natural resources as well as increased monetary gain for the community.

Information available for proprietary systematic innovation by machines originates from big data on markets and proprietary data from databases inside the innovating enterprise. Knowledge on how the product or service may do in the marketplace will be generated from complexity analysis, taking a multitude of parameters that could influence the product or service into account. Machine learning may be through applying machine consciousness of the factors at play and by changing competitive approaches by self-programming and improving market selection algorithms. The driver is speed to market and timing and positioning of the product or service in the market. The outcome is formally registered intellectual property and direct monetary gain.

Figure 4 shows how the innovation regimes and innovation agents come together (Botha, 2017). The basis of the comparison is stating the most important reason for applying a specific agent/regime combination as indicated in each regime in Figure 4.

In human innovation, the description represents the status quo in innovation. Open grassroots innovation is aimed at generating social value, open systematic innovation is about pre-competitive advantage that can be exploited further, closed grassroots innovation brings business value to communities and proprietary systematic innovation leads to competitive intellectual property and products and services.
In human–machine co-innovation, open grassroots innovation benefits from the unravelling of social complexity by intelligent machine application. Open systematic innovation benefits largely from applying machine intelligence to complex social networking in the crowdsourcing environment and the ability to quickly select those innovations with the best business potential. Closed grassroots innovation will lead to well-modelled prospecting of business opportunities that the community at large can benefit from. Proprietary systematic innovation will benefit from human–machine co-innovation in the competitive advantage fast decision making can bring, the creation of new markets and in matching products and services with the dynamism of the markets.

In autonomous machine innovation, open grassroots innovation may initially be limited as trust is being built. The fact that humans are very often not trusted in this innovation regime may make the intelligent machine the preferred independent and objective innovation agent for communities. Open systematic innovation will largely benefit from conflict resolution or avoidance in the open innovation domain. The complexity of crowdsourcing and the potential for confusion or malicious contributions may be revealed easily by machine intelligence. When machines become the innovation agent for closed grassroots innovation, products and services emanating from this innovation regime may be released on the mainstream markets much faster due to custom fit of need and demand by intelligent machines. Finally, machine innovation applied to the best-known innovation regime, that of proprietary systematic innovation, may improve the chances of market leadership through first-to-market strategies and redefining the intellectual property regime.

5. Conclusion
This concept paper reports on the advantages of possible future innovation conducted by intelligent machines. A thought experiment was done, using the future thinking space and lens where the future-shaping factors of technology, behaviour of people and events were
used to reveal that the innovation edge for future machine innovation will be shaped by technologival innovation, disruptive innovation, social innovation, market innovation, sustainable innovation and integration innovation. The technologies required for the machine intelligence are available or emerging. When combined in dedicated innovation support systems, applying these technologies may have beneficial impacts on the behaviour of people and on certain large events. Market needs exhibited by the consumer of today and tomorrow, and the way innovators are addressing them, call for advanced innovation processes that are fast and lead to products and services that are customised and effective, being produced in a manufacturing regime where machine intelligence and innovation will play an increasing role. In this complex environment, intelligent machine innovation will become a necessity in future. The impact of emerging events that have the potential to change the world of work and living could be mitigated by machine innovation, or humans could be assisted to adapt to these changes.

The evolution of machine innovation is likely to move from humans as innovation agents, to human–machine co-innovation and eventually autonomous machine innovation. All three innovation agent scenarios will prevail in future.

The major contribution by this conceptual paper is a mind model that was developed to conceptualise the role of machine innovation in future. This model is based on known innovation regimes described by the open and proprietary innovation domains and the grassroots and systematic innovation modes. These were characterised for human innovation and machine innovation separately in terms of information required for innovation, the knowledge that leads to contextualisation, learning modes, innovation drivers and main outcomes for each innovation regime. This mind model assists in the understanding of how innovation conducted by the three innovation agents (human innovation, human–machine co-innovation and autonomous machine innovation) align with primary reasons in each innovation regime to choose a specific combination of innovation agents.

The limitation of the work lies in the fact that it is a conceptual paper where something new is proposed for which there are limited theoretical frameworks available as of yet. Existing theories from other fields (such as future thinking) were transferred onto this new concept to construct the proposed framework. The concept was created, but not tested in engineering and technology management practice.

The scientific value of this paper will manifest itself in the fact that it becomes clear that humans will not be the sole custodians of innovation in future. They will find themselves in partnership with intelligent machines that will make innovation more powerful. Sometimes humans will have to stand back and let intelligent machines do innovation that is too complex for the human mind or innovation that has to take place too fast for conventional innovation processes. National systems of innovation, linking physical innovation infrastructure and the organisation of innovative people, will be replaced with virtual innovation networks consisting of machine relationships, shared codified knowledge and experience and connectivity. This may solve the problem that some existing national systems of innovation are not very efficient. This inefficiency often results from the focus being too much on connecting the right organisations and structures and not on doing the real innovation. Intelligent machine innovation may rectify this.

The whole world of innovation management, national systems of innovation and business model innovation will be disrupted. Innovation at the fast-moving edge between the present and future, driven by the need to operate in often chaotic circumstances, will be the norm in how we manufacture our products, offer our services, create our environments and react to global events. The challenge is to let this happen to the advantage of humankind and the earth.
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