The role of digital technologies for the service transformation of industrial companies

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The role of digital technologies in service business transformation is under-investigated. This paper contributes to filling this gap by addressing how disruptive technologies such as the Internet of Things (IoT), cloud computing (CC) and predictive analytics (PA) facilitate service transformation in industrial companies. Through the Data-Information-Knowledge-Wisdom (DIKW) model, we discuss how the abovementioned technologies transform low-level entities such as data into information and knowledge to support service transformation. We propose a set of digital capabilities based on the extant literature and the findings from four case studies. Then we discuss how these capabilities support the service transformation trajectories of manufacturers proposed by Kowalkowski et al. (2015). We find that IoT is foundational to any service transformation although it is mostly needed to become an *availability provider.* PA is essential for moving to the *performance provider* profile. Besides providing scalability in all profiles, CC is specifically used to implement an *industrializer* strategy, therefore leading to standardized, repeatable and productized offerings.

Keywords: service-orientated manufacturing systems; service transformation; digital capabilities; Internet of Things; cloud computing; predictive analytics, DIKW.

1. Introduction

The literature is in agreement that digital technologies (hereafter DTs) facilitate the service innovation of manufacturers (Neu and Brown 2005; Kindström and Kowalkowski 2009; Belvedere, Grando and Bielli 2013; Coreynen, Matthyssens and Van Bockhaven 2016) by enabling novel product-service offerings (Lerch and Gotsch 2015), transforming the structure of supply chains (Vendrell-Herrero et al. 2016) and reshaping industry competition (Porter and Heppelman 2014). However, little research has specifically focused on the role of DTs in such service transformation, implying '*a lack of awareness or appreciation of the information and communication technologies* *that are enabling many product-centric service offerings to occur in practice*' (Lightfoot, Baines and Smart 2013, 1421). This paper aims at filling this gap, as it addresses how three DTs – the Internet of Things (IoT), cloud computing (CC) and predictive analytics (PA) – support the service transformation of manufacturing companies. We build our study on the literature at the intersection of the research streams on servitization and the digital transformation of manufacturers. In particular, we refer to Kowalkowski et al. (2015) to describe the strategic trajectories of service transformation, while the three DTs are positioned in relation to the Data-Information-Knowledge-Wisdom hierarchy (Rowley, 2007). Based on the extant literature and the findings from four case studies, we propose a list of digital capabilities central to the service transformation. The case-based research is also meant to discuss how purposively selected companies leverage IoT, CC and PA to pursue different service transformation paths.

The paper is organized as follows: Section 2 provides the theoretical background, and Section 3 introduces the research questions and methodology. Section 4 illustrates the case studies. Section 5 provides a discussion of the case study findings in light of the research questions and the background, while Section 6 draws the study's conclusions and points out the limitations as well as avenues of future research.

2. Literature review

2.1 Defining the Internet-of-Things (IoT), Cloud Computing (CC) and Predictive Analytics (PA) and their impact on knowledge generation

Research reports highlight that intelligent products, connectivity, CC and big data analytics are expected to be disruptive for companies' business strategies and operational execution (Butner and Lubowe 2015; Boston Consulting Group 2016). In support of this view, Porter and Heppelman (2014) show how smart products (i.e. products with some kind of awareness and connectivity) in combination with CC and big data analytics can reshape the competition of entire industries.

Therefore, this paper focuses on DTs and explores how the rise of IoT, CC and PA is affecting the service transformation of industrial companies. Despite that the theoretical background of these technologies is still in the formation process, several concepts are widely accepted. For the paper's scope, we refer to the definitions given in Table 1.

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Moreover, we use the Data-Information-Knowledge-Wisdom (DIKW) hierarchy (Figure 1), a widely recognized model from the information management literature (Rowley 2007), to illustrate the boundaries of and the relationships between IoT, CC and PA, as reported in Table 2.

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DIKW contextualizes how entities at lower levels (e.g. data) are shaped into entities at higher levels of the hierarchy (e.g. information and knowledge). Hierarchical models such as DIKW have been largely used by scholars in the field of information systems management (Gibson and Nolan 1974), to capture the evolution of information systems and DTs and connect them to specific business needs and functions. Following this line of reasoning, we assume that the DIKW hierarchy can be employed to discriminate the functions enabled by IoT, CC and PA. In particular, we argue that the basic functions of IoT (e.g. sensing, connectivity) are crucial for collecting and transmitting field data. The combination of CC and IoT allows the development of information (level 1), since IoT enables continuous feeds of context-aware data, whereas CC facilitates the creation of large 'data lakes' (IaaS) as well as the deployment of applications (SaaS) used to access and process data and share information. Finally, the combination of IoT, CC and PA is essential for generating new knowledge. In fact, the adoption of CC can largely facilitate the sophistication of PA algorithms for data analysis, reasoning, interpretation, simulation and cognitive computing. From its side, IoT is foundational for securing data collection and machine-to-machine communication. The relationships between the DTs and the DIKW levels are summarized in Figure 1.

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2.2 Digital capabilities for service transformation

Focusing on the digital capabilities provided by IoT, CC and PA, this research complements existing studies that explore the role of other information technologies for the service transformation of industrial companies (Belvedere, Grando and Bielli 2013; Coreynen, Matthyssens and Van Bockhaven 2016). Moreover, it integrates the large body of research that investigates the organizational capabilities required for service transformation (Storbacka 2013; Ulaga and Reinartz 2011). Hereafter, we use the term *capability* to describe the 'firm's capacity to deploy resources for a desired end result' (Helfat and Lieberman 2002), and *digital capability* to identify those capabilities that are exclusively deployed thanks to the DTs analysed in this study. In line with the tenets of the service dominant logic (Akaka and Vargo 2014), we assume that technology behaves as an operant resource and plays an active role in value co-creation.

Previous research shows consensus on the relevance of DTs in service transformation, but a comprehensive view is still missing. In their seminal paper, Allmendinger and Lombreglia (2005) examine the functions enabled by connected products and discuss the strategies followed by the vanguard of industrial companies to deliver smart services. They point out the functions that are crucial in this respect: a) monitoring product status and condition, b) user profiling and tracking behaviours, c) self-diagnostics, d) mapping product and user locations and movements and e) control and automation. In line with these findings, Porter and Heppelmann (2014) argue that making products smarter progressively enables four kinds of capabilities: a) monitoring product status and condition, b) controlling and personalizing product functioning, c) optimizing and enhancing the product/process performance and d) providing self-operating/autonomous products. Fano and Gershman (2002) state that user profiling and localization capabilities are essential for delivering digital services that, in the age of ubiquitous computing, take advantage of always-on interactive channels. RFID and other IoT technologies are crucial for tracing spare parts (Cheng, Barton and Prabhu 2010). Baines and Lightfoot (2013) identify the core functions in delivering advanced services and suggest that the traditional information systems of manufacturers should be extended with capabilities such as monitoring, transmitting, storing, analysing and interpreting data. In particular, remote monitoring helps companies anticipate faults and deliver proactive customer support services (Grubic, 2014). Analytics tools combined with advanced monitoring and communication technologies, moreover, allow the development of capabilities that are completely new for industrial firms, such as processing, analysing and interpreting data from the installed base (Ulaga and Reinartz 2011; Evans and Annunziata 2012; Iansiti and Lakhani 2014).

The abovementioned studies find agreement in pointing out that these capabilities will be crucial for manufacturers to offer professional services. However, they examine only superficially the linkages among the capabilities and the service transformation.

2.3 Service transformation paths

Previous research examined the service transformation of manufacturing companies by using different lenses of investigation (Brax and Visintin 2016). The literature points out that such a transformation can be described in terms of the shift of product-service offering (Kowalkowski et al. 2015)

(1) from product- to process-oriented services (Eggert et al. 2014; Raddats and Easingwood 2010; Ulaga and Reinartz 2011; Windahl and Lakemond 2010; Zhang, Guo and Zhao, 2016);
(2) from standardized to customized solutions (Matthyssens and Vandenbempt 2010; Penttinen and Palmer 2007);
(3) from transactional deals to long-term contractual agreements (Oliva and Kallenberg 2003; Tukker 2004).

Since '*servitization is more multifaceted and multidirectional than literature assumes*' (Kowalkowski et al. 2015), companies do not undertake unidirectional repositioning of their offerings, as suggested in the taxonomy by Tukker (2004). Instead, they may occupy multiple positions along the service transformation continuum to satisfy different customers' needs. We also agree that in certain situations, companies can also reduce the relative importance of their service offering, especially when technology diffusion increases and standards become established.

On these premises, we ground our research on the model by Kowalkowski et al. (2015), which captures the multiple perspectives of servitization. Moving from the 'basic' profile of *equipment supplier*, characterized by a product-oriented and standardized offering, the model identifies three trajectories – namely *becoming an availability provider*, *becoming a performance provider* and *becoming an industrializer* – and explains the interplay of service growth strategies, as summarized in Table 3.

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3. Research methodology

3.1 Research questions

Although the importance of DTs for service transformation has been acknowledged, and the impact of technologies is expected to be contingent upon the type of services provided (Kowalkowski, Kindström and Gebauer 2013), the linkages among DTs and service transformation strategies have been overlooked by the literature.

This study contributes to filling this knowledge gap by exploring the role of IoT, CC and PA in the service transformation of manufacturing companies and addressing the following questions (see the research framework in Figure 2):

RQ1) *Which digital capabilities can be induced by the adoption of IoT, CC and PA to facilitate the service transformation of manufacturing companies?*

RQ2) *Which relations can be drawn between the mentioned technologies (IoT, CC, PA) and the service transformation trajectories described in section 2.3?*

- INSERT FIGURE 2 HERE -

3.2 Research methodology

The research described in this study is exploratory, as the topic addressed is at an early stage of maturity. Miles and Huberman (1994) advise beginning theory-building research by developing a research framework and research questions (reported in the previous section). Then, using a qualitative multiple case-study method, these questions are addressed on the basis of findings from a sample of four companies. Case research has proven to be particularly beneficial in the early explorative stages of theory development, when the phenomena under study are not completely understood (Voss, Tsikriktsis and Frohlich 2002; Yin 2009).

We purposively select four leading companies participating in the ASAP Service Management Forum[1], an industry-academia community addressing service innovation in manufacturing companies established more than a decade ago. Case selection is based on the following criteria: a) adequate representation of cutting-edge technology-driven service innovations based on IoT, CC and/or PA, b) adequate representation of different service transformation paths and c) availability to share information and participate in the study. The main descriptive information about the cases is summarized in Table 4, which also reports the number of interviews and respondents involved in each case. The information has been gathered through semi-structured interviews (Fontana and Frey 1994) aimed at generally investigating themes such as the services/solution object of the study; the strategic role attached by the company to the offer; the arrangements, organizations and technologies used to develop novel offerings and the way data were collected and managed as well as information protected. To enhance the study's reliability, three researchers participated in the interviews simultaneously, and different company managers were consulted (including roles such as digital and/or product-service innovation manager, product and product planning manager, service and support manager). The interviews were transcribed. Consistency of information and adherence to reality were evaluated through independent coding and cross-checked by the researchers, followed by an internal meeting to converge to a general consensus (Baxter and Jack 2008). Minutes and main messages were then sent to the informants for review along with requests for clarifications.

The information gathered has been complemented and triangulated with secondary sources such as company documentation, websites and company speeches in

[1] www.asapsmf.org , accessed on July 20th, 2016 (website in Italian)

public workshops. The answers provided by the managers have been analysed according to the framework shown in Figure 2 to understand, for each service provided by the studied case and for the whole offering, the impact of each DT investigated as well as its relation with the trajectories described in Table 3. In particular, as suggested by Miles and Huberman (1994), we have used tabular displays to categorize and connect constructs related to digital capabilities (e.g. '*we have totally redesigned the control system of the scooter engine to allow the user, through its card, to activate the scooter*') to the type of product-service offered (e.g. access to a free floating fleet of shared scooters, '*whose usage is paid on the basis of the distance travelled*').

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4. Case studies

4.1 Piaggio

Recent environmental and social pressures have stimulated some players in the automotive industry to develop new solutions for city mobility based on shared vehicles (Mahut et al. 2017). Using their smartphones, customers can promptly locate, book and activate the requested vehicle and pay the service on the basis of the actual usage. Premised on these concepts, ENJOY is a business initiative developed through a joint venture between Fiat Chrysler Automobiles and ENI covering five Italian cities[2]. ENJOY customers have the possibility of renting – besides cars – a fleet of three-wheeled scooters provided by Piaggio. To comply with the requirements of the free-floating mobility solution, Piaggio undertook manifold product redesign activities. It redesigned the saddle and host sensors and actuators that connect with the ENJOY

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[2] as of January 2017, from https://enjoy.eni.com/en

smartphone application to deactivate the immobilizer, open the saddle and let the user take the key and the helmet. A sensor for GPS localization and others that measure the inclination and acceleration of the scooter have been introduced to provide alerts in case of accidents or hits. The scooter control unit has been redesigned to achieve and host new data such as fuel consumption, acceleration and braking intensity. Managers plan to use insights into customers' behaviours derived from vehicle usage to support the development of new products and ad-hoc solutions. For instance, by analysing the density and timing of scooter movements, managers can target specific customer segments, such as residents of the same building, to develop tailored solutions. At the same time, managers are considering how to exploit real-time connectivity to develop condition monitoring and preventive maintenance services.

4.2 Canon

Canon has over time developed document management solutions in the form of pay-per-page contracts (Rapaccini 2015). As Canon bills its customers on the basis of printed pages, the company aims to maximize equipment uptime. For this reason, service contracts include the replenishment of consumables and some planned maintenance as well as parts and labour for repair. Periodically, Canon collects data about machine status and number of copies printed to issue invoices and schedule maintenance interventions and toner supplies. Initially, customers as well as field technicians – who periodically visit the customers' facilities – were in charge of reporting these data to the Canon offices. The rise of internet-based technologies enhanced the possibility of having increasingly more connected machines that regularly send their meters to the company's ERP (enterprise resource planning). As emerged from the initial ad hoc projects carried out by Canon subsidiaries to automate data collection and invoicing, connecting printers to the internet raised issues in term of security, doubts about complexity and costs due to hardware and software modifications. To overcome these issues and benefit from a large scale project, Canon developed the cloud platform eMaintenance®. Today, Canon equipment installed across the world can connect and send to the platform data related to meters and machine status, ink levels, activity log and fault registry. Before installation, printers are pre-configured with an assigned IP. As soon as they are plugged into the customer network, they establish a secure socket layer internet connection and register themselves on the platform, where their master data (i.e. serial numbers, customer, contract settings, etc.) have been previously uploaded. Canon also resorts to an independent dealer network, to which it recently extended eMaintenance services. In this case, Canon adopted web-service technologies to provide its partners with a secure access to sensitive information regarding customer bases and service contracts belonging to other dealers.

4.3 KONE

One of the largest elevator companies in the world, in the last decade KONE has refocused its mission as a company ‘dedicated to people flow’. Working around this concept, KONE invested resources into designing smoother, safer and more personalized and integrated people flow solutions. KONE also offers full risk contractual services on the installed base, taking over the responsibility for achieving a contractually agreed availability level of elevators. However, due to the heterogeneity, complexity and size of the installed base, KONE has had some difficulties in monitoring whether the promised performance is actually achieved. In addition, about 60% of elevator components are procured from external suppliers, and this introduces further complexity. To overcome this situation, the company recently entered into an agreement with IBM to leverage on IBM’s Watson technology for developing smart buildings solutions. First, an ongoing project is exploiting the machine learning capabilities of Watson to develop condition monitoring and predictive maintenance services that minimize downtime and speed up equipment restoration. Besides detecting incipient failures and automating service calls, the company expects to be able to remotely manage most of the technical issues. Furthermore, following a 'system of systems' perspective (Porter and Heppelmann 2014), all devices and plants – e.g. sliding doors, escalators, elevators – installed in the building will be interconnected to provide integrated solutions that adapt themselves to the contingency of the people flow and optimize their performance. To this concern, KONE and IBM are developing analytics to estimate the total cost of moving people inside a building and the energy savings that correspond to different control logics. They also expect that IoT technologies will facilitate security control and automation in a manner that should make it easier for supervision systems to restrict access to certain areas for security reasons. Last, they are working on 'smarter' elevators, which self-adapt to people's disabilities and hindrances.

4.4 Alpha

Beginning as a typical manufacturing company making the most of its revenue by selling industrial products and repair services to the Oil & Gas industry, for quite a long time Alpha has offered performance-based services (Selviaridis and Wynstra, 2015). In recent years, Alpha started a large software project (Alpha Software) to accelerate the development of DTs and services. Leveraging on technologies to better exploit its advanced system of technical knowledge and years of experience, Alpha has developed a cloud platform for building IoT applications for industrial equipment. Alpha also provides subsidiaries and customers with field devices that can connect to the control units of industrial machines and transmit data via the internet or 3G/4G networks. The developers of IoT applications can access the cloud platform and create repositories on which the data collected from the field devices can be stored. Then, they have access to manifold tools that can be instantiated and tailored in the form of a PaaS. For instance, there are workspaces for creating asset management applications; for developing dashboards that run on mobile devices; for developing analytics, time series and statistical analysis and for integrating simulation models developed in Matlab® or Simulink® or other environments. According to a mid-term roadmap, Alpha is migrating into its platform the applications for condition monitoring and health management previously developed by software engineers in proprietary tools (the core of contractual service agreements offered by Alpha). It is in the vision of Alpha that any manufacturer of industrial equipment can subscribe to the platform and develop their own industrial applications. The more objects and applications that become available as building blocks of the PaaS strategy, the less coding activity will be required. Ultimately, Alpha aims at facilitating the formation of an ecosystem of different actors, such as suppliers, technology providers, research centres and systems integrators, which share knowledge on predictive techniques. It appears evident that the adoption of a complete (i.e. IaaS, SaaS, PaaS) cloud model is essential for achieving this goal.

5. Discussion

In light of the theoretical background presented in Section 2, this section discusses the findings from the case studies and addresses the research questions reported in Section 3.2.

5.1 Digital capabilities (RQ1)

Based on our conceptual elaboration on the literature review in Section 2 and the case studies described in Section 4, we identified 11 digital capabilities that are induced by the technologies studied in this paper. We ordered these capabilities based on their ideal position in the DIKW hierarchy, moving from lower to higher levels – that is, from data to information and knowledge. Table 5 describes the capabilities and their linkages with IoT, CC or PA and discusses the relevance of these technology trends in relation to the case studies.

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In sum, we postulate that IoT is foundational for most of the capabilities identified, as it allows the collection and transmission of data upon which firms can deploy advanced functions and services. For this reason, all the cases significantly resort to one or more of the capabilities associated with IoT. For instance, Canon and Piaggio identify both product and customer/user to develop *pay-per-use* revenue models. The role of CC is threefold. First, it is essential for storing huge amounts of field data in a convenient and efficient way (IaaS layer). This in turn allows data aggregation and processing (IaaS and SaaS layers coupled) and information gathering. For example, Canon extracts information concerning different products operated by the same customer. By purposively aggregating data concerning users and users' departments, organizations and machine IDs, Canon is able to correctly bill the customer for the whole fleet and generate invoices including information that helps the customer's accounting process. This is enabled by integrating IoT data hosted on the eMaintenance platform with the company's ERP and applications.

Last, CC is crucial for creating 'data lakes' that allow the exploitation of PA related capabilities – such as prediction, adaptive control and optimization and autonomy (see Table 5). This latter function is linked to the use of PaaS layers and is employed when the company decides to stimulate the creation of new ecosystems as in the cases of Alpha and KONE.

5.2 Relations among IoT, CC, PA and the service transformation paths (RQ2)

Thanks to its ability to capture, contextualize and transmit data, IoT is pervasive in the implementation of any service transformation strategy. This is consistent with the foundational role of data in the DIKW hierarchy. To put in place initiatives that move towards the *availability provider* profile, IoT enables efficient data collection from widespread fleets. This is exemplified by Canon, which introduced internet technologies and connected remote machines to local databases to automate the reading of meters long before the advent of CC technologies. In addition, IoT technologies are core to other relevant capabilities of pay-per-use offerings, such as identification, tracking, localization and time-stamping. However, moving toward the *availability provider* profile also benefits from the combination of IoT and CC in its lower layers. IaaS is extremely efficient for storing field data captured by connected machines and SaaS for having applications that process the cloud's raw data and generate and share information across the organization. Companies implementing a *performance provider* strategy usually strive for field data, as they have to determine how the desired performance can be achieved. We found that in this situation, IoT, CC and PA are combined to extract knowledge from field data and make significant predictions on products' faults and customers' behaviours. PA techniques are used to a) set anticipated or pre-emptive actions – such as issuing preventive maintenance or shipping spare parts and b) simulate the service level to be achieved in correspondence with different operating policies and resources configuration to estimate how benefits counterbalance costs. This situation is exemplified by KONE (see Figure 3), which is introducing new control logics to reduce energy consumption without reducing service levels as well as to prevent that, under certain conditions, people may gain access to areas that are restricted for security reasons.

Further considerations concern the use of IaaS and SaaS layers. We argue that their adoption is not a prerequisite for moving along the two abovementioned paths, since data can be collected and processed in traditional ways, such as stored in a local database where applications embedding prediction algorithms run. This is the case with the monitoring and diagnostic services that Alpha offered before the launch of its cloud platform. However, IaaS and SaaS are powerful mechanisms for scaling infrastructure in line with business growth. This is clear in an *industrializer* trajectory, which pushes companies to standardize and industrialize what they had previously developed, tested and successfully sold in other profiles (i.e. availability- or performance-oriented) to reach larger customer bases. Once economies of scale and standardization are achieved, the PaaS layer offers cutting-edge technology to integrate the building blocks of a modular service offering. For instance, Canon exemplifies how an availability provider industrializes its pay-per-page solutions and extends the newly created capabilities well outside its organization. Alpha moves further, as it exploits CC to industrialize performance-based offerings. By using this platform, Alpha aims at making data collection from industrial equipment easier and facilitating the creation of industrial internet applications that actually reproduce Alpha's know-how in regard to prediction models but that prospectively will generate new knowledge from a larger ecosystem. This view is in line with that of Lusch and Nambisan (2015), who state that service platforms can '*enhance the efficiency and effectiveness of service exchange by liquefying resources and increasing resource density*'. In other words, we confirm the service innovation potential of DTs since they increase the fluidity of resources. In addition, we postulate that the combination of IoT, CC and PA is relevant particularly in those firms that aim at 'productizing' their service offering, to lead back again to an equivalent of the equipment supplier role (Kowalkowski et al. 2015) and sell advanced services with a *service-as-a-product* approach.

The framework of Figure 3 summarizes these findings and identifies the DTs enabling the corresponding trajectories. In line with Kowalkowski et al. (2015), we assert that IoT, CC, PA or their combinations specifically facilitate moves from and to a specific strategic profile.

- INSERT FIGURE 3 APPROXIMATELY HERE -

6. Conclusions

6.1 Contribution to research

The role of DTs in the service transformation of industrial companies is still under-investigated (Akaka and Vargo 2014). This paper reports an exploratory effort to fill this gap, providing the following contributions.

First, we focus on three DTs frequently mentioned in the service transformation literature: IoT, CC and PA. We provide a systematization of these technologies, and we discuss their features in relation to the DIKW hierarchy (Rowley 2007). To the best of our knowledge, previous research has not dealt with the use of the DIKW framework to classify and describe the role and scope of IoT, CC and PA.

Second, we identify 11 key digital capabilities for service transformation that we elaborate from the literature and four case studies. This adds to the existing body of research by formalizing and increasing understanding on this issue and complements the broader research stream dealing with the organizational capabilities for service transformation (e.g. Storbacka [2011]; Gebauer et al. [2017]).

Third, we suggest that the role of the three technologies in the service transformation of manufacturing companies should be examined in light of the service transformation trajectory pursued. We analyse in particular the three service transformation paths proposed by Kowalkowski et al. (2015), and our findings are summarized in Figure 3. Our discussion suggests that IoT has a foundational role for undertaking the *availability provider* and *performance provider* paths. Moreover, companies undertaking a *performance provider* path rely heavily on PA to extract knowledge from the installed base data and develop advanced services (Baines and Lightfoot 2013). The IaaS and SaaS layers of CC act in these trajectories as important, yet non-mandatory, enablers to achieve cost efficiency. Finally, in the *industrializer* trajectory, the full benefits of standardization, modularization and scalability that enable companies to offer solutions obtained by recombining the components of intermediate or advanced offerings in a mass customization fashion is also achieved by implementing the PaaS layer of CC. This is, to the best of our knowledge, among the first studies trying to establish a link between the DTs and, on one hand, the (digital) capabilities enabled and, on the other hand, their role in supporting specific servitization strategies.

Fourth and last, this study is in line with recent works challenging the view of service transformation as a move along a continuum, usually assumed in the literature (e.g. Oliva and Kallenberg [2003]), and calling for deeper investigation of trial-and-error approaches and deservitization moves (Kowalkowski, Gebauer and Oliva 2017a; Kowalkowski et al. 2017b). We contribute to this research stream, trying to shed light on specific service transformation trajectories (including a standardization and 'productization' trajectory) by discussing which steps in the technological capabilities of an organization are required to successfully undertake each service transformation path.

6.2 Managerial implications

The findings described in this paper also entail relevant implications for practitioners. The debate on transformation related to the 'servitization of the manufacturing firm' and to the rise of the 'Industry 4.0' is heating up rapidly. However, a deep understanding of how to successfully undertake these transformations and how to apply DTs is still lacking in the managerial community. In fact, servitization presents several challenges (Alghisi and Saccani 2015), resulting in the so-called servitization paradox (Gebauer, Fleisch and Friedli 2005) that may lead companies to the opposite process of deservitization (Valtakovski 2017) or to even go bankrupt (Benedettini, Swink and Neely 2017). On the other hand, manufacturing companies (and in particular SMEs, which often lack adequate knowledge about new DTs) may find it difficult to a) develop a clear understanding of how digitization can create value for their customers, b) prioritize investments and c) successfully carry out digitization projects (Chalal, Boucher and Marquès 2015).

In this context, as a first contribution this paper supports managers in developing a clearer understanding of the role of DTs. By shedding light on the digital capabilities enabled by the three DTs, we help managers understand the service innovation potential of such technologies for their own product-service offerings. Such an increased conceptual clarity can support the full exploitation of the IoT, CC and PA technologies currently embedded in a company's product-service architecture.

Second, the identification of the relations among DTs and the different service transformation trajectories allows managers to align at a strategic level their service growth plans with decisions about the digitalization of their business (at the product or process level) by designing technology innovation projects consistent with business model innovation or service portfolio expansion plans. In addition, managers can appreciate the current technological endowment and the projected service transformation trajectory.

Third, the identification of a set of digital capabilities related to the different DTs may inform investment decisions on hardware/software improvements aimed at developing specific capabilities. At the same time, having connected such capabilities with planned service trajectories, companies can also better identify which new skills are crucial for their personnel to acquire and develop for the short or long term and target hiring processes consistently.

In an attempt to generalize and make more ‘actionable’ for practitioners the findings from this study, we propose a model that shows how IoT, CC and PA can be exploited by industrial companies in their shift toward the service business. This model (see Figure 3), which synthetizes the linkages between each technological layer and the diverse service growth trajectories, is the major contribution of this paper to the field of research focused on industrial companies’ digital transformation and shift to the service business.

6.3 Limitations and future research directions

This study comes with some limitations. The main one concerns the external validity of our findings. As for all qualitative research, truly general inferences cannot be made. In particular, the four case studies were chosen for reasons of appropriateness rather than of representativeness. This paper develops theoretical insights concerning digital capabilities and their patterns in relation to the three technologies and the three service transformation paths analysed. The study does not test them, and, as such, the extent to which our results can be generalized remains unclear. Future research should obtain additional qualitative data to replicate our findings. Moreover, the four cases do not cover the strategic path of companies moving from an *availability provider* to a *performance provider* state; specific cases covering this trajectory should be studied.

Also, little evidence has been found concerning autonomy capability in the case studies. We may argue that through *autonomy* a manufacturer can achieve the highest degree of productization of its services, since the functions typically offered by the manufacturer – or by its partners – become embedded in a smarter product. In particular, autonomy requires the full exploitation of the potential of the three technologies. IoT supports data collection and contextualization and enables secure machine-to-machine connections, while PA generates the knowledge that is progressively incorporated into a smart, connected system of products (Happelman and Porter 2014). Finally, CC technology makes this knowledge adaptable, evolutionary and responsive. Future research should address this capability more deeply.

Another limitation calls for an extension of the research. We investigate the digital capabilities related to IoT, CC and PA, since they are considered the most disruptive and relevant technologies for service transformation, but the role of other relevant technologies such as augmented reality or additive manufacturing remains unexplored. Future research ventures should address these technologies to develop a full set of digital capabilities supporting the service transformation as well as to examine in greater detail how these capabilities affect the design and development of new product-services and smart services offerings.

Moreover, through the trajectories described, all the case companies expand into new strategic profiles rather than completely substituting the previous product-service offering. Investigation has been called upon the management of multiple service offerings and strategic positioning at the same time (Kowalkowski et al. 2015; Benson-Rea, Brodie and Sima 2013). However, our research does not explicitly address how such multiple positioning is sustained through, among others, digital capabilities. Future efforts should aim at unveiling this subject.

Finally, the four cases show different strategies for digital capabilities development. In the case of Alpha, an internal path was followed, where a new business unit was developed internally, exploiting the internal knowledge on PA. On the other hand, KONE resorted to an external provider (i.e. IBM) to support the development of the new offer. Finally, mixed approaches were followed by Piaggio and Canon. The literature on service transformation has debated on the internal versus external development path for the development of organizational capabilities (Kowalkowski, Kindström and Witell 2011) as well as on supplier relationships for service delivery (Bastl et al. 2012; Saccani, Visintin and Rapaccini 2014). An interesting avenue for future research would be the investigation of such topics specifically for the development and delivery of the digital capabilities supporting service transformation.

Acknowledgements

This paper has been inspired by the activity of the ASAP Service Management Forum (www.asapsmf.org), a community where scholars and practitioners collaborate in developing research projects and share findings in the servitization and service management fields.

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Table 1. Technologies in the scope of this paper (IoT, CC, PA).

Name	Description	Enablers	References
Internet of Things (IoT), a.k.a. Industrial Internet, Internet of Every Things (IoE)	IoT is the internet of the future, a global network in which billions of devices can be heterogeneously interconnected to exchange data and interact to extend their functions beyond the physical world and reach common goals without direct human intervention.	Tags, sensors, actuators, connectivity devices. Communication network and standards (e.g. IEEE 802 ZigBee, WLAN, Low Energy Bluetooth, 3G/4G/5G, RFID, NFC). Protocols and languages for content management and data encoding. Service oriented architectures (SOA). Extended network management (IPv6).	Li et al. 2015; Evans and Annunziata 2012; Giusto et al. 2012; Atzori, Iera and Morabito 2010; Lee and Lee 2015
Cloud computing (CC), a.k.a. ubiquitous computing, on-demand computing	CC allows ubiquitous access to a shared pool of computing resources – such as servers, storages, operating systems – that can be conveniently, configured and provisioned and on-demand, with minimal management effort.	The term CC can entail different services: *Infrastructure as a Service (IaaS)* provides access to a remote infrastructure that users can configure to install and run operating systems and applications. *Software as a Service (SaaS)*	Mell and Grance 2010; Arockiam, Monikandan and Parthasarathy 2011

		provides direct access to software applications that run on a cloud infrastructure, which users do not have to manage. *Platform as a Service (PaaS)* is used to deploy applications that are directly developed in the cloud.	
Predictive analytics (PA), a.k.a. cognitive computing, machine learning, data mining, big data analytics	PA is the application of skills, expertise and algorithms on collected data to estimate the likelihood an event will take place in the future.	PA leverages software and data mining techniques to identify relationships between explanatory and criterion variables to uncover hidden patterns and unknown correlations and to extract useful information from data. Machine learning (ML) and computational statistics are keys in developing models that predict future outcomes from the confirmed relationships. These techniques find proper application to large amounts of data (big data, open data analytics).	Ogunleye 2014; Hair 2007; Zhong et al. 2016

Table 2. The DIKW hierarchy and its relationship with IoT, CC and PA (elaborated from Rowley 2007)

Level	Entity	Description	Know what	Relationship to IoT, CC and PA	Example
0	Data	Data are elementary descriptions of objects' properties (e.g. activities, events, transactions) generated by observation with different forms.	Nothing. Lacking contextual interpretation, data have no intrinsic value and do not provide specific answers.	IoT allows collecting and transmitting data in a secure and efficient way.	Sensors periodically record weather data – such as temperature and position – and transmit them to a central database through the mobile network.
1	Information	Information is generated through data processing (i.e. selection, sorting, aggregation, classification, calculation and statistical inference).	Who, what, when, where and how many.	Cloud computing facilitates storing and manipulating data and provides data accessibility and processing functions.	An algorithm that can easily calculate the average temperature of a period on the basis of collected data.
2	Knowledge	Knowledge is the combination of information that – by adding expert opinion, understanding, accumulated learning and experience – results in valuable insights, know-how and actionable instructions.	How and how-to questions and help decision-making.	Predictive analytics allows the application of algorithms, artificial intelligence or soft computing methods to develop business intelligence and decision support	Once training and validation on a large dataset is achieved, a regression model is used to predict next day temperatures. An application warns people living in the vicinity if hot weather is expected.

Level	Entity	Description	Know what	Relationship to IoT, CC and PA	Example
				systems.	
3	Wisdom*	Wisdom is generated by personal judgments and ethical, aesthetic and social considerations applied to knowledge to determine and take into account – besides what is known – what is good.	To support the understanding and appreciation of why specific actions have to be taken, putting into action the most appropriate behaviour.	Even the most advanced technology has no role in wisdom-driven decisions, as they still have remarkable limitations in regard to ethics and morality reasoning. Therefore, we do not consider the influence of IoT, CC and PA at this level	Based on past experience and predictions, a civil protection agency decides to intensify a medical assistance service for elderly people to better protect them from heatstroke.

*As wisdom is uniquely a human state, we consider level 3 of the hierarchy out of the paper's scope.

Table 3. Service transformation trajectories of industrial companies (based on Kowalkowski et al. [2015]).

Strategic trajectory	**Offering**	**Drivers and barriers**
(Becoming an) Availability provider	Use-oriented solutions based upon integrated bundles of products and services with longer time horizons and growing shares of extensive service level agreements. Increasing concentration of services focused on customer processes and asset efficiency.	*Drivers:* Customer loyalty, business growth and stable revenues push top management to rethink a company's service configuration. *Barriers:* Internal resistance to change, product-based culture and processes, low capabilities of coordination.
(Becoming a) Performance provider	Services developed with a long-term orientation to satisfy specific customer needs and to ensure the achievement of requested performances.	*Drivers:* Specific customer demand, differentiation needs, creation of strategic partnerships and customer wrapping. *Barriers:* Incapability to properly develop and manage operational and financial risks as well as integration and coordination among partners.
(Becoming an) Industrializer	Single and/or standardized solutions derived by unbundling customized product-service packages or recombining components of advanced offerings.	*Drivers:* Economies of scale, creation of standards to address a larger customer base or utilization of in-house knowledge and resources. *Barriers:* Low service experience due to a poor knowledge of product-service process delivery and customers experience together with a scarce modularization competence.

Table 4: Case companies' description

Company description	Offering	Case study scope and service transformation path	Number of interviews and roles of respondents
Piaggio engineers and manufactures two-wheeled vehicles and compact commercial vehicles.	The traditional business of Piaggio is product-centric. However, the company has recently started offering scooter sharing services in Milan and in Rome (Italy) in collaboration with other partners.	The study examines the technological changes to traditional products to enable free-floating scooter sharing services in the cities of Milan and Rome. This initiative is coherent with the strategy of an equipment supplier that explores the *availability provider path*.	2 interviews Roles: Head of Strategic Innovation; Product Planning Specialist
KONE is a leading manufacturer of elevators and 'people flow' systems for small and large buildings.	Elevators, escalators, automatic doors and gates worldwide. KONE also provides engineering, maintenance and modernization services.	We focus on technologies enabling the integration services for large building management. KONE offers intelligent systems with remote control for energy saving, safety and security issues. This case investigates the digital capabilities relevant for *becoming a performance provider*.	2 interviews each involving 2 managers from KONE and 1 manager from IBM Roles: - KONE: Head of IoT Architecture; Director of New Business Concepts, New Services & Solutions - IBM: Cross Service Lines Services Leader
Canon Italia is the local subsidiary of the Japanese manufacturer.	Consumer electronics products, digital cameras, projectors, imaging technologies, printers, multifunctional copiers and document management solutions.	We study the technologies used to offer – directly or through a dealer network – office equipment (copiers, printers, plotters) under pay-per-use agreements. This business model is coherent with the trajectory of an availability provider that *industrializes* its product-service offer to sell it as a commodity.	3 interviews involving managers of Italian subsidiaries service departments and the software team located in London Roles: Director Service &

Company description	Offering	Case study scope and service transformation path	Number of interviews and roles of respondents
			Support, European Product Specialist, Technical Support Manager
Alpha is part of a large multinational group. Alpha produces rotating equipment for manifold applications in the Oil & Gas sector.	Gas turbines, pumps and compressors, parts, field maintenance, repairs, time and material contracts, long-term full-risk service contracts.	We focus on the relationships between the start-up of digital services and the underlying technologies. This corresponds to the trajectory of a performance provider that is consolidating and expanding its business through scalable technologies (*industrializer path*).	1 interview with a manager of the remote service centre, 1 interview with three managers of the digital service team. Roles: Engineering Digital Solution Manager, Senior Engineer for Health Management System, Product Manager

Table 5: Digital capabilities for service transformation

Capability	Related question	Description and relation to product-service development	Relation to IoT, CC, PA	Relation to case studies
Identification (user)	*Who is using the product at a specific time instance and/or usage instance?*	Identification of the user in each use instance; examples are car sharing services, copiers and printers that employ smart cards and/or PIN codes to log users into the product before they can use it. This capability is relevant for developing pay-per-use services and individual billing.	The use of tracing and identification technologies, such as barcodes/QR codes readers (cameras and applications), RFID/NFC tags and antennas, optic or biometric sensors, is typical of **IoT** applications. Users are linked to their master data, including name and address, contract entitlements, access rights, credit card numbers, etc. **CC** can host these data in a scalable repository and enable secure connections with field devices.	Piaggio uses smart cards to enable access to and activation of free floating scooters in its pay-per-use mobility services. Canon uses smart cards and/or personal login passwords to enable individual accounting and billing of the copies from a fleet of printers.
Identification (product)	*Which specific product instance and product configuration is under consideration?*	Identification of the specific product (e.g. serial number) of its architectural and functional configuration (firmware versions, BoMs, components, etc.). This capability is relevant in pay-per-use services as	Manifold **IoT** technologies can allow asset identification. As long as virtual reality technologies and graphics engines are widespread, digital representations of products can be accurately built and maintained (Wuest et al. 2016). Storage capacity is no longer a limit thanks to the	Piaggio, Canon, KONE: only units that are univocally registered on the corresponding platform or application can connect and send their data. Alpha: the configuration of each asset connected

Capability	Related question	Description and relation to product-service development	Relation to IoT, CC, PA	Relation to case studies
		well as in traditional product-support services.	adoption of **CC**.	can be mapped via an asset management module
Geo-localization	*Where is the product located (at a specific time/usage instance)?*	Continuous product localization in a map. Can support fleet management of, e.g., cars or forklift trucks. This capability is relevant in location-based services and fleet management.	**IoT:** GPS technologies are used in outdoor applications. Beacons, passive and active RFID tags in combination with Wi-Fi triangulation result more effective for indoor positioning. When this information is stored in **CC** platforms, it is integrated with product and customer data to exploit existing application program interfaces (API) for the most common maps platforms and services.	Piaggio modified scooters employing GPS technology to be located on a map by customers. The map is available on the web and smartphone applications and is provided by Google Maps© services.
Time-stamping	*At what time has a specific event been triggered?*	Association of a (certified) timing related to a known event such as product access, activation, stop, and fault. This capability is relevant in availability-based services that employ time-	Time-stamping authorities can issue trusted time-stamps according to specific standards. In most situations, it is sufficient that the event is triggered by default database management technologies (**CC**), as **IoT** allows real-time clock data transmission.	Trusted time-stamping services are not implemented due to their cost.

Capability	Related question	Description and relation to product-service development	Relation to IoT, CC, PA	Relation to case studies
		based pricing and in pay-per-use services.		
Intensity assessment	*How much a product (or a specific part) has been used?*	Indicates the level of product usage and/or the units it has produced. It can be measured in hours, km, printed pages, cycles, etc. This capability is relevant in availability-based services that employ consumption-based pricing and in pay-per-use services.	**IoT** and **CC** are the key technologies: e.g., smart meters digitally register and transmit via a communication network the consumption of physical resources, output produced and/or length/time of use.	Piaggio's customers are billed with a fixed fee per time unit with an extra charge beyond a given amount of kms. Canon bills a fixed monthly fee and charges extra to users whose printed copies exceed an agreed threshold.
Condition monitoring	*How is the product working?*	Remote monitoring of product status and working parameters such as temperatures, pressures, acceleration, vibrations, speed, etc. Alarms may be triggered when critical thresholds are overcome. This capability is relevant in performance-based	Sensors collect and communicate analogic or digital data to a control unit/data logger that can also connect and transmit (**IoT**) these data to remote applications, where they can be stored and elaborated (**CC**).	KONE and Alpha register the operating hours and conditions of connected equipment.

Capability	Related question	Description and relation to product-service development	Relation to IoT, CC, PA	Relation to case studies
		services that promise specific levels of uptime.		
Usage monitoring	*Why is the product used?*	Association of the usage instance to a specific mission or task. This capability is relevant in performance-based services that promise specific levels of service quality and mission achievements.	**IoT** allows data collection and transmission. Besides storing, **CC** can facilitate the development of applications that match these data with information about the usage mission.	Piaggio is developing data mining techniques to determine patterns in scooter usage.
Prediction	*What then? What will a specific condition or event lead to?*	Analysis and interpretation of latest data to likely predict future behaviour. This capability is relevant in performance-based services that promise specific levels of uptime to proactively reduce the time of intervention and restore from faults.	**PA** is applied on data collected with **IoT** and processed with **CC**.	Predictive models for fault prevention are core in Alpha's offerings. KONE is also conducting research and development in this field.
Adaptive (remote) control	*How can the issue be solved or the user experience improved?*	Remote actions for product configuration and control to restore some	Supervisors, when alerted by condition-monitoring services or **PA** models, can activate actuators	Currently, Alpha does not intend to move the equipment control logics

Capability	Related question	Description and relation to product-service development	Relation to IoT, CC, PA	Relation to case studies
		functions or to prevent failures. This capability is relevant in performance-based services that promise specific levels of efficiency in product use due to external supervisory control.	from remote, reconfigure the machine settings, make diagnostic checks, and upgrade firmware to solve technical issues. **IoT** enables bidirectional communications through user-friendly interfaces, that can be developed in **CC** PaaS environment.	from field agents and supervisory control systems to the cloud platform. KONE has integrated the supervisory systems into building management systems to switch elevators on or off.
Optimization and prescriptions	*How things can be done better/more effectively/efficiently?*	Real-time analysis of field data – in integration with predictive models and decision support systems – can help improve product and process performance. This capability is relevant in performance-based services that promise specific levels of efficiency in product use due to internal supervisory control.	Information coming from **PA** are used to reconfigure or restore the product settings. This is strictly related to the previous capability, as it still builds on **IoT** and **CC.**	Exploiting Watson technology, KONE wants to develop sophisticated control logics that reduce energy consumption on the base of people flows, whose data are collected with different **IoT** technologies and shared and elaborated into a **CC** platform.
Autonomy	*How can the product do it by itself?*	Autonomous management of functions and	**IoT, CC** and **PA** can enable the forming of heterarchical systems	KONE's view is to integrate sliding doors'

Capability	Related question	Description and relation to product-service development	Relation to IoT, CC, PA	Relation to case studies
		connections with other products and systems performed by the product itself. This capability is relevant in performance-based services that promise specific levels of automation in product use.	composed of intelligent products and cyber-physical systems that communicate and cooperate to obtain a common objective.	and elevators' control systems to create an autonomous and intelligent people flow control system.

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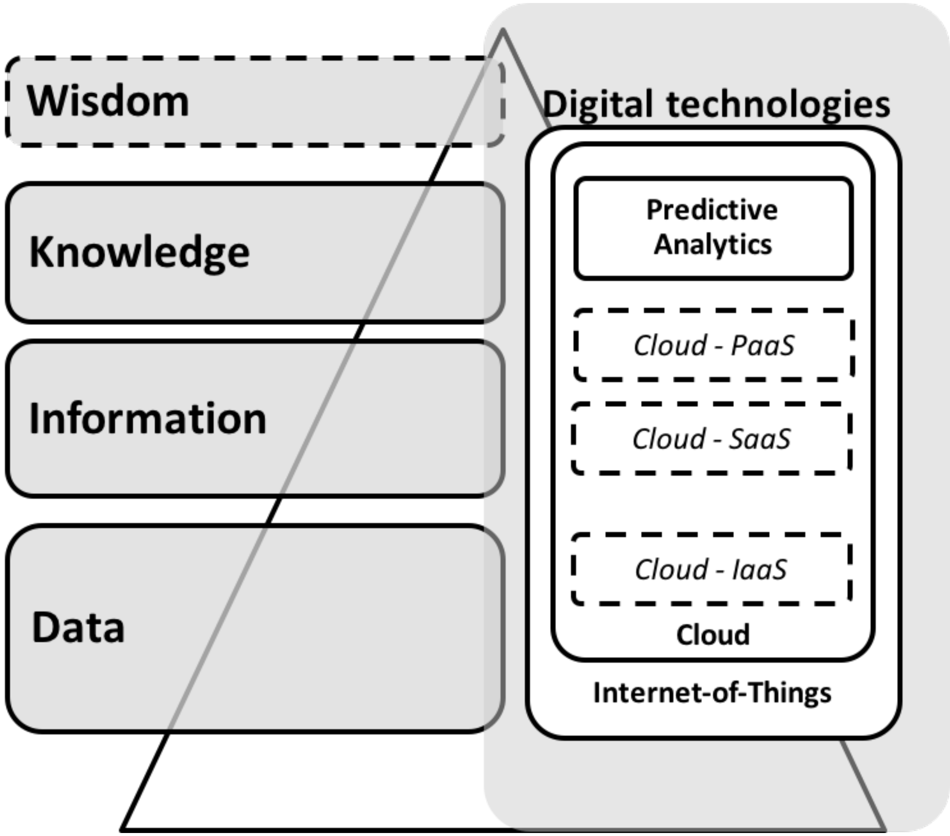

Figure 1. Research framework – Digital technologies and DIKW hierarchy

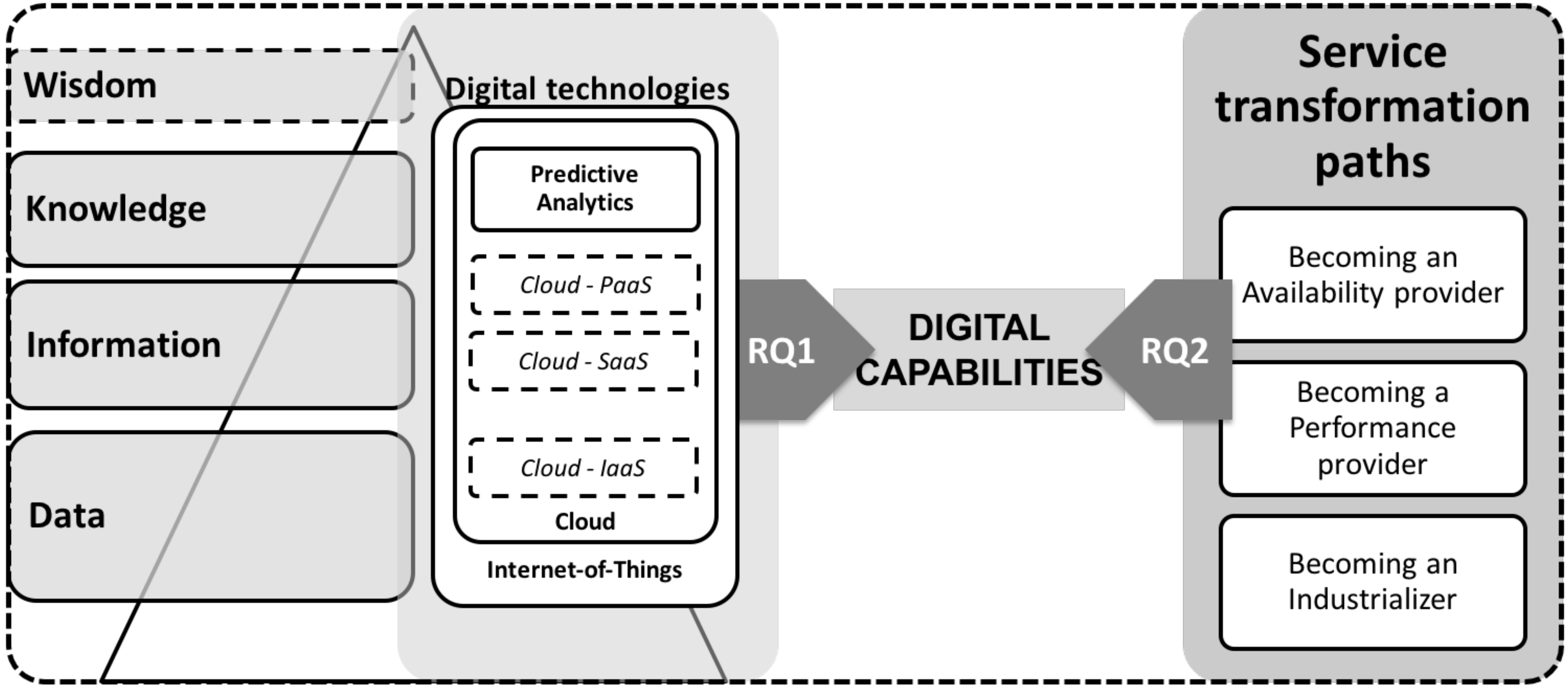

Figure 2. Research framework

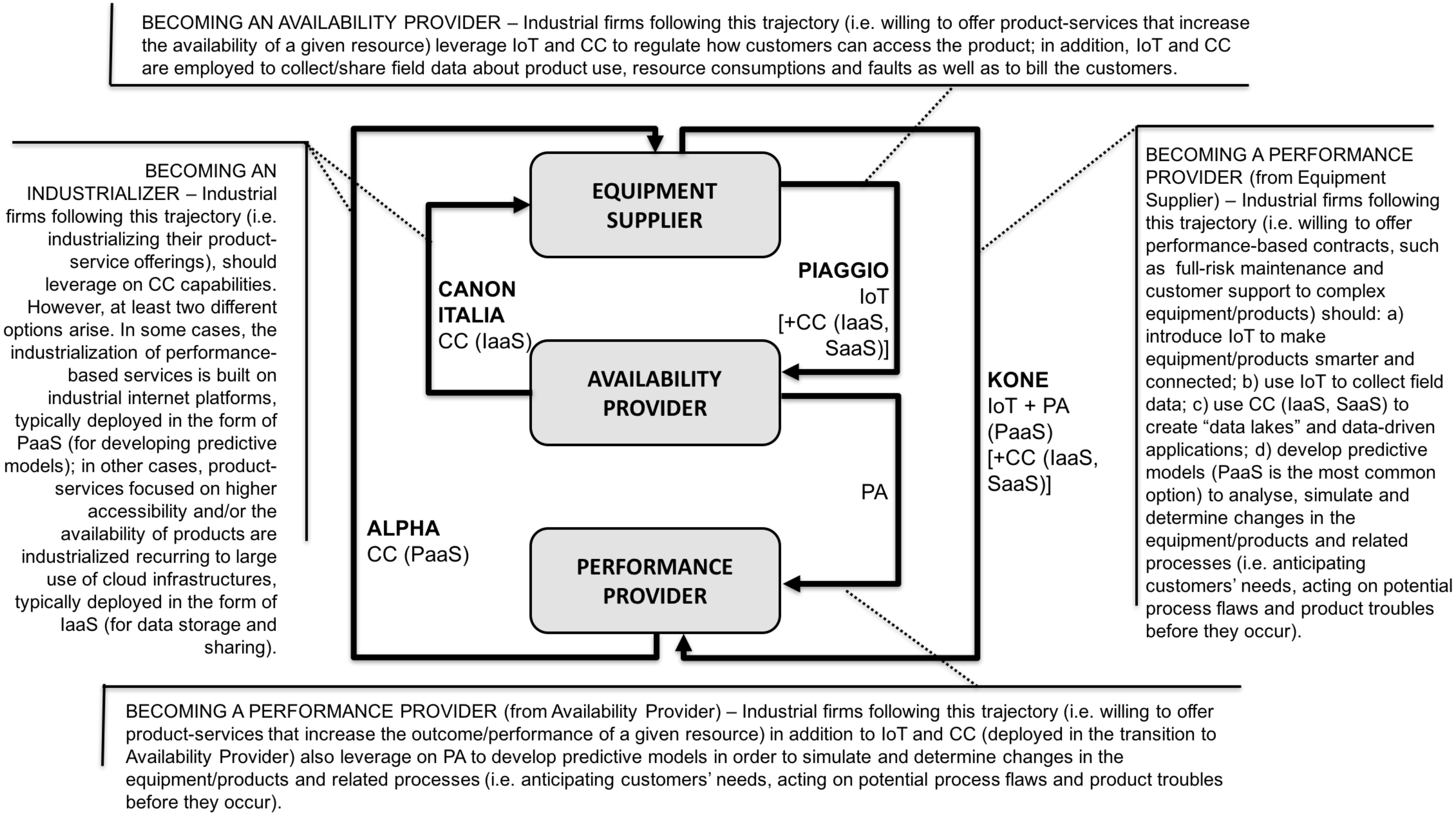

Figure 3. Relations between IoT, CC, PA and the service-growth trajectories of industrial firms and recommendations on the use of DTs