Decision Support Systems 189 (2025) 114365

Contents lists available at ScienceDirect

Decision Support Systems

journal homepage: www.elsevier.com/locate/dss

Realizing desired effects from digitized product affordances: A case study of key inhibiting factors

Ainara Novales [a,*], Martin Mocker [b,c], Eric van Heck [a], Jan Dul [a]

[a] Technology and Operations Management Department, Erasmus University Rotterdam, Burgemeester Oudlaan 50, 3062, PA, Rotterdam, the Netherlands
[b] Reutlingen University, Alteburgstraße 150, 72762 Reutlingen, Germany
[c] MIT Center for Information Systems Research, 245 First Street, Cambridge, MA, USA

A R T I C L E I N F O

Keywords:
Digitized products
Internet of things (IoT)
Digital innovation
Technology affordances
Affordance actualization
Necessary Condition Analysis (NCA)

A B S T R A C T

Despite the potential of IoT-enriched digitized products, firms struggle to generate desired impact. We investigate the alignment of actualized digitized product potentials (i.e., affordances) with organizational goals, examining how the emergence of critical inhibiting factors affect the generation of desired effects. We conduct an embedded single case study of four actualized digitized product potentials within a professional equipment manufacturer and explore how the emergence of inhibiting factors prevents the generation of desired effects. Using Necessary Condition Analysis (NCA), six key inhibiting factors are identified. Our findings contribute to affordance theory and digital innovation research in three ways: a) we provide an extended affordance-actualization model that theorizes the process by which emerging key inhibiting factors are addressed via the implementation of (re-)actions to generate desired effects that are aligned with the organizational goals of actualized digitized product potentials, (b) we identify six key inhibiting factors that affect the generation of desired effects and that re-examine the role of data with respect to the "technology" element in affordance theory, and (c) we apply NCA to affordance theory for the first time and show how it can contribute to identifying critical factors during the realization of technology potentials.

1. Introduction

The global Internet of Things (IoT) market is projected to grow to USD 3352.97 billion by 2030 [1]. Advancements in information technologies (IT), have fostered the digitization of physical products allowing manufacturers to enrich their products with digital functionalities [2]. Examples of these digitized products include Tesla's connected cars, or Signify's Philips Hue connected lightbulbs.

Digitized products exhibit a generative potential "as users continue to add and remove applications and change their functional capabilities" throughout their lifetime ([4], p. 1403). Generativity allows producers to repurpose products and pursue new potentials [4–6], even when the products are in users' hands [3,6,7]. E.g., the Philips Hue lightbulb enables users to set advanced light scenes (e.g., relax, read) via Amazon's Alexa artificial intelligence assistant [8], functionality that was unforeseen when Philips Lighting (now Signify) created Hue in 2012. Thus, the recombination of digitized products' unique attributes affords novel potentials for innovation and value creation [7,9].

Despite the limitless potentials offered by digitized products, there has been a slow uptake by businesses [10,11]. This slow uptake of digitized products—despite their value creation opportunity— is an indication of how challenging it is for manufacturers to generate desired effects from digitizing products. Companies are challenged with identifying and implementing use cases that go beyond the aesthetics of their analog products and that provide relevant use value [12,13]: "just because [a company] can make something with IoT technology doesn't mean people will want it" [14]. Given firms' struggle with realizing value with their digitized product potentials, in this paper we set to investigate the process by which manufacturers generate—or not—desired effects.

As digitized products remain in a state of flux due to generativity, the innovation process for digitized products becomes more complex, too [3,6]. While digital technologies (such as cloud computing, IoT) facilitate experimentation and rapid scaling, they also bring a greater level of uncertainty regarding how processes unfold in time and space, changing from linear to non-linear iterative innovation processes [6]. Thus, the development of pervasive digital technologies challenges the assumptions of prior studies on digital innovation management that

* Corresponding author.
E-mail addresses: novales@rsm.nl (A. Novales), martin@mocker.nl (M. Mocker), evanheck@rsm.nl (E. van Heck), jdul@rsm.nl (J. Dul).

https://doi.org/10.1016/j.dss.2024.114365
Received 19 June 2023; Received in revised form 2 November 2024; Accepted 2 November 2024
Available online 4 November 2024

presupposed innovation to be a well-bounded phenomenon, with centralized innovation agency and clear distinction between innovation processes and outcomes [4,6]. As discussed by Nambisan et al. ([6], p.225), "less bounded innovation outcomes and processes also reflect newer success criteria (for example, ones that reflect the potential for radical rescoping of the product, community-based generativity, […], etc.) and demand newer theories that incorporate such metrics and underlying factors".

While IS researchers increasingly focus on the materiality of digital innovation [6], the development of unbounded digitized products requires scholars to conduct further exploratory research [4]. Affordance theory has become a popular lens in IS research to investigate the transformative character of digital technologies and their generative potentials [15,16]. Affordance theory allows studying how a technology is repurposed by investigating the action potentials it offers actors based on their goals, the material properties of the technology, and the use context [15]. Yet there is limited research that has investigated the actualization of digitized products' potentials (e.g., Dremel et al. [17] explore the realization of big data analytics potentials, which are in some cases linked to digitized products) and that there is a lack of understanding of how producers generate—or not—intended value from the realization of digitized product potentials.

Our study explores this research gap and contributes to the ongoing dialog on the actualization of IT affordances. By investigating well-known factors that affect IT adoption, we identify key factors that affect the realization of digitized product potentials and that negatively influence the alignment with organizational goals. We investigate the following research questions: *How do firms realize desired effects with their digitized product potentials? What are key inhibitors that firms need to address?*

Our study contributes to research on technology affordances and digital innovation by (a) providing an extended affordance-actualization model that theorizes the process by which emerging key inhibitors are addressed via the implementation of (re-)actions to generate desired effects that are aligned with organizational goals, (b) identifying six key inhibitors that affect the generation of desired effects and that re-examine the role of data with respect to the "technology" element in affordance theory, and (c) applying necessary condition analysis (NCA) to affordance theory for the first time, showing how it can contribute to identifying critical factors during the realization of technology potentials. Our study also contributes to practice and presents three guidelines that firms should consider.

2. Theoretical background

2.1. Digitized products and digital innovation

The emergence of digitized products changes the way companies innovate and generate value with their offerings (e.g., [2,6]). Based on the functional logic and the physical embedded part that executes it [3], digitized products, offer many innovative potentials (e.g., Tesla connected cars enable technicians to conduct remote maintenance) – some of which may be even unpredictable at the time of production [2,3,6]. Digitized products have an ambivalent ontology [18] and can act as operant resources, i.e., provide a basis ingredient for other innovation initiatives. At the same time, fueling new innovative outcomes with digitized products also requires innovation in the process of innovation – e.g., to deal with the different clock speeds of hardware and software development [2]. Thus, the innovation outcome and the innovation process become more entangled.

The ambivalent ontology of digitized products and the diminishing ability to clearly distinguish between innovation processes and outcomes call for novel theories and methods to investigate how digital innovation unfolds [6]. One such theory proposed by Nambisan et al. [6] is affordance theory, which can help investigate the challenged assumption that digital innovation is a well-bounded phenomenon with centralized agency. As innovation with digitized product potentials challenges previous research that investigated digital innovation in outcomes and processes as distinctive phenomena, it becomes increasingly relevant to understand how exactly innovation –and, thus, the realization of digitized product potentials—is impacted [6].

The study of digitized product affordances has gained some attention recently: Herterich et al. [9] investigate how firms perceive four potentials of digitized products that are related to service innovation; Benbunan-Fich [19] investigates wearables' potentials to identify the drivers of their success; and Herterich et al. [20] look at how digitized product potentials lead to value propositions of smart service ecosystems.

Despite the increasing number of studies that investigate the emergence and perception of digitized product potentials, the realization of value and, thus, their alignment with the organizational goals remains unclear and underexplored. In this study we look at this gap in research to shed light on how firms realize value with digitized product potentials (as innovative outcomes) while also innovating in the actualization process, thereby taking an affordance theory lens.

2.2. Affordance theory

Affordance theory, which has its origin in ecological psychology [21], has been extensively used in IS research (e.g., [16,22,23]) to investigate the 'action potentials' of a technology (e.g., a digitized product) "without seeing technology as having deterministic outcomes" [24]. As depicted in Fig. 1, it is the interaction among the *technology*, the abilities and goals of the *actor*, and the *context* in which the technology is being used that shape the affordances [23,25] (referred to as TAC). Thus, affordances are relational [26] and neither originate from the technology nor from the actor alone [25].

Based on a literature review, Bernhard et al. [27] propose four consecutive affordance-related processes: the emergence of action potentials (i.e., affordance existence), the recognition (i.e., the perception of the affordances), the realization (i.e., the actualization of the affordances) and the effects.

Originally, ecological psychologists assumed that actors were easily capable of actualizing affordances and achieving desired effects – and therefore placed less emphasis on the affordance actualization and effects [22]. However, IT affordances are more complex than affordances discussed by ecological psychologists (e.g., the potential to sit on a chair). Thus, the process that follows affordance perception requires more attention [22]. For instance, for the affordance of informing the service team with product performance data, the actor will have to develop skills to be able to collect, store and analyze data. Once the affordance is actualized, the product might also need to be adapted, e.g., updating sensors, until the desired effect of saving costs is achieved.

Strong et al. [22] recognized the existence of factors (e.g., lack of abilities) that firms need to address to successfully actualize their affordances. They introduce the concept of 'immediate concrete outcomes' and propose that the actualization process is an iterative process in which these immediate concrete outcomes provide feedback (as limiting/inhibiting constraints) that informs subsequent (re-)actions before successfully actualizing the affordances. This iterative learning process is what Bernhard et al. [27] refer to as actualization effort. Strong et al. [22] also propose that while some actualized affordances might directly lead to achieving their goal, others might require dealing with constraints and implementing more (re-)actions. They suggest that the 'alignment' of actualized affordances with organizational goals can be used as an early indicator for measuring success (i.e., realizing desired value/effects) with actualized affordances and that future research should explore this concept.

We investigate this 'alignment' by exploring how 'immediate concrete outcomes' in the form of inhibiting factors lead/lead not to achieving the actor's expected goals (i.e., are aligned with their goals) and, thus, generate desired effects (Fig. 1).

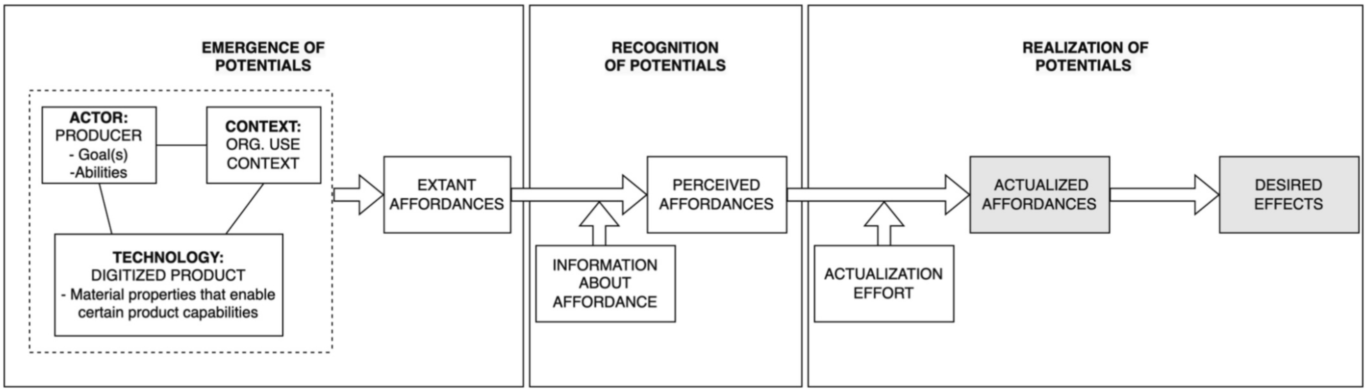


Fig. 1. Affordance-process [7–9]. The shaded area indicates the focus of our research.

3. Categorizing key inhibiting factors and formulating propositions

To identify potential inhibiting factors for generating desired effects, we conducted a detailed review of articles published in leading IS and management journals (see Appendix A for details). We posit that 'important' inhibiting factors identified in the literature, often with regression-based studies, may be 'critical' in the sense of being necessary conditions [29]. We reviewed articles that used the Technology-Organization-Environment (TOE) framework [30] in various IS domains to identify enablers and inhibitors for a successful implementation/adoption of a technology and identified fourteen 'important' inhibitors. We then formulated a set of propositions (Table 1) assuming that the inhibitor is 'critical': that the absence (low level) of these inhibitors is necessary for the desired effects. Technology factors encompass internal and external technologies available to the firm [31]. Organization factors describe characteristics of the firm's organization and available competences [31]. Environment factors refer to external conditions in which the firm operates (e.g., customers, competitors, partners) [31].

The reason for selecting the TOE Framework was two-fold. First, it is a framework that has been extensively used in various IS domains to investigate IT adoption at an organizational level (e.g., [31–33]). Second, the TOE components can be directly mapped to the three TAC elements of affordance theory (technology-technology, organization-actor and environment-context), which helps us make sure that all three aspects are being considered. Consequently, recent articles have combined the TOE framework with affordance theory to study the implementation from a socio-technical view (e.g., [35,36]).

In this article, we validate the formulated propositions to identify if these inhibitors are critical and must, therefore, be absent (have a low level) to generate desired effects.

4. Research methodology

4.1. Research design

An embedded single case study of the firm identified by the pseudonym ProfEQ was executed by investigating four actualized potentials (i.e., four affordances each representing one embedded unit of analysis). Since the investigation of digitized product potentials is relatively new, with scarce literature, we chose to use a case study research design. According to Yin [37], a case study is applicable when the research object is still under development and is investigated within its real-life context. The choice for conducting an embedded single case study was motivated by our aim to investigate the variability in effects generation, trying to relate it to the existence or absence of inhibitors across different potentials, while keeping the context (i.e. company, organization) and technology (i.e. digitized product) elements of the potentials fixed. As a common practice with embedded case studies, which often represent a form of mixed methods research [37], we collected qualitative data from multiple interviews and secondary sources as well as

Table 1
Overview of our fourteen propositions regarding the necessity of TAC elements.

Technology-related factors:
A low level of *technology-related factors* … is necessary to generate desired effects from digitized product affordances.
With technology related factors being:
Proposition T1. … "lack of technology/data competence" …
Proposition T2. … "lack of availability of technology/data" …
Proposition T3. … "lack of adequate technology/data infrastructure" …
Actor-related factors
A low level of *actor-related factors* … is necessary to generate desired effects from digitized product affordances.
Proposition A1. … "lack of organizational support/commitment (e.g., top mgmt, other units)" …
Proposition A2. "lack of access to required resources"
Proposition A3. … "deficient collaboration/information sharing" …
Proposition A4. … "unclear accountability/incentives"…
Proposition A5. … "organizational complexity" …
Proposition A6. … "inadequate organizational culture" …
Proposition A7. … "lack of specific business skills other than those related to tech/data" …
Proposition A8. … "lack of shared vision/strategy" …
Proposition A9. … "lack of focus/prioritization" …
Context-related factors
A low level of *context-related factors* … is necessary to generate desired effects from digitized product affordances.
Proposition C1. … "lack of customer readiness" …
Proposition C2. … "lack of partner readiness" …

quantitative data with a structured questionnaire, which we then analyzed using qualitative content analysis and necessary condition analysis (NCA), respectively.

4.2. Case company

ProfEQ is a market leader in professional cleaning equipment manufacturing that offers both consumer (B2C) and professional (B2B) products. Headquartered in Europe, it employs over 10,000 people worldwide and sells its products via its over 100 sales and service subsidiaries organized as independent legal entities. We investigated ProfEQ's digitized B2B product offerings. The firm digitized its first product offering, called Line, in 2013. Line is a fleet management system for a range of connected machines (e.g., floor scrubbers). The machines contain sensors included in a Data Collection and Transmission Unit enabling the collection and transfer of product use and performance data.

The choice to investigate ProfEQ was motivated by the firm's successful realization of multiple potentials (i.e., affordances) for its Line digitized products, one of which was generating the desired effect (i.e., effects were aligned with the organizational goal of that potential) while the others were not yet. In 2016, the company had perceived about 10 potentials [38]. By the end of 2018, the company had successfully actualized four of the potentials they had perceived back in 2016. The potentials had been actualized and ProfEQ was collecting data. Yet, while one potential was generating desired effects, the other three were not generating expected benefits/effects due to challenges/inhibitors.

We investigate these four actualized potentials to understand how the existence of critical inhibitors affects the alignment of generated effects with the potentials' goals.

4.3. Data collection

While ProfEQ is a large manufacturing company, at the time of this study the B2B digitized products' team consisted of around 20 employees. We conducted eleven interviews with eight employees including the director of digitized products, three product managers, the sales manager for digitized products, the head of aftersales services, the consulting services manager, and the product owner of the digitized products' platform. Eight interviews were conducted in person, while three pre-case discussions were held over the phone with the director of digitized products in preparation for the case interviews. In Appendix B, we provide more information about our data collection process.

The three product managers and the requirements engineer were responsible for the potential ‘refining the product’ with the goal of using data to inform future product designs and functionality. The manager consulting services was responsible for the potential ‘providing consulting services’ and the sales manager was responsible for the ‘informing sales’ potential. Last, the head of aftersales was responsible for ‘informing service technicians’. The director of digitized products and the head of aftersales services had an overview of all four potentials.

Next to using data from the interviews, we also collected data with a structured questionnaire and from internal (company reports, performance data) and external documents (press releases, online interviews, online articles, product leaflets). Collecting data from different sources is one of the major strengths of case study data collection [37]. Triangulating these different sources helped us to increase the validity of our study. Appendix C presents our research approach to ensure validity and reliability in more detail.

4.4. Data analysis: Necessary condition analysis (NCA)

We applied Necessary Condition Analysis (NCA) [39,40] to analyze the data from the interviews and questionnaire and investigate which inhibitors could be necessary conditions. These are factors that must be absent (have a low level) for generating desired effects: i.e., if the factor has a high value, no desired effects will be generated, and a single factor can stop the outcome to exist because no compensation is possible. Although causal reasoning is usually based on ‘sufficiency’ causal logic (a factor *produces* an outcome), ‘necessity’ causal reasoning (a factor *enables* an outcome) is fundamentally different and can provide new insights. When necessary condition propositions are formulated (as we do in Table 1), empirical testing must be done with a method that can capture necessity for ensuring theory-method fit [29] and NCA is a promising approach for this (e.g., [41,42]) with applications in many research fields [43].

In this article, we use the ‘contingency table approach’ of NCA for evaluating necessary conditions [39]. Fig. 2 shows a graphic visualization of a possible data pattern when a low level of an inhibiting factor is necessary for generating a desired effect. The inhibitor has five levels from low to high and the dichotomous effect has two levels (i.e., generated or not generated desired effect). The example shows that there are no cases in the two upper right cells, which indicates that it is not possible to have a desired effect when the inhibiting factor is high. We take the deterministic view on necessity and test by falsification the emptiness of upper right part of the contingency table with four cases [43]. This means that necessity is expected to be present in each single case, and consequently, that each single case could reject the necessary condition claim. When the proposition is not falsified (rejected) and when support is obtained from the qualitative analysis, we keep the necessity proposition as our theoretical proposal.

The effect size (d) of the necessary condition can be calculated in terms of the number of cells with the function $d = C/S$, where C represents the ceiling zone (related to the number of empty cells in the upper right corner) and S the scope (related to the total number of cells) [39]. We used the empirical scope to avoid overestimation. As discussed by Dul ([39], p.30) “a given effect size can be small in one context and large in another [and] general qualifications for the size of an effect as “small,” “medium,” or “large” are therefore disputable”. Based on generally accepted guidelines and like other values in statistics (e.g., *p*-value, cohen's d), Dul et al. [46] propose a general qualification where an effect of $0 < d < 0.1$ is considered “small”, $0.1 \leq d < 0.3$ “medium”, $0.3 \leq d < 0.5$ “large”, and $d \geq 0.5$ “very large”. It is important to note that the magnitude of the effect size does not directly indicate its practical relevance, which is dependent upon the context [44].

Given our limited number of cases we used a strict criterion to not reject necessity. First, we used a very large effect size $d \geq 0.5$ to not reject a necessary condition. Second, because of a possible lack of variation with the values of some inhibitors and to avoid incorrectly not rejecting our propositions, we only performed NCA with those inhibitors that had at least a case with one of the low scores *and* one of the high scores.

4.5. Data analysis: Qualitative content analysis

Next to evaluating the quantitative data from the questionnaire with NCA, a qualitative content analysis of the interviews was conducted using NVivo and based on the coding approach proposed by Gioia et al.

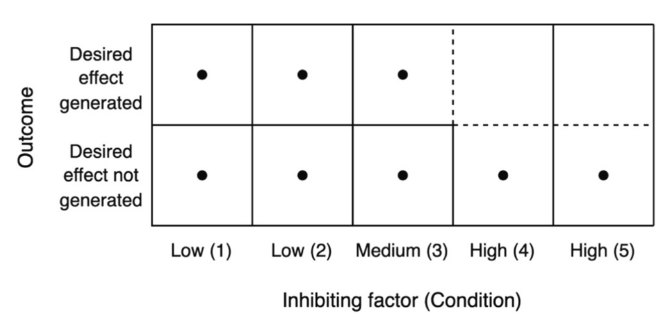


Fig. 2. Contingency matrix of our discrete necessary condition.

[45]. In the first step, codes were identified within each interview selecting text instances referring to the affordance-elements and effects' generation. This process was done iteratively, excluding non-relevant codes, and subsequently adding missing codes. In the second step, we then sought for similarities and differences in the codes, as part of a within-embedded unit analysis and by searching for cross-embedded unit similarities and differences. This process led to emerging second order themes (e.g., "inadequate sales targets") [45]. We performed this process for each of the affordance-cases (i.e., embedded unit of analysis), generating rich stories about the effects' generation process. In the last step, we grouped all the identified second order themes into aggregated dimensions representing the inhibiting factors (e.g., lack of quality data) and connected the themes into an extended affordance-actualization model. We used the data from secondary sources to corroborate the information provided by the interviewees: e.g., newspaper articles talking about the implementation of the product or the won innovation award were used to confirm that the implementation had been successful. Given the newness of digitized products and the relatively small number of interviewees, the content analysis helped us triangulate interview data with company documentation and the NCA, thereby, enriching our explanation of the investigated phenomena [46]. See Appendix D for an overview of the coding process.

5. Four affordances

We investigated four potentials (i.e., four embedded units of the case) that have been actualized by ProfEQ. So far, the firm has generated the desired effect from one of the potentials: 'refining the product'. For the other three potentials ('providing consulting services', 'informing service', and 'informing sales'), there are still key inhibiting factors that are preventing ProfEQ from achieving its desired effects. In Appendix E we provide a description of each potential, the goal targeted by ProfEQ with the potential (i.e., desired effect), evidence for its successful actualization, as well as evidence for its (lack of) generation of desired effects. Across the four potentials the context (same company, ProfEQ) and technology (same product, Line) elements were kept fixed. The actor was also kept fixed (i.e., same organization) although variability existed in the actor's goal for each potential, as different goals lead to different potentials [23].

6. Empirical findings

6.1. Rating of the inhibiting factors

Table 2 provides the results of NCA. The inhibiting factors are categorized by affordance element (i.e., technology, actor, context), and their score for each potential as well as the NCA effect sizes are provided. To make the analysis easier to read, the scores were labelled as very low (1), low (2), medium (value 3), high (4) and very high (5).

It turned out that six factors (A1, A2, A7, A8, A9, C2) did not have enough variation of low and high condition scores to be able to perform an NCA and are, therefore, not included in Table 2. These factors may be important according to the literature, but we could not analyze with NCA whether they are critical inhibiting factors. One factor (T1) had a low necessity effect size, but this effect size did not pass the threshold that we had set. According to NCA, the other six may be considered as critical: T2, T3, A3, A4, A6 and C1. These are critical inhibitors that have a potential necessity relation on desired effects. In the following section, we investigate the underlying logic of these identified inhibitors.

6.2. Underlying logic of the key inhibiting factors

Beyond providing further evidence for validating the propositions, the qualitative content analysis provided us with a deeper understanding of the underlying logic and the causal mechanism of the identified key inhibiting factors. As discussed by Dul [43], it is important to discuss why the condition X is necessary for the outcome Y. The necessity relation can then be argued by answering the following three questions: (1) why if the desired effect is present, the level of the inhibitor is low? (2) why if the level of the inhibitor is high, the desired effect is absent? and (3) why can a high level of the inhibitor not be compensated by a substitute to allow the outcome to exist? In what follows, we discuss the logic of the potential key inhibitors by answering these three questions and refine the propositions into findings.

Regarding proposition T2, interviewees stated that the issue was not the lack of data availability per se, but to the availability of data of sufficient quality. The reasons were manyfold. For instance, for the potential 'informing service', the error code 'low voltage' was generated each time the machine was turned off.

> *The problem has not been getting the error codes and transmitting them. Just the sheer amount and the quality of the error codes was and still is a problem.* – Product Manager Line

The lack of quality data was sometimes related to a lack of consistency in collecting the data or to the lack of standards in the definition of the error codes.

> *[There is a lack of] standard between different machines. Different or [even] the same occurrences had different names, different error codes for the same problem.* – Product Manager Line

Table 2
Rating of the TAC factors. Factors with a high NCA effect size are in bold.

	Afford. A *Refining the product*	**Afford. B** *Providing consulting services*	**Afford. C** *Inform. Service*	**Afford. D** *Inform. Sales*	**Effect Size (d)**
Desired Effect	Yes	No	No	No	
Technology-related factors					
T1. Lack of technology /data competence	Medium (3)	High (4)	Very low (1)	Very low (1)	0.33
T2. Lack of availability of technology/data	Low (2)	Medium (3)	Very high (5)	Very high (5)	1.00
T3. Lack of adequate tech./ data infrastructure	Very low (1)	High (4)	High (4)	High (4)	1.00
Actor-related factors					
A3. Deficient collaboration /information sharing	Very low (1)	Medium (3)	Medium (3)	High (4)	1.00
A4. Unclear accountability /incentives	Low (2)	Very high (5)	High (4)	Very high (5)	1.00
A5. Organizational complexity	High (4)	High (4)	Medium (3)	Low (2)	0.00
A6. Inadequate organizational culture	Low (2)	Medium (3)	High (4)	Low (2)	1.00
Context-related factors					
C1. Lack of customer readiness	Low (1)	Medium (3)	Low (2)	High (4)	1.00

For the potential ‘refining the product’, a low level of the inhibitor was present as the required data was available and in good quality. For the other three potentials because data was not available in the right quality, the recommendations that employees were delivering to the customers or the decisions they were making were not based on actual and accurate data. This led to missing the chance of a helpful consulting, sales call, service preparation, respectively, and, thus, to not achieving desired effects.

ProfEQ could try to get product use and performance data for these potentials elsewhere, but customers are not measuring their machine use in other ways, or they could try to make the recommendations for sales and service based on gut feel or experience. However, for ‘providing consulting services’ what is convincing customers is that recommendations are based on actual use. Similarly, for the potentials ‘informing service’ and ‘informing sales’ what is driving the technician's decision (e.g., tools and parts to bring to a service appointment) and the sales employee's decision (e.g., selling an upgrade for a machine that is being overused) is actual use and performance data, without which employees won't be able to meet the customers' needs and, thus, no desired effects will be achieved. Based on this evidence, we refine proposition T2 as: *Finding 1. A lack of availability of quality data inhibits the generation of desired effects from actualized digitized products affordances.*

In relation to proposition T3, all interviewees agreed that the issue was the lack of integration between different IT systems (i.e., IT infrastructure), which prevented them from generating desired effects, as these potentials often require data from different IT systems. This lack of integration led to increased IT complexity, as the analysts had to make use of multiple databases and systems that did not share information.

> *We have the data in different platforms, it's an issue definitely. […] My analyst has eight different databases. To put the data together, to find the reference from one database in the other… this does not help to be fast.* – Head of Aftersales Services.

This problem was in some cases also related to a lack of standards in the definition of the systems, which worsened and hampered the integration of the systems and data.

> *We have different systems in the subsidiaries. Big subsidiaries have a totally different CRM system.* – Head of Aftersales Services

For the potential ‘refining the product’, this inhibitor was absent because of the implementation of one standard and integrated infrastructure.

> *When it comes to telematics data [for refining the product], we managed to have one system in use worldwide that all countries use. So that probably also was the learning […] We went for one standard infrastructure.* – Product Manager Line

For the other three potentials because data is not integrated in one central database, service technicians and salespeople are not able to access all the data they need to generate the desired effects or have to collect data manually from multiple sources, which ultimately leads to not generating desired effects. If certain data cannot be easily accessed, employees can try combining data manually. While this can be done for PoCs, with thousands of data points being collected for the realized potentials, ProfEQ is not able to do this at scale. Based on this evidence, we refine proposition T3 in the following way: *Finding 2. A lack of integration and compatibility of IT systems and data sources inhibits the generation of desired effects from actualized digitized products affordances.*

Regarding proposition A3, as mentioned above, ‘informing sales’ and ‘informing service technicians’ are actualized by the sales and service subsidiaries that are organized as independent legal entities. According to the interviewees, this affected the collaboration and information sharing between the subsidiaries and the main organization.

> *When we request the subsidiaries to analyze data, if we generated a problem, we do not get feedback, they do not have time. They do not […] verify our results […] So it's collaboration [that is the issue].* – Head of Aftersales Services

This was also linked to a lack information sharing with subsidiaries. E.g., while service technicians were aware of the problems with error codes, they didn't report back.

> *All technicians knew, but they didn't report back: “Don't look in the error memory, it's full with thousands of errors”. […] This would have rang a lot of alarm bells, but it didn't.* – Requirements Engineer and Product Owner Digitized Products Platform

For the potential ‘refining the product’, there is close collaboration among R&D, software development and product managers. As a digitized product entails multiple layers (e.g., logic, physical components, data), the development of improved future products requires cross-departmental collaboration and information sharing. However, for the other three potentials, there is a lack of collaboration and information sharing between the headquarter (e.g., the cleaning competence center) and the subsidiaries (i.e., sales, service), which leads to service technicians, salespeople, and consultants facing problems such as a lack of professional cleaning knowledge or lack of information about customer needs that prevent the generation of desired effects. As a substitute for lack of collaboration/information sharing, ProfEQ could hire employees with a wide spectrum of skills (e.g., software, hardware, product management). However, finding employees with such a wide knowledge is unrealistic. Based on this evidence, we refine proposition A3 as: *Finding 3. A lack of collaboration/information sharing across (digital and non-digital) units inhibits the generation of desired effects from actualized digitized products affordances.*

For the inhibiting factor underlying proposition A4, interviewees were unanimous that the issue was that responsibilities for digitized products were not clear, i.e., there was a lack of accountability, which is key to generate desired effects from the potentials.

Someone has to feel responsible for it to make it successful. – Mgr. Consult Serv.

As the product manager for Line stated when discussing the potential ‘informing service technicians’, the issue was that once the product was ready and the potential had been actualized, there were no clear goals or strategies to generate desired effects.

> *When we had the tool ready for the service technicians to read the error codes, in most subsidiaries there hasn't been any clear strategies. […] Who is going to be responsible for it? […] There hasn't been that much structure […] to establish clear responsibilities*. – Product Manager Line

As an example, the director digitized products discussed the successful case of one subsidiary, where in contrast to most subsidiaries that had no clear accountability, one employee was made responsible to sell digitized products and was incentivized for it.

> *There was [one subsidiary] that never got to roll out, but they just told one of their employees “you are in charge of making digital products happen, you're going to be incentivized, part of your pay is part of the sales success of that”. And guess who's selling the most licenses of all subsidiaries? They are. And she made it all happen. […] That's the big difference [accountability]* – Director Digitized Products

Interviewees all agreed that to define clear and successful accountability, an incentive-system needs to be defined, which is adapted to digitized products.

> *There is an incentive system but it's bad because the incentive is based on revenue. Usually, the sales force spends more time in selling a €10,000 machine than in a subscription for €60. This is the main problem. […] In the subsidiary, the priority is set on machine sales. These are the targets. They do not have digitization targets or digital product targets.* – Head of Aftersales Services

For the potential ‘refining the product’, engineers have clear accountabilities, and they have high willingness to use the data generated by the machines as they themselves developed them. However, for the other three potentials, employees are not willing to use the data because of a lack of incentives and/or accountability. Thus, data is not being used and desired effects are not being generated. Potentially, a high commitment could be achieved even without extrinsic incentives. While it is hard to achieve such a commitment, even if firms manage to have committed employees working actively towards improving the business, this will not replace the need for defining clear accountabilities. Based on this evidence, we refine proposition A4 as: *Finding 4. A lack of clear accountability and incentives inhibits the generation of desired effects from actualized digitized products affordances.*

Regarding the inhibitor inadequate organizational culture (proposition A6), interviewees mentioned that the challenge was dealing with a lack of mindset to sell digitized products and offerings. Having sold machines for many years, employee's mindsets and culture were geared towards selling traditional non-digitized machines.

> *The biggest challenge for me is a cultural change in the company. We've been selling machines for many years. Before I can even think about selling digitized products to customers, I have to convince my salesforce, marketing, product development,* etc. *that this actually makes sense*. – Director Digitized Products

Recent organizational changes, such as creating a specific unit for digitized products and solutions, were helping to change the organizational culture and the mindset of the employees, at least in the headquarters. Having subsidiaries set as independent legal entities made it hard for ProfEQ to have an organizational culture change.

> *We needed a long time to change the mind from producing machines and selling machines to also offering digital tools. Now I think we got it, here at the headquarter at least. If we have a look on our subsidiaries […] it's quite a big challenge to change their mindset.* – Manager Consulting Services

For the potential ‘refining the product’, employees are all located in the headquarters. Recent organizational changes had led to increasing trust between different parts of the organization and created a strong data-driven culture set around selling digitized products. However, for the other three potentials, while collaboration between employees from the headquarters and the subsidiaries is required, there is a lack of shared culture and a lack of mindset in the subsidiaries to sell digitized products. Potentially a high level of lack of adequate organizational culture could be substituted with strong institutionalization of processes that create organizational stability. However, implementing institutionalized processes can bring more rigidity and while they shape culture, they do not replace the need for a culture of trust and data-driven mindset. Based on this evidence, we refine proposition A6 as: *Finding 5. A lack of adequate organizational culture and mindset that fits the needs of digitized products inhibits the generation of desired effects from actualized digitized products affordances.*

Regarding customer readiness (proposition C1), one big challenge was that customers don't have anyone at the customer site that can interpret the data generated.

> *Even if they believe in the theoretical benefits of it, they say “well, we don't have anyone in our company to look at the data and interpret it”. Because you need to do that, the system doesn't tell you what to do. It just gives you the information […] you need to make your own decisions.* – Director Digitized Products

For the potential ‘refining the product’, the product engineers use product performance data. For the engineers to have that data the customers need to be ready to use and operate the machines. Since this type of data is generated automatically from the operation of the machine, which customers can do, performance data is readily available. However, for the other three potentials, employees also need data generated from the use of the features of the products. As customers are not ready to use some of those features, then consultants, sales and service employees do not get the data. A potential substitute could be an autonomous machine that analyses the data and optimizes itself. However, customers would still have to be ready to employ that machine in their facilities. In addition, this technology is in most cases not available yet, and if it is, it is too expensive. Based on this evidence, we refine proposition C1 as: *Finding 6. A lack of customer readiness (regarding the ability to manage data) inhibits the generation of desired effects from actualized digitized products affordances.*

7. Discussion

Our findings provide evidence that supports the necessity relation of the identified six key inhibitors and suggest that the underlying logic of all six key inhibiting factors revolves around the role of data. Three key inhibiting factors (T2, T3, A3) stress the importance of quality, integrated, shared data for generating desired effects from digitized products. The other three key inhibiting factors build on the relevance of the ability to manage this data, both intra-organizationally (A4, A6) and inter-organizationally (C1).

Firms ought to design their IT and data infrastructure in a modular way to enable rapid integration and sharing of quality data. So far, past research has adopted sufficiency logic instead of necessity logic, despite claiming necessity with statements such as *requires, is necessary for,* etc. For instance, Chen et al. ([47], p.27) discuss the *necessity* of integrated data and state that the collection of data “*requires* the integration of internal, external, real-time and batch-processed data, whether structured or unstructured, to provide the base for big data analytics.” The NCA in our study provides evidence for the need of quality, integrated and shared data following a necessity logic and, thus, ensuring a theory-method fit. Companies also need to adapt incentives, build an adequate organizational culture and ensure customer readiness. Generating desired effects from digitized product potentials requires adapting incentives and roles (in some cases creating completely new ones, e.g., a sales manager for digitized products). Although the relevance of incentives is not something new (e.g., Kaplan and Henderson ([48], p.30) highlight the relevance of “incentives in dealing with change”), our findings indicate that digitized products require incentives that are adapted to meet their unique characteristics (e.g., lower revenues from low monthly subscriptions vs high, one-off product sales), which are fundamentally different from those of physical products or other digital technologies that only have a software component. Besides, our findings emphasize the need for having an adequate organizational culture that enables innovation and experimentation. Last, and in line with recent research, our study shows how involving and collaborating with customers – as a practice related to distributed agency – can help to drive innovation (e.g., [6,49,50]). For firms to benefit from customer involvement (e.g., by collecting product use data), they must make sure that customers are able to adopt the new digital technology.

8. Learning to align: An extended affordance-actualization model

Our findings provide evidence that reinforces Majchrzak's and Markus's [23] and Strong et al.'s [22] suggestion that actualized affordances of IT artifacts not always lead to achieving the affordance's goal and emphasize how the alignment of the affordances can be used as an indicator of the fit between the affordances' outcomes and goals. While in some cases actualized potentials might directly lead to generating effects that are aligned with their goal, in many cases actors face emerging inhibitors or constraints that need to be addressed before the affordance can generate desired effects.

Inhibiting factors originate from the three elements that make up the affordance: technology (e.g., lack of integration and compatibility of IT systems and data sources), actor (e.g., lack of clear accountability) or context (lack of customer readiness). And even if they originate from one element, our findings reveal that just as affordances, inhibiting factors are also relational and arise from a lack of fit between the technology, actor, and context. For instance, the "lack of availability of quality data" arises because the available data is inadequate to meet the actor's goal in the given use context. More concretely, for the affordance 'informing service' ProfEQ faced a lack of available quality data because the error codes (data part of the technology) that were defined where not meaningful for the service technicians (actor) for their aimed goal of saving costs in maintenance (use context). This lack of fit between the TAC elements was leading to generating outcomes (too many meaningless alarms/alerts) that were not aligned with the affordance goal of saving cost. To solve this, ProfEQ mentioned that they had to redefine the error codes (a re-action related to the technology) to have their needs reflected in the meaning of the codes (a new action related to the actor element). This example demonstrates that (re-) actions following the inhibiting factors are also TAC-related.

The empirical evidence in our study suggests that just as during the actualization, in which actors need to do adjustments in the affordance elements based on feedback [22], aligning the actualized affordances to meet their goals and generate desired effects is also an iterative process in which feedback derived from emerging key inhibitors leads to (re-) actions to address those key inhibitors (see Fig. 3). Following the emergence of inhibiting factors firms will need to adjust the TAC elements to be able to address them and achieve desired effects. Such adjustments can be new actions or re-actions (i.e., readjustments of some of the actions implemented to actualize the affordance).

Our empirical findings also provide evidence that not all factors represent key inhibitors (i.e., necessary conditions) that must be absent or have a low level for generating desired effects, and thus achieve alignment. E.g., while ProfEQ was affected by high organizational complexity also for the affordance 'refining the product', this inhibitor did not represent a key inhibitor, as ProfEQ was generating desired effects from this affordance despite facing this constraint. Firms must, thus, identify and prioritize those inhibitors that are critical and *need to be absent* (necessity approach) for generating value.

As shown in Fig. 3, the feedback loops in the actualization and alignment exemplify how firms experiment and learn through the actualization process. As suggested by Strong et al. [22] and as reflected in our findings, actualizing affordances and generating desired effects represent a process of organizational learning in which actors undertake a course of action, which they then adapt based on emerging critical inhibitors to get closer to their desired effects [52,53]. Central to this test-and-learn process is the use of feedback from the outcomes derived from prior actions to inform subsequent actions (i.e., re-actions) [52] to ultimately generate desired effects aligned with the affordances' goals.

9. Implications for theory and practice

9.1. Implications for theory

Our research responds to the calls for novel theorizing on affordance actualization [22] and digital innovation management (e.g., [6]), advancing theory on digitized product affordances, a field with scarce although growing literature [18].

9.1.1. Affordance theory

We provide an extended affordance-actualization model based on Strong et al. [22] that clarifies the process by which actualized digitized product affordances are or are not aligned with their goals and, thus, lead or lead not to desired effects. Our study examines and conceptualizes the "alignment of actualization" proposed by Strong et al. [22]. To the best of our knowledge, our study is the first one to investigate this concept.

Our empirical results provide evidence for how emerging inhibitors/constraints lead to a lack of alignment of actualized affordances with their goals, thereby affecting desired effects' generation. Feedback during the alignment of actualization, which is generated by emerging critical inhibitors that affect the generation of desired effects, demonstrates that learning happens continuously during the realization of digitized product affordances, requiring actors to readjust the TAC elements via the implementation of (re-)actions. This is also aligned with prior research relating to lean start-up methodology [54] and organizational learning theories that advocate that innovation and new product success demand continuous experimentation, learning and recombination of resources. Our model provides a foundation in which further research can build to study the actualization of technology affordances and stresses the need to also investigate the alignment of

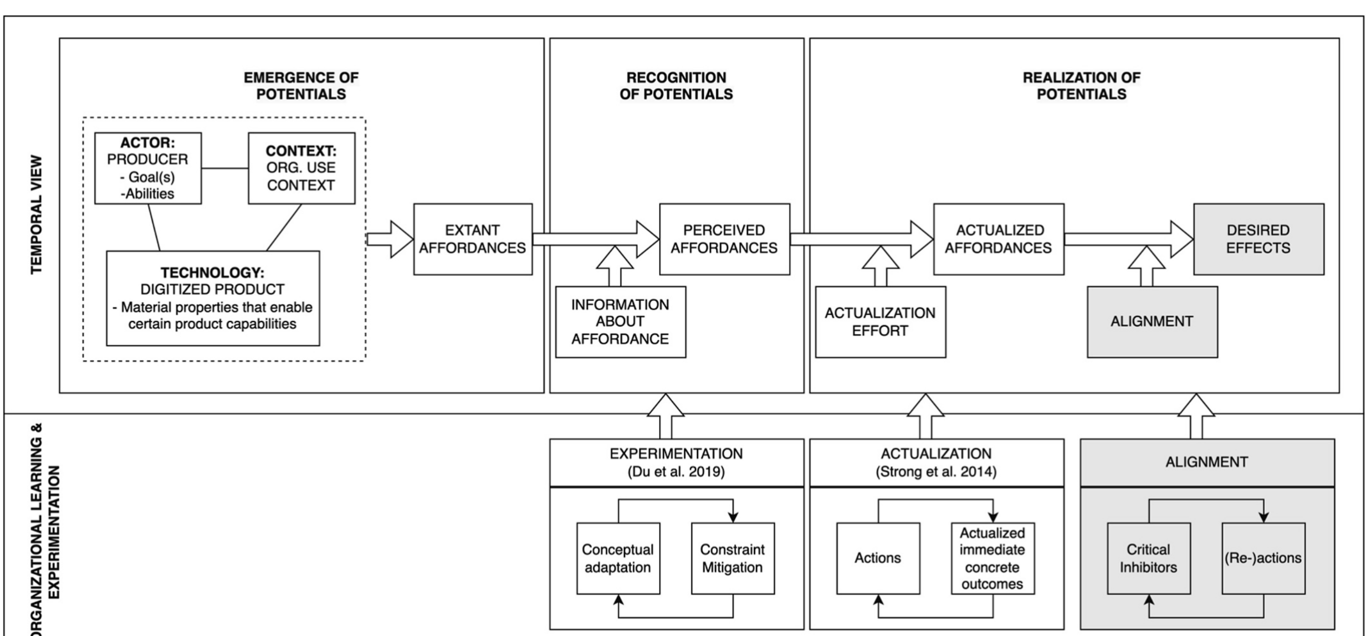


Fig. 3. Extended affordance-actualization model (based on [22,28,51]).

affordances with their goals. Further, our paper provides evidence of how the novel technique of NCA [40] can be used to identify key inhibitors or failure predictors that prevent success from a necessity perspective (a factor *enables* an outcome), instead of basing conclusions on a 'sufficiency' causal logic (a factor *produces* an outcome), which has been the approach followed by prior research on digital innovation and product digitization. This novel perspective is fundamentally different and provides new insights that can help firms to better prioritize their actions.

9.1.2. Digital innovation management

As IoT-enabled decision support systems, digitized products allow producers to generate value by enabling limitless potentials that optimize and extend their use, thereby fueling innovation. Prior literature that investigated digitized products as decision support systems is limited so far and has mainly focused on investigating the perception of digitized products potentials (e.g., [55–57]). Our study advances research beyond perceived digitized product potentials to focus on their realization and value generation.

Our findings contribute to the ongoing discourse on the diminishing boundaries between the outcome and process of innovation and the shift towards a more distributed innovation agency [6]. The unique characteristics of digitized products (i.e. of the innovation *outcome*)—reprogrammability and generativity [3] — permit unforeseen potentials and bring "together a greater level of unpredictability and overlap" ([6], p. 225). This has repercussions for the innovation *process*: to deal with increasing unpredictability in digitized products that do not have clearly established use cases [28], our findings suggest that companies need to embrace a continuous test-and-learn approach. By experimenting over time and, thus, testing the fit of the three affordance elements (technology, actor, and context), organizations can validate whether the realization of the identified potentials is aligned with the organizational goals.

The identified six key inhibitors re-examine the role of data within all three elements of affordances: while existing studies tend to focus on systems and tools, it is ultimately the data (as part of the technology element of affordances) and the ability to manage it (actor- and context-related factors) that influence impact generation with digitized product potentials. Regarding *technology*, organizations need to share and integrate quality data from multiple sources (e.g., telematic unit, customer web portal), some of which may not even be in place when the product is first implemented. At the same time, distributed agency requires that employees and customers are ready to collect and make sense of the data. Regarding the *actor* element of affordances, employees need to work closely across units and share data, as well as embrace new ways of working to deal, e.g., with the different clock speed of digital and physical innovation. Also part of the actor element: incentives need to be adopted to meet the hybridity (data-infusion) of digitized products. Regarding *context*, users are more familiar with analog use cases of digitized products (e.g., cleaning the floor with the scrubber dryer) and will need training and experimentation to get used to adopting more innovative, data-driven use cases (e.g., remote servicing, updating features over the air).

To the best of our knowledge, our study is the first one to validate the impact of critical inhibitors in digitized product innovation management following a *necessity* logic, instead of the most widely adopted *sufficiency* logic, thus ensuring a theory-method fit.

9.2. Implications for practice

In our introduction, we stated that the slow uptake of digitized products hints at the existence of challenges for firms to generate desired effects from the digital enrichment of their products. Our study provides three guidelines to generate value.

The need to prioritize challenges. Some of the inhibiting factors we identify may seem obvious to practitioners. But beyond any specific individual inhibitor, as companies face many different challenges, they need to prioritize those factors that are critical, as not all the factors represent key (i.e., critical) factors that must be absent or have a low value to realize value. This emphasizes the relevance for firms to identify and prioritize critical factors. As dealing with inhibitors requires effort and iterations through the implementation of (re-)actions, firms must identify which factors need to be addressed.

The need to prioritize data over technology. The identified key inhibitors highlight the relevance of data with respect to the "technology" element of digitized products and re-examine the role of data. While systems and tools are important, firms must make sure that quality, integrated and shared data is available and that culture, incentives, and competences are appropriate to manage the data; even more so given the generative and latent trait of digitized products, as new use cases may require new data sources.

The need to realize that you will not get it right the first time. Our empirical findings indicate that digitized product innovators might want to implement feedback loops into all steps of the product life cycle to formalize a "test-and-learn" culture enhancing the actualization and desired effects generation of digitized product potentials. While transactional sales of physical products suggest the "test-and-learn" cycle has ended once the product is deployed, our study suggests that this is not true for digitized products. Companies need to enable this test-and-learn process over time to ensure alignment of the digitized product potentials and their goals.

10. Conclusion and limitations of the study

In this article, we clarify the process by which actualized digitized product potentials are or are not aligned with their goals and, thus, lead or lead not to desired effects. We provide an extended affordance-actualization model to study the effects of technology potentials. Our findings stress the need for researchers to investigate the alignment of actualized affordances, which represents the last step towards meeting the organizational goals sought with their potentials.

Our article provides evidence of how the NCA [40] can be used to identify predictors preventing success, following a necessity logic instead of the common sufficiency logic, thereby ensuring a theory-method fit. Based on qualitative content analysis and NCA of four digitized product affordances, our study identifies six key factors that inhibit desired effects' generation. Our empirical results regarding the underlying logic of the key inhibitors re-examine the role of data and contribute to advancing our understanding of digital innovation management with digitized products.

Our research has limitations. We base our analysis on a single case, limiting generalizability of our findings on key inhibiting factors. As our analysis is based on digitized products, our extended affordance-actualization model might not be applicable to other types of IT. Also, we were only able to run NCA on eight propositions. Thus, we could not falsify if the untested inhibitors represent key factors or not.

CRediT authorship contribution statement

Ainara Novales: Writing – review & editing, Writing – original draft, Visualization, Validation, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Martin Mocker:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Eric van Heck:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Jan Dul:** Writing – review & editing, Writing – original draft, Validation, Methodology, Formal analysis, Data curation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data that has been used is confidential.

Appendix A. Overview of the selected academic articles that investigated IT/IS adoptions using the TOE-Framework and literature review

To identify potential critical inhibitors, we conducted an in-depth literature review of papers that we had identified using a keyword search in the leading database EBSCO Business Source Premier. We looked for papers that mentioned "TOE" in the abstract and that were peer-reviewed and written in English language. Our search yielded a total of 95 papers. Following Webster and Watson's guidelines, we first looked for articles in leading IS and management journals, as "the major contributions are likely to be in the leading journals" ([58], p. 16)., and selected the papers that had been published in leading journals (i.e., that were ranked A or B in the journal ranking VHB-Jourqual 3). After reviewing these papers, 13 articles that investigated critical inhibitors of IS/IT adoption were added to the article pool: Aboelmaged (2014), Bernroider and Schmöllerl (2013), Cao et al. (2014), Chan et al. (2012), Chan and Chong (2013), Chen et al. (2015), Lian et al. (2014), Lin and Lin (2008), Oliveira et al. (2014), Venkatesh and Bala (2012), Wei et al. (2015), Yeo and Grant (2018), and Zhu et al. (2004). In this process, we discarded papers like e.g., Li et al. (2013) that while published in a leading journal (Decision Support Systems) was qualitative in nature and investigated the impact of TOE factors in a very specific context, humanitarian disasters, which is very distant from the focus of our paper on digitized products. We then went backward by looking at the citations of the thirteen papers in our article pool and forward by looking at papers that have cited the identified articles, adding 10 more papers to our article pool: Chau and Tam (1997), Cooper and Zmud (1990), Damanpour (1996), Grover (1993), Iacovou et al. (1995), Kuan and Chau (2001), Premkumar and Ramamurthy (1994), Ramamurthy et al. (1999), Thong (1999), and Zhu et al. (2003). In total, we had 23 papers in our article pool. While none of the articles made use of affordance theory, they identified inhibitors for adoption and desired effects' generation that we could map to the three TAC elements. We then selected the factors that were most applicable to our research field [34] –even if that meant deselecting factors that were mentioned often. E.g., "External pressure" got mentioned most often—17 times—, but a lack of external pressure does not make sense as an inhibitor of desired effects derived from actualized affordances. Similarly, "technology complexity" does not apply well to desired effects' generation from actualized affordances (after all the company managed to implement the technology and put it in use) and "perceived challenges" or "perceived barriers" are too abstract to be meaningful. Last, we also renamed some of the factors that might not be easily understood by everyone (e.g., "absorptive capacity" was changed to focus/prioritization).

After identifying fourteen 'important' inhibitors, we formulated a set of fourteen propositions assuming that the inhibitor is 'critical': that the absence (low level) of these inhibitors is necessary for the desired effects (see Table 1). These propositions are formulated following the logic of necessary condition analysis (NCA) to identify the key factors that are necessary for the desired effects. As we look at inhibitors, a necessary condition needs to be absent (have a low level) for the desired effects to materialize. Section 4.4 provides more information of our approach with NCA.

Appendix B. Data collection

During the pre-case discussions we sought to better understand the phenomenon under study (i.e., desired effects' generation with digitized products at ProfEQ) to select the embedded units of analysis (i.e., potential cases that ProfEQ had been actualized). We therefore asked questions regarding the relevance of digitized products and how the products were used to generate desired effects (e.g., which data was generated by the products, and how this data was used for achieving potential benefits). The pre-case discussions helped us understand the context for digitized products at ProfEQ and focus the case interviews on those potentials that had been successfully actualized. Interviewees were selected following snowball sampling to ensure that all relevant actors were included in this case [37]. Once the actualized potentials had been identified in the pre-case discussions with the director of digitized products, the interviewees that were closely working on the realization of those potentials were selected.

The eight case interviews had two separate parts. The first half consisted of semi-structured questions that aimed at exploring the main inhibiting factors. In the second half, we asked interviewees to fill in a structured questionnaire to assess the previously identified TAC factors and measure the level of presence of these factors. The items in the questionnaire were conceptualized based on the literature review described in Section 3 and Appendix A. All items were measured in a five-point Likert scale ranging from 1 (very low) to 5 (very high). To validate the content of the interview questions and the questionnaire items, we asked the director of digitized products to provide feedback on the relevance and clarity of the questions and items. Based on his feedback we adjusted the interview protocol and questionnaire in preparation for the case interviews. Our approach to building the questionnaire is based on the methods of prior research (e.g., [59,60]).

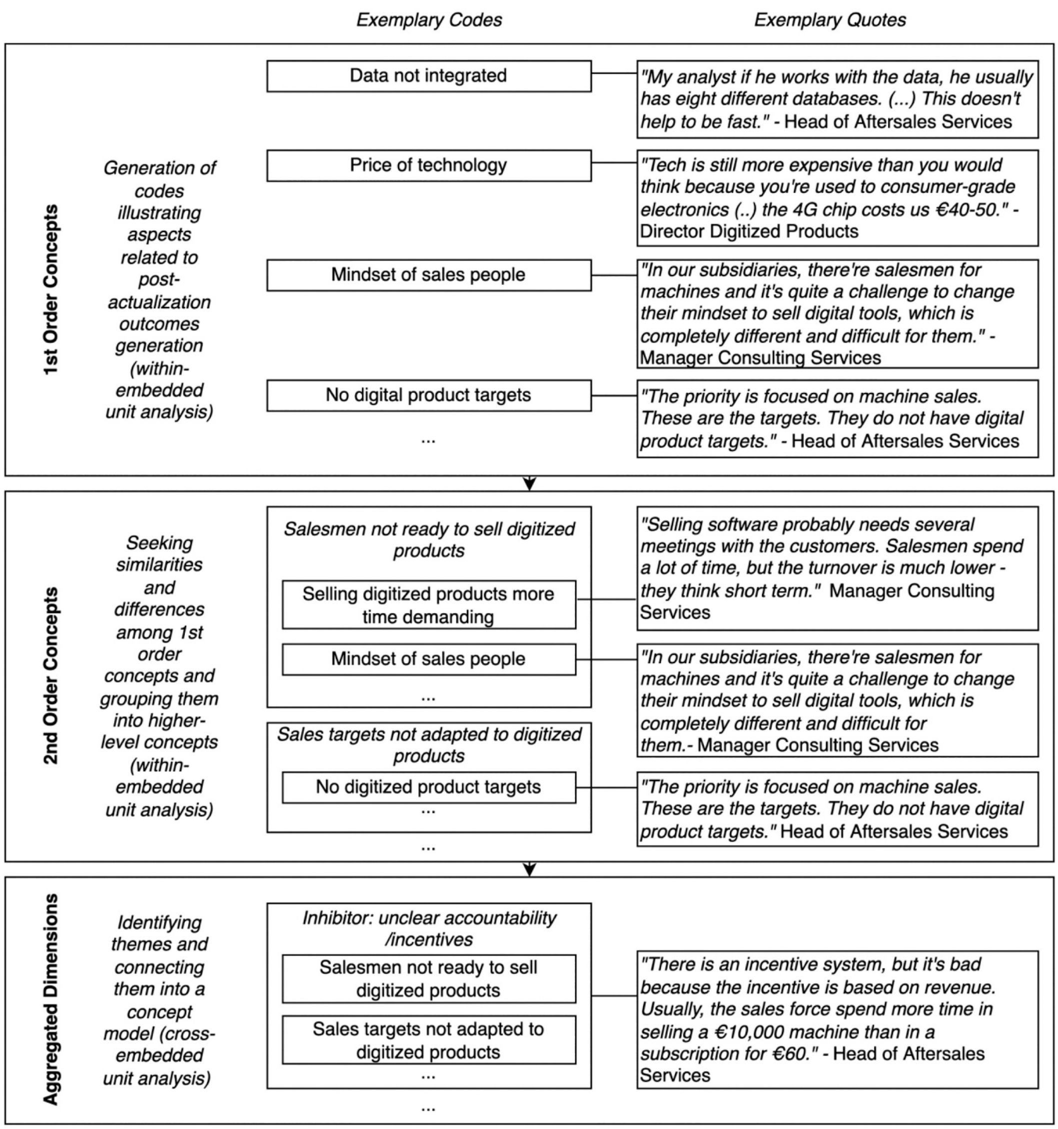
The structured questionnaire allowed us to produce perceptional quantitative data as part of the case study evidence [37] and to quantify the level of the condition (average score of all interviewees, dependent variable) to be used for NCA.

Appendix C. Case study validity and reliability

To assure the quality of our research study, we followed the case study tactics proposed by Yin [37].

Criterion	*Case Study Tactic*	*How we applied it in this study*
Construct validity	Use multiple sources of evidence	Multiple interviews, structured questionnaire, company internal documents (company reports, performance data), external documents (press releases, online interviews, online articles, product leaflets)
	Establish chain of evidence	A chronological narrative document linking the evidence from all interviews
	Have key informants review draft case study report	Every participant reviewed their quotes and the case study report The director of digitized products conducted a final review of the case study report and the article
Internal validity	Pattern matching	Predictions derived from falsifiable propositions based on existing literature were matched with evidence from the cross-embedded unit analysis and the structured questionnaire
	Use of logic models	Causal relationship, flow of events that was matched with evidence from the cross-embedded unit analysis
External validity	Using replication logic	The same propositions were tested during the semi-structured interviews and with the structured questionnaire
	Increasing degrees of freedom	Multiple (four) affordances (i.e., embedded units of analysis; one generating desired outcomes, three still not generating desired outcomes) were compared to empirically test the propositions
Reliability	Use of case study protocol	A case study protocol was created
	Developing a case study database	Every interview was recorded and transcribed (total of 73,438 words); field notes were taken; additional documentation (internal and external) was used; a case study narrative was created.

Appendix D. Overview of the coding process with sample quotes



Appendix E. Overview of affordance cases

	Affordance A: Refining the Product
Description	This affordance refers to the firm's potential to refine the product, by e.g., enhancing the product design or by changing components, based on product performance and use data collected by the Data Collection and Transmission Unit (DCTU). *[The engineers] they also have the possibility to transmit four times per day, three times per day. They can define "I want the data every five seconds". You know exactly what is happening with the machine. You get information about how often the customer uses a dedicated function. This is meaningless information for the customer. But if we design a machine and the customers do not use a function or only one time, we can get rid of the function and save money.* – Head of Aftersales Services
Desired effect (i.e., affordance goal)	The goal with this potential was to use the data generated by the Line machines to learn about the actual product use and performance and thereby inform the product development to enhance the product design of future products to save money. *We wanted to learn about the actual usage of the machine from a product management perspective. (…) If you have a big base of installed machines […], you can actually look whether or not that engine had been over-engineered or under-engineered. And you can save a lot of money in future projects if you know that.* – Director Digitized Products
Evidence for successful actualization	ProfEQ introduced an extra feature in the DCTU that allowed engineers to define the data they want to collect (e.g., operating hours or location), as well as their preferred frequency for data collection (e.g., every second or three times per hour). Besides, a data warehouse was created where all this data is made available to the engineers. *We put a new feature on the telematics unit that collects data at high resolution, which we don't need [for the customer-facing offerings]. [… The engineers,] they can configure it and then every five milliseconds get the voltage and so on, for example. This creates a lot of data. […] We created the project data warehouse, which in the first place takes this data, organizes it neatly and then offers an infrastructure. […] The engineers they write their own scripts and then they power up automatically a huge farm of servers that is calculating those things.* – Requirements Engineer and Product Owner Digitized Products Platform
Evidence for (lack of) desired effect generation	ProfEQ has successfully managed to achieve its targeted desired effect. The engineers at ProfEQ have access to the data generated by Line machines via an implemented data warehouse, which is helping them to learn about the real use of machines and improve some features in the design (e.g., change the engine to a less powerful one in case the engine is over-engineered), thereby saving costs. *The developers and test department are using this data and its own completely different system that has been created. […] the product managers of the new machine, they really like it […] So development is getting better.* – Requirements Engineer and Product Owner Digitized Products Platform
	Affordance B: Providing Consulting Services
Description	This affordance refers to the firm's potential to consult its customers based on the product performance and use data generated by the Line machines and on data specific to the customer (e.g., labor costs). Based on this data, ProfEQ can provide recommendations to its customers so that they can optimize their operational processes. *We can provide consultant services. We can take a look at the [Line] data and tell our customers, well, you know, we saw that you have a machine […], but you're not really using it. And there is another machine that's totally running past its limit. […] why don't you exchange those two machines? It would help you a lot.* – Director Digitized Products
Desired effect (i.e., affordance goal)	The goal with this potential was to provide a consulting service to customers to improve their processes and machines' usage, and thereby generate a new source of revenue and potentially more sales for ProfEQ via a consulting service. *The goal is to enable the sales subsidiaries to do consulting projects. […And then] basically use this consulting process as a way of sales, a sales tool. You consult your customer on what they need and try to sell products that way.* – Director Digitized Products
Evidence for successful actualization	ProfEQ has successfully actualized this potential and conducted a handful of consulting projects with large pilot customers. To do so ProfEQ collected all the data generated by the Line machines over a time period, and then analyzed it to identify anomalies and/or sub-optimal use of the machines (e.g., under- or over-utilization). Besides, customers were also asked to provide relevant information/insights, such as labor costs. After the data was analyzed, ProfEQ went back to the customers to provide recommendations and to discuss whether the recommendations could be implemented. *We have all the data about the performance of the machines […] We asked [our customers] for their labor costs, for their cost per hour. The customer has to share some insights with us, but it is quite easy to calculate their savings.* – Manager Consulting Services
Evidence for (lack of) desired effect generation	Although ProfEQ has managed to consult some customers and provide them with guidelines to optimize their processes, so far, these projects have been pilot projects and ProfEQ has not yet generated revenue from this potential or scaled it beyond the pilot projects. Thus, ProfEQ is currently not generating its desired effects from this potential. *We made quite a few sales of that. But of course, that doesn't scale. Once again, somebody from my team has to look at this and then we have to talk to customers,* etc. – Director Digitized Products
	Affordance C: Informing Service Technicians
Description	This affordance refers to the potential to use the product as a service/diagnostics tool, i.e., to inform the service technicians about the machine condition, including its location, serial number, and error codes and thereby define what the problem is so that they are prepared for a repair before they are on site. *Our service can look at these machines remotely, and when there is a problem with the machine, we already know what's going on, so we know the serial number, the part number of that machine, and we know the error code. So, if a service technician leaves to fix that machine, he already knows all these things and can bring the right spare part.* – Director Digitized Products
Desired effect (i.e., affordance goal)	The effect targeted with this potential was to do remote diagnostics and inform the service department with data about the machine performance to enhance the service process and reduce costs by reducing visits to the customers' setting. *The original goal [to create Line] was a service tool, so a remote diagnostics tool. […] this saves a trip, and this saves us service time. So, the more machines we outfit with our telematics unit, the more money we save. Simple equation.* – Director Digitized Products
Evidence for successful actualization	To bring this potential live, ProfEQ collected error codes from the machines (e.g., low voltage). These error codes were then displayed in the web-portal service view, allowing service technicians to access the information about the machines remotely. *We have a digital tool to help the service technician find the problem of the machine in an easy way […*via*] remote access […] before we are on site.* – Head of Aftersales Services
Evidence for (lack of) desired effect generation	Due to unexpected issues with the error codes that led to the machines producing too many error codes that were not meaningful, ProfEQ is not yet generating the desired effect from this potential. *What we're not yet generating value with, is the whole service part. […] We found out that it's not as easy as it might seem. […] We're still in the process of solving it. […] a single machine sends 10,000 error codes a day; […] there obviously is something wrong with how machines are generating error codes.* – Product Manager Line
	Affordance C: Informing Sales
Description	This affordance refers to the potential to use product use and performance data to inform the sales department and, thereby, enhance the sales process by having a more focused and customized sales approach to target customers better. *With the [Line] data together with the service, with the CRM data, we have life cycle information of the product, we didn't have before. […] That*

(*continued on next page*)

(*continued*)

	Affordance C: Informing Sales
	means we have arguments for sales. That our life cycle costs, hopefully, are below the life cycle costs of our competitors. – Head of Aftersales Services
Desired effect (i.e., affordance goal)	With this potential, the effect expected by ProfEQ is that the salespeople check the data and reports available in the web-portal and, thereby, get more knowledge about the customers before they go to talk to them and try to generate sales. *The vision is that the salesmen check the [web-portal] before talking to a customer.* – Sales Manager Digitized Products
Evidence for successful actualization	To bring this potential live, the Line data collected via the DCTU and stored in a specific database is displayed in the web-portal portal in the salespeople view. In this portal, salespeople can generate customer-specific reports to create arguments for sales for their customers. Besides, they also have access to other data sources (e.g., CRM data) that can also help them create better arguments for sales. *We are working exactly on that with analytics and data. (…) We do it with terabytes of data per machine and this information is passed to the subsidiaries. So that they have information when they try to sell a machine.* – Head of Aftersales Services
Evidence for (lack of) desired effect generation	Salespeople are not yet using this information before going to the customers. They only do it on few occasions when the sales manager digitized products joins them. Thus, ProfEQ is not generating the desired effect from this potential yet. *Maybe in five years it will be the norm, but at the moment it's a matter of time. The time of the salesmen. Who has the time? […] They use it when I am with them. – Sales Manager Digitized Products*

Appendix F. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.dss.2024.114365.

References

[1] Fortune Business Insights, Internet of Things (IoT) Market Size, 2023-2030, Market Research Report, 2022. Available at: https://shorturl.at/5RVZV.
[2] M.E. Porter, J.E. Heppelmann, How smart, connected products are transforming competition, Harv. Bus. Rev. 92 (2014) 64–88.
[3] Y. Yoo, O. Henfridsson, K. Lyytinen, The new organizing logic of digital innovation: an agenda for information systems research, Inf. Syst. Res. 21 (2010) 724–735.
[4] Y. Yoo, R.J. Boland, K. Lyytinen, A. Majchrzak, Organizing for innovation in the digitized world, Organ. Sci. 23 (2012) 1398–1408.
[5] M.E. Porter, J.E. Heppelmann, How smart, connected products are transforming companies, Harv. Bus. Rev. 93 (2015) 96–114.
[6] S. Nambisan, K. Lyytinen, A. Majchrzak, M. Song, Digital innovation management: reinventing innovation management research in a digital world, MIS Q. 41 (2017) 223–238.
[7] M. Barrett, E. Davidson, J. Prabhu, S.L. Vargo, Service innovation in the digital age: key contributions and future directions, MIS Q. 39 (2015) 135–154.
[8] Signify, Philips Hue. https://www2.meethue.com/en-us/, 2023 (accessed 13 Feb 2023).
[9] M. Herterich, A. Eck, F. Uebernickel, Exploring how digitised products enable industrial service innovation - an affordance perspective, in: Proceedings of the 24th European Conference on Information Systems (ECIS), 2016.
[10] S. Jernigan, S. Ransbotham, D. Kiron, Data sharing and analytics drive success with IoT, MIT Sloan Manag. Rev. Res. Report (September 2016).
[11] M. Mocker, J.W. Ross, C.M. Beath, How Companies Use Digital Technologies to Enhance Customer Offerings – Summary of Survey Findings, MIT CISR WP, no. 434, 2019.
[12] R. Shanks, F. Hintermann, Designing Smart-Home Products That People Will Actually Use, Harvard Business Review Online, 2019.
[13] G. Hui, Do people really want smarter toothbrushes? Harv. Bus. Rev. Online (2014).
[14] C. Smith, Do Your Customers Actually Want a "Smart" Version of Your Product?, Harvard Business Review Online, 2017.
[15] I. Hutchby, Technologies, texts and affordances, Sociology 35 (2001) 441–456.
[16] M.L. Markus, M.S. Silver, A Foundation for the Study of IT effects, J. Assoc. Inf. Syst. 9 (2008) 609–632.
[17] C. Dremel, M.M. Herterich, J. Wulf, J. Vom Brocke, Actualizing big data analytics affordances: a revelatory case study, Inf. Manag. 57 (2020) 1–21.
[18] J. Kallinikos, A. Aaltonen, A. Marton, The ambivalent ontology of digital artifacts, MIS Q. 37 (2013) 357–370..
[19] R. Benbunan-Fich, An affordance lens for wearable information systems, Eur. J. Inf. Syst. 28 (2019) 256–271.
[20] M.M. Herterich, C. Dremel, J. Wulf, J. vom Brocke, The emergence of smart service ecosystems, Inf. Syst. J. 33 (2023) 524–566.
[21] J.J. Gibson, The theory of affordances, in: R. Shaw, J. Bransford (Eds.), Perceiving, Acting and Knowing: Towards an Ecological Psychology, Wiley, 1997, pp. 67–82.
[22] D. Strong, S.A. Johnson, B. Tulu, J. Trudel, O. Volkoff, L.R. Pelletier, I. Bar-On, L. Garber, A theory of organization-EHR affordance actualization, J. AIS 15 (2014) 53–85.
[23] A. Majchrzak, M.L. Markus, Technology affordances and constraints in management information systems, in: Encyclopedia of Management Theory, Sage Publications, 2012.
[24] E. Klecun, R. Hibberd, V. Lichtner, Affordance theory perspectives on it and healthcare organisation, in: Proceedings of the 37th ICIS, 2016.
[25] P.M. Leonardi, When does technology use enable network change in organisations? A comparative study of feature use and shared affordances, MIS Q. 37 (2013) 749–775.
[26] R.F. Zammuto, T.L. Griffith, A. Majchrzak, D.J. Dougherty, S. Faraj, Information technology and changing fabric of organisation, Organ. Sci. 18 (2007) 749–762.
[27] E. Bernhard, J. Recker, A. Burton-Jones, Understanding the actualisation of affordances, in: Proc. of the 34th International Conference on Information Systems, 2013.
[28] W. Du, S. Pan, D. Leidner, W. Ying, Affordances, experimentation and actualization of FinTech, J. Strateg. Inf. Syst. 28 (2019) 50–65.
[29] J. Bokrantz, J. Dul, Building and testing necessity theories in supply chain management, J. Supply Chain Manag. (2022) 1–18.
[30] L. Tornatzky, M. Fleischer, The Processes of Technological Innovation, Lexington, 1990.
[31] K. Zhu, K. Kraemer, X. Sean, Electronic business adoption by European firms, Eur. J. Inf. Syst. 12 (2003) 251–268.
[32] V. Venkatesh, H. Bala, Adoption and impacts of interorganizational business process standards: role of partnering synergy, Inf. Syst. Res. 23 (2012) 1131–1157.
[33] D. Chen, D. Preston, M. Swink, How the use of big data analytics affects value creation in supply chain management, J. Manag. IS. 32 (2015) 4–39.
[34] J. Baker, The technology-organization-environment framework, in: Y.K. Dwivedi, L.M. Scott, L. Schneberger, I.S. Systems (Eds.), Information Systems Theory: Explaining and Predicting Our Digital Society, University of Hamburg, 2012.
[35] C.M.D. Remy, T. Pärnpuu, J. Hedman, Smart Cities & Sustainable Information Systems, Copenhagen Business School. DIGI Communications No. 2018/2, 2018.
[36] C. Wendt, M. Adam, A. Benlian, S. Kraus, Let's connect to keep the distance: how SMEs leverage information and communication technologies to address the COVID-19 crisis, Inf. Syst. Front. 24 (2021) 1061–1079.
[37] R.K. Yin, Case Study Research: Design and Methods, Sage, 2003.
[38] A. Novales, M. Mocker, E. van Heck, Producer-side use cases of digitized products: what's best for your company?. Proc. of the Fortieth Internation Conference on Information Systems, 2019.
[39] J. Dul, Necessary condition analysis (NCA): logic and methodology of 'necessary but not sufficient' causality, Organ. Res. Methods 19 (2016) 10–52.
[40] J. Dul, Conducting Necessary Condition Analysis for Business and Management Students, Sage Publications, Mastering Business Research Methods series, 2020.
[41] H. Aguinis, R.S. Ramani, W.F. Cascio, Methodological practices in international business research: an after-action review of challenges and solutions, J. Int. Bus. Stud. 51 (2020) 1593–1608.
[42] D.D. Bergh, B.K. Boyd, K. Byron, S. Gove, D.J. Ketchen Jr., What constitutes a methodological contribution? J. Manag. 48 (2022) 1835–1848.
[43] J. Dul, Advances in Necessary Condition Analysis. https://shorturl.at/C5lnZ, 2021.
[44] J. Dul, S. Hauff, R.B. Bouncken, Necessary condition analysis (NCA): review of research topics and guidelines for good practice, Rev. Manag. Sci. 17 (2023) 683–714.
[45] D.A. Gioia, K.G. Corley, A.L. Hamilton, Seeking qualitative rigor in inductive research, Organ. Res. Methods 16 (2012) 15–31.
[46] T. Jick, Mixing qualitative and quantitative methods: triangulation in action, Adm. Sci. Q. 24 (1979) 602–611..
[47] H.M. Chen, R. Schütz, R. Kazman, F. Matthes, How Lufthansa capitalized on big data for business model renovation, MIS Q. Exec. 16 (2017) 19–34.
[48] S. Kaplan, R. Henderson, Inertia and incentives: bridging organisational economics and organisational theory, Organ. Sci. 16 (2005) 509–521.
[49] O. El Sawy, H. Amsinck, P. Kræmmergaard, A. Vinther, How LEGO built the foundations and enterprise capabilities, MISQ Execut. 15 (2016) 141–166.
[50] T. Saldanha, S. Mithas, M.S. Krishnan, Leveraging customer involvement for fueling innovation, MIS Q. 41 (2017) 267–286.
[51] E. Stoeckli, C. Dremel, F. Uebernickel, W. Brenner, How affordances of Chatbots cross the chasm between social and traditional enterprise systems, Electron. Mark. 30 (2020) 369–403.

[52] A.H. Van de Ven, D. Polley, Learning while innovating, Organ. Sci. 3 (1992) 92–116.
[53] J.G. March, J.P. Olsen, The uncertainty of the past: organizational learning under ambiguity, Eur J Polit Res 3 (1975) 147–171.
[54] S. Blank, Why the lean start-up changes everything, Harv. Bus. Rev. 91 (2013) 63–72.
[55] M. Thibaud, H. Chia, W. Zhou, S. Piramuthu, Internet of things (IoT) in high-risk environment, health and safety (EHS) industries: a comprehensive review, Decis. Support. Syst. 108 (2018) 79–95.
[56] W.J. Hsu, J. Liou, H. Lo, A group decision-making approach for exploring trends in the development of the healthcare industry in Taiwan, Decis. Support. Syst. 141 (2021).
[57] P. Wu, F. Chu, N. Saidani, H. Chen, W. Zhou, IoT-based location and quality decision-making in emerging shared parking facilities with competition, Decis. Support. Syst. 134 (2020).
[58] J. Webster, R.T. Watson, Analyzing the past to prepare for the future: writing a literature review, MIS Q. 26 (2002) 13–23.
[59] W.D. Salisbury, W.W. Chin, A. Gopal, P.R. Newsted, Research report: better theory through measurement—developing a scale to capture consensus on appropriation, Inf. Syst. Res. 13 (1) (2002) 91–103.
[60] T.S. Ragu-Nathan, M. Tarafdar, B.S. Ragu-Nathan, Q. Tu, The consequences of technostress for end users in organizations: conceptual developmentand empirical validation, Inf. Syst. Res. 19 (4) (2008) 417–433.

Ainara Novales is a research affiliate at Rotterdam School of Management, Erasmus University. She investigates the impact of digitization on products and services as well as on sustainability. Her research interests include digital innovation, platform ecosystems, internet of things, low-code/no-code development, GenAI, and digital sustainability. She has published her work in international journals and conference proceedings, including MIS Quarterly Executive, Communications of the Association for Information Systems (CAIS) and the International Conference on Information Systems (ICIS).

Martin Mocker is a professor of information systems at ESB Business School, Reutlingen University, Germany and an academic research fellow at the Massachusetts Institute of Technology Center for Information Systems Research. He is co-author of the book "Designed for Digital: How to Architect Your Business for Sustained Success" (MIT Press, 2019). His publications have received the Best Paper Award at the CIO Forum of the International Conference on Information Systems and the Best Conference Paper in IS Education Award by the Association of Information Systems.

Eric van Heck is the chaired professor of Information Management and Markets at the Rotterdam School of Management, Erasmus University. He is a fellow of the Erasmus Research Institute of Management and a member of the Erasmus Center for Data Analytics. His research focuses on auction markets, business analytics, circular and digital business design, and digital work. In 2020, he received the AIS Sandra Slaughter Service Award, the AIS Technology Challenge Award, and the AIS Impact Award, and, in 2021, the INFORMS ISS Design Science Award. His latest book for a general audience is Technology Meets Flowers. Unlocking the Circular and Digital Economy (Springer Nature, 2021).

Jan Dul is a professor of Technology and Human Factors at Rotterdam School of Management, Erasmus University, The Netherlands. He has backgrounds in technical, medical and social sciences and has written more than 200 publications including papers and books on research methodology. He is the founder of Necessary Condition Analysis (NCA). Two of his recent books are Conducting Necessary Condition Analysis (Sage, 2020) and Necessary Condition Analysis. Foundations and Application (Chapman & Hall/CRC, forthcoming).