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SPECIAL ISSUE ARTICLE



Pattern-based development of digital platforms

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Digital platforms have been reshaping the structure of whole industries. Whereas previous developments mainly have taken place within the business-to-consumer (B2C) or consumer-to-consumer (C2C) market, the business-to-business (B2B) market is at the edge of the so-called platform economy. Leading companies step out of their core business and develop their own platforms. The paper at hand presents a methodology to master the challenges of developing digital platforms by using patterns, which represent proven principles of already established platforms. The methodology is based on a holistic pattern catalogue that can be used independently from the task at hand. We show in detail how we derived a catalogue with 37 platform patterns and how the catalogue can be applied to the development of digital platforms. The corresponding methodology contains three phases. Within the first phase, a specific platform idea is being developed. The second phase addresses the collaboration of an abstract platform concept. Finally, a specific digital platform concept is worked out. **KEYWORDS**

B2B platforms, digital platform, manufacturing industry, multisided markets, platform economy, platform markets

1 | DIGITAL PLATFORM, PLATFORM ECOSYSTEM AND PLATFORM ECONOMY

The term 'platform' has its roots in the French word 'plateforme' (raised space). Since the 19th century at the latest, the term platform has been used in the sense of 'base, foundation' (Riecke, 2014). Various disciplines have taken up this definition and developed it in a specific way; in mechanical engineering, for example, a platform is a constructive base on which various products can be built (Reillier & Reillier, 2017). The specific definitions have in common that these platforms are understood as a system of constant core components and variable peripheral components (Baldwin & Woodard, 2009). The separation into constant components in the core and variable components in the periphery is also part of digital intermediary platforms and goes back to the work of Rochet and Tirole in the context of two-sided markets (Baums, 2015; Rochet & Tirole, 2003). Numerous authors have taken up the work of Rochet and Tirole and developed their own definitions for digital platforms. In the paper at hand, only intermediary platforms are considered. Such platforms bring together different groups of participants in the sense of a multisided market. A closer look at platform definitions reveals some overarching commonalities that form the basis for the understanding of the term in this paper:

- · Digital platforms are intermediaries and enable interactions and the exchange of values between at least two different, interdependent user groups (Evans & Schmalensee, 2016; Gassmann, Frankenberger, & Csik, 2017; Moazed & Johnson, 2016; Parker, van Alstyne, & Choudary, 2017).
- Digital platforms consist of constant components in the core and variable components in the periphery (Choudary, 2015; Parker et al., 2017; Tiwana, 2014).
- Platform operators provide the basic infrastructure and define the interaction rules of the game and general conditions (Choudary, 2015; Moazed & Johnson, 2016; Parker et al., 2017; Tiwana, 2014).

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- Users of digital platforms exchange services or products, information and currencies (e.g. money or data) in order to create added value for at least one of the groups (Choudary, 2015; Moazed & Johnson, 2016; Parker et al., 2017).
- The success of digital platforms is mainly caused by strong network effects; indirect network effects usually have a higher influence (Evans & Schmalensee, 2016; Gassmann et al., 2017; Moazed & Johnson, 2016; Parker et al., 2017).

For the present work, the following understanding of a digital platform is used. A digital platform is characterized by strong network effects, links two or more different and interdependent groups of participants and enables value-added interactions through the exchange of products, services, information and/or currencies (e.g. money or data). The users of a platform are part of the variable periphery and access a consistent core. The platform operator provides the basic infrastructure and defines the rules and framework for the platform.

The success of a digital platform is not based on internal resources but on the ecosystem in which the platform is embedded (Parker et al., 2017). The concept of the business ecosystem was already discussed by James Moore in 1993. In analogy to a biological ecosystem, a business ecosystem consists of partners that are mutually dependent on each other, offer complementary services and thus achieve a higher degree of individualization of products and services than each of them alone (Moore, 1993). The formation of such ecosystems in industry is favoured by platforms. Engels, Plass, and Rammig (2017) take up the concept of the ecosystem and state that in a platform ecosystem, the economic mechanisms behind a digital platform as well as the stakeholders involved and their relationships are described. According to Evans and Schmalensee (2016), these stakeholders include all persons, companies, institutions and other environmental factors that influence the value created by a platform. This value is created by using stakeholder data to orchestrate physical and digital resources across the ecosystem (Choudary, 2015).

Digital ecosystems and the associated platform economy increasingly came into the focus of innovation policy debates (Kagermann et al., 2015). In the present study, the term describes a state in the future in which the most significant economic sectors have undergone a transformation into platform-based ecosystems (Kenney & Zysman, 2016). The platform economy will blur the boundaries between companies and industries (Engels et al., 2017; Jaekel, 2017; Seiberth, 2015). Geographical borders will become less important, although cultural, linguistic and legal barriers still have to be overcome (Engelhardt, von Wangler, & Wischmann, 2017). The platform economy is associated with distinct collaborative value creation structures, which require new business models to successfully distribute products, services and value units (Evans, Hagiu, & Schmalensee, 2004; Kagermann et al., 2015). The relationship between the terms 'digital platform', 'platform ecosystem' and 'platform economy' is shown in Figure 1.

The core value of a platform company is not a classic physical value unit but an infrastructure that enables interactions between producers and consumers. The design of the key interaction is therefore the core of each digital platform. The key interaction is the reason why participants use digital platforms (Jaekel, 2017; Parker et al., 2017). The anatomy of a key interaction consists of four characteristics (Choudary, 2015; Moazed & Johnson, 2016):

- Value creation: Each key interaction involves at least one producer who creates the value unit. The production of value units by the producer marks the starting point of a platform interaction (Jaekel, 2017; Moazed & Johnson, 2016; Parker et al., 2017).
- 2. Connection: The connection of producers and consumers is enabled through filtering and individualization of the platform content. Filtering ensures that only high-quality value units are offered. Filter mechanisms support desirable behaviour and punish undesirable behaviour (Choudary, 2015; Jaekel, 2017). With the help of filters, a specific consumer gains access to the content relevant to him. Digital platforms that are able to provide their



FIGURE 1 Relationship between the terms 'digital platform', 'platform ecosystem' and 'platform economy' [Colour figure can be viewed at wileyonlinelibrary.com]

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consumers with individualized content encourage them to continue participating (Parker et al., 2017).

- Consumption: Each key interaction involves at least one participant who consumes the value unit that is relevant for him. Consumption can take different forms depending on the value unit. For example, the consumption of digital value units often takes place directly via the platform (Choudary, 2015; Jaekel, 2017; Moazed & Johnson, 2016).
- Compensation: The key interaction is completed with compensation. It is characteristic that the consumer transmits a return service to the producer for the value unit received (Moazed & Johnson, 2016).

In a key interaction, information, value units and payments are exchanged. A producer and a consumer first exchange information. Then the producer transmits a value unit to the consumer and receives a payment in return. The payment does not always have to be monetary but can also take the form of data or evaluations. The payment can also be made in form of a payment slip. The number of key interactions increases with the scope of services/products offered and the number of participants in the platform ecosystem. The constantly repeating key interactions are made possible by three basic functions of a platform (Choudary, 2015; Cusumano, Gawer, & Yoffie, 2019; Moazed & Johnson, 2016; Parker et al., 2017):

- Match: The most relevant value units must always be provided for the consumers. With an increasing number of producers, the scope of the platform offerings increases, making it more difficult for consumers to identify the desired offer. Filters are suitable for merging the value unit provided by the producer with the corresponding consumer.
- Facilitate: Platform companies do not control value creation but provide an infrastructure that enables value creation. Programs are introduced and policies established that regulate interactions and promote desired behaviour. Filter mechanisms ensure that highquality content is provided on the platform and that desirable interactions are enabled.

 Pull: Key interactions are made possible by luring participants to the platform and keeping them there. Platforms have to overcome the chicken-and-egg problem (Who joins the platform first? Producer or consumer?). The aim is to make participation on the platform as easy as possible for potential participants. Because the focus of business activities is on repetitive interactions, it must be ensured that the participants are regularly active. In order to prevent unwanted behaviour of the participants, membership checks can be useful.

Figure 2 shows an aggregated representation of the functionality of a digital platform.

In summary, the pull effect enables the quantitative scaling of a platform by promoting production and consumption. Filter mechanisms ensure that the quality of the consumer experience is guaranteed as the platform grows (Jaekel, 2017). On the basis of the filtered and individualized content, suitable producers and consumers can interact in key interactions and initiate the exchange.

2 | THE DISRUPTIVE POTENTIAL OF DIGITAL PLATFORMS

In the course of digitization, the platform model is experiencing an impressive renaissance and is putting established companies across industries under pressure (Linz, Müller-Stewens, æ Zimmermann, 2017). Former well-established enterprises like Nokia or Blackberry are now dominated by platform enterprises like Apple. Whereas the previous developments mainly have taken place within the business-to-consumer (B2C) or consumer-to-consumer (C2C) market, the business-to-business (B2B) market is also experiencing the first signs of upcoming platform enterprises. Leading companies are stepping out of their core business and develop own platforms. Additionally, agile start-ups begin to build platform solutions and services for digital platforms (Libert, Beck, & Wind, 2016). Well-known examples are 365FarmNet and Predix. Figure 3 shows some examples for the historical development of digital platforms in B2C/C2C and B2B markets.



FIGURE 2 Aggregated representation of the functionality of a digital platform [Colour figure can be viewed at wileyonlinelibrary. com]



FIGURE 3 Historical development of digital platforms in business-to-consumer (B2C)/consumer-to-consumer (C2C) and business-to-business (B2B) markets [Colour figure can be viewed at wileyonlinelibrary.com]

Following Parker et al., the disruptive potential of digital platforms is based on two major economic advantages: (1) marginal costs and (2) network effects. These advantages enable companies to expand their platform businesses with relatively low investments compared with traditional businesses (Parker et al., 2017).

Marginal costs describe the additional costs that occur if an additional unit of a certain product or service is being produced (O'Sullivan & Sheffrin, 2003). For instance, if the Hilton Worldwide Holdings Inc. decides to expand to a new market, they need to invest in new buildings and new personal staff. Contrary to this, if Airbnb decides to expand to a new market, they do not need such investments. The new accommodations are provided by private homeowners who also act as staff for the customers of Airbnb. The additional costs for these new accommodations are almost not existing, which allows platforms to expand their business with minimal costs, once their platforms are established and running (see Figure 4). Relative to linear businesses, platforms require even less investments in order to expand. Moreover, the low cost of supply makes it possible that platforms can grow to a much larger size than linear businesses can. The costs of a linear business will always continue to rise as it grows due to an increasing complexity whereas the costs of a platform tend to level off logarithmically. In theory, platforms can even capture the total market volume (Moazed & Johnson, 2016).

The network effect describes how the consumer value of a product changes when the number of consumers of the same product or complementary products changes. A distinction is made between the direct and indirect network effects. The direct network effect was described in 1986 by Katz and Shapiro and states that a product's value changes with the total number of consumers of that product (Katz & Shapiro, 1986). Often referred examples for this effect are telephones and fax machines. Figure 5 shows the exponential increase in possible connections with increasing numbers of participants.

Within the context of digital platforms, the direct network effect occurs, for example, on social media platforms such as Facebook. The indirect network effect occurs when the value of a product changes as soon as the number of consumers of another product changes without a direct relationship between these products (Shapiro & Varian, 1998). The indirect network effect is characteristic for twosided or multisided markets. Thereby, an increased number of participants on the one side of the market tend to increase the number of participants on the other side of the market. This effect is the driving force behind digital platforms like Airbnb or Uber. Positive network effects are the foundation for digital platforms. Thus, the more users a



FIGURE 4 Course of marginal costs in traditional companies and in platform companies (Moazed & amp; Johnson, 2016) [Colour figure can be viewed at wileyonlinelibrary.com]



FIGURE 5 Exponential increase in possible connections with increasing number of participants (Tiwana, 2014) [Colour figure can be viewed at wileyonlinelibrary.com]

platform has, the more attractive it becomes for other users. This is referred to as self-reinforcing 'chain reactions' that—once initiated—lead to the rapid growth of digital platforms. This is why for each market only a very number of platforms can economically exist (Eisenmann, Parker, & Alstyne, 2006).

3 | DRIVERS OF DIGITAL PLATFORMS

The rise of the digital platform is changing the traditional competitive landscape (Alstyne, Parker, & Choudary, 2016). Technological enablers are paving the way for these changes (Engelhardt et al., 2017; Parker et al., 2017). Market demands for platform functionalities are causing platforms to spread faster and faster (Parker et al., 2017; Sauer, Dopfer, Schmeiss, & Gassmann, 2016). Based on technology push and market pull, a distinction can be made between market- and technology-induced stimuli for digital platforms (Bullinger, 1994). Technology push is an impulse for an idea, which has its origin in a new technology (Specht & Möhrle, 2002). Market pull describes an impulse for an idea that starts with a changed consumer need within a specific market (Gerpott, 2005). Market pull and technology push are never or only very rarely used in their pure form in reality; they are

rather to be understood as planning concepts (Herstatt & Lettl, 2000). A meeting of both impulses often leads to ground-breaking success and is decisive for the success of innovation (Gausemeier et al., 2019; Spath & Warschat, 2008). Figure 6 shows the comparison of both approaches in the context of digital platforms.

3.1 | Technological enablers

Industrial production is subject to constant change. Mechanization, electrification and automation have already led to profound changes in industrial value creation. We are currently undergoing another fundamental change—the so-called fourth industrial revolution or Industry 4.0. The central driver of this change is digitalization (Bauernhansl, 2017; Kagermann, Wahlster, & Helbig, 2013). Digitization is considered a megatrend of the 21st century and describes the changes caused by digital technologies from the perspective of manufacturing companies (Echterfeld, 2020). Digitization describes from a technical point of view the conversion of analogue data into digital data (Mertens & Barbian, 2016). Digital technologies support 'the acquisition, processing, storage, presentation or transmission of data and information' (Stähler, 2002). The



FIGURE 6 Technological enablers and customer needs as drivers of digital platforms based on bridging the tension between technology push and market pull according to Bullinger (1994) [Colour figure can be viewed at wileyonlinelibrary.com] technological enablers of digital platforms lie in mastering these digital technologies (Evans & Schmalensee, 2016; Parker et al., 2017). In the scientific literature, the following three enablers in particular have emerged as crucial:

- Networking: Driven by the expansion of broadband connections and mobile networks, the networking of our world is constantly increasing (Kaeser, 2015). The number of objects and industrial plants networked with the Internet will increase to about 500 billion by 2030 (Kagermann, Riemenperger, Leukert, & Wahlster, 2017). The resulting Internet of Things enables the integration of numerous players and industrial facilities into digital platforms, thus preparing the ground for the platform economy (Evans & Schmalensee, 2016). Platform operators can network players with each other who have never been in contact and significantly reduce the time and effort required for initiation (Altman, Nagle, & Tushman, 2013; Benner & Tushman, 2015).
- Availability: Benefiting from falling prices for components (e.g. processors) and the increasing establishment of cloud computing, the costs for data storage and availability have fallen steadily in recent years (Matyssek, 2017). Cloud computing allows software, storage capacities and computing power to be offered as additional services on digital platforms at low marginal costs (Engels et al., 2017). Cloud services enable cross-device and location-independent data access (Evans & Schmalensee, 2016).
- Processing: Data handling plays a decisive role in the success of digital platforms (Winter, 2017). Data processing enables digital value-added services and opens the way to completely new revenue sources (Engels et al., 2017). The reduction in the size of transistors has increased the computing capacity of processors by a factor of 300 from 1981 to 2014 (Evans & Schmalensee, 2016). Furthermore, decisive progress has been made in (advanced) analytics using intelligent algorithms (Choudary, 2015). Increasingly large and unstructured data volumes can be evaluated faster and faster, which enables numerous platform services (Röglinger & Urbach, 2017).

3.2 | (Enhanced) customer needs

Technological drivers are enabling the emergence of digital platforms, whereas the customers' needs result in more and more comprehensive platform functionality (Evans & Schmalensee, 2016; Jaekel, 2017). Due to the change from seller's to buyer's markets, companies must increasingly win over consumers and fulfil their wishes as economically as possible (Gausemeier & Plass, 2014; Ohms, 2000). Digital platforms can meet some of these new needs particularly well (Parsons, Leutiger, Lang, & Born, 2016). In line with the idea of the market pull, selected needs act as drivers for the spread of digital platforms (Jaekel, 2017). Some pioneering digital platforms have enabled and triggered changes in consumer needs. Airbnb and Uber, for example, have played a decisive role in triggering the trend towards collaborative consumption

(Evans & Schmalensee, 2016). The most important of these changes are explained below:

- Collaborative consumption: The term describes a change in consumer behaviour from owning to sharing goods, also known as 'sharing economy' (Heinrichs & Grunenberg, 2012). Digital platforms counter this trend primarily by bringing together different players at low transaction costs (Engelhardt et al., 2017). The success of digital platforms like Airbnb and Uber is closely linked to the trend of collaborative consumption (Baldi, 2016; Heinrichs & Grunenberg, 2012). Collaborative consumption also has an impact on manufacturing companies, which can, for example, sell high-priced products to consumer segments with low purchasing power (Herrmann-Fankhänel, 2018).
- Holistic solutions: Consumers increasingly expect holistic solutions that combine complementary products and services (e.g. a general contractor for home automation) (fortiss Gmbh, 2016). Individual companies often do not have the necessary skills to offer consumers a holistic solution as specific domain knowledge is often required (Arbeitskreis Smart Service Welt and acatech, 2015). Digital platforms make it possible to bring together the competencies of different companies within an ecosystem (Tiwana, 2014).
- Service orientation: The increasing service orientation is regarded as one of the central drivers for changing established business models (Baines et al., 2007; Morelli, 2002). Vandermerwe and Rada (1988) speak of servitization. Physical products are supplemented by services in order to create added value (Baines et al., 2007). This allows companies to address challenges such as declining revenues (Sayar & Er, 2018). In this area of tension, digital services, which complement physical products, are moving into the focus of companies (Frank et al., 2018). Digital platforms are increasingly used to provide these services (Baums, Schlössler, & Scott, 2015).
- Individualization: Consumers increasingly demand individualized products instead of homogeneous market services (Tiwana, 2014; Williamson & de Meyer, 2012). Digital platforms enable such individualization by promoting modular products (Baums, 2015; Park, 2018). Furthermore, platforms as mediators bring together a large number of different actors (Alstyne et al., 2016). They enable the operator to focus on the core of the platform, whereas producers can sell niche products in small quantities (Engels et al., 2017).

The functionality of digital platforms is radically different from the functionality of traditional products (Choudary, 2015; Cusumano et al., 2019). Companies that want to develop a platform face the problem that customers cannot articulate their need for such a solution because they are simply not aware of it (von Wangenheim & Holzmüller, 2005). The underlying latent customer needs are unconsciously present and can only be captured insufficiently with the classic methods of market research (Stolper, 2008). They are, however, no less real than articulated needs and represent a high potential for disruptive innovation (Hamel & Prahalad, 1997; Kärkkäinen, Piippo, Puumalainen, & Tuominen, 2001). The technological enablers enable first pioneer platforms that take up latent customer needs and prove the practicability of digital platforms in the sense of a 'proof of concept' in a specific application (McAfee & Brynjolfsson, 2017; Teece, 2018). In this paper, a pioneer platform refers to a digital platform that was first used within a specific industry (e.g. Airbnb in 2009). Pioneering work makes it possible to articulate latent customer needs, which results in imitation platforms in the same industry (e.g. Wimdu in 2011) or a completely different one (Jaekel, 2017). An example of a platform that satisfies the need for collaborative consumption in a completely different industry is WeWork. The company rents office space where central elements such as meeting rooms are shared (Konrad, 2014). The advantages of digital platforms are becoming clear through the increasing range of platforms on offer, whereby previously latent consumer needs are becoming apparent and are increasing (Kenney & Zysman, 2015; McAfee & Brynjolfsson, 2017). The consequence are imitator platforms, which can represent a competition to the own offer (Reillier & Reillier, 2017). Figure 7 clearly illustrates the relationships described.

The technological foundations for digital platforms are already in place in many areas of industry, and the development of a digital platform is associated with significant opportunities such as increased sales and consumer loyalty. However, companies must also be aware of the risks. Many platforms fail to achieve critical mass and the high initial costs of successful platform operation. Small- and medium-sized companies lack opportunities to enter the platform economy. These companies need knowledge of existing platforms and best practices to master the leap into the platform economy. These knowledge deficits of companies can be eliminated by using patterns. Patterns are connecting elements in a problem-solution relationship (see Figure 8).

Latent Customer Needs
Collaborative Consumption

Holistic Solutions

Individu-

alization

+

Service Orientation

Technological

Networking

Availability

Processing

Enablers



i

Proof of

Concept

Rise of Platforms

within the Industry

Imitator Platform

Pioneering Platform

Articulated and increased customer needs

Problems are obstacles that must be overcome in the transition from an initial situation to a desired target state. If the transition is successful, the path to it is a solution. By applying patterns, users can increase the efficiency of problem solving (Amshoff, Dülme, Echterfeld, & Gausemeier, 2015). The present analysis takes up the definition of Alexander et al. A platform pattern therefore consists of a problem that companies have to overcome again and again when building digital platforms and a solution with which this problem can always be overcome (Alexander, Ishikawa, & Silverstein, 1977). These patterns are derived from reality and then documented in order to externalize the identified patterns. With the documentation, third parties gain access to the patterns (Kohls, 2014).

4 | APPROACHES TO DEVELOP AND SHAPE DIGITAL PLATFORMS

There are several approaches in the scientific literature that are dedicated to the pattern-based development of digital platforms. These can be roughly divided into three categories: (1) approaches to identify, document and apply patterns; (2) framework models to develop digital platforms; and (3) pattern-based approaches to shape digital platforms.

4.1 | Approaches to identify, document and apply patterns

Patterns are present in many different domains. They occur wherever people are confronted with similar problems that can be solved with

> **FIGURE 7** Principle of positive feedback between technological enablers and (latent) consumer needs leads to the rise of platforms within the industry [Colour figure can be viewed at wileyonlinelibrary.com]

FIGURE 8 Relationship between obstacles, solution and proven principle (Echterhoff, 2014) [Colour figure can be viewed at wileyonlinelibrary.com]

the same solution. An application of the pattern concept that is frequently mentioned in literature goes back to the architectural theorist Alexander, who developed 253 patterns for the design of cities and buildings in the 1970s (Alexander, 1979; Alexander et al., 1977). Since then, this idea has been taken up regularly, for example, in software development. Software developers can use patterns to build on the knowledge of other and more experienced developers to solve their own problems (Kohls, 2014). Another example of the use of patterns is the design of business models. Through business model patterns, the success of particularly profitable companies becomes transparent, and other companies are provided with the solution knowledge of these successful companies with the help of patterns (Echterhoff, Koldewey, & Gausemeier, 2017).

4.2 | Framework models to develop digital platforms

In holistic framework models, several relevant elements of digital platforms are considered in aggregated form. The aim of these framework models is to support companies in planning and building their own digital platforms. An example is provided by Choudary, who describes a four-stage process for building a digital platform based on key interaction. This construction process is tangled by a platform canvas, which shows all elements relevant for the platform construction (Choudary, 2015). Similar canvas-based approaches for platform construction are provided by Walter and Lohse (2018). Such approaches have in common that they deal in detail with the procedure for building a platform, but the design of the individual process steps is not particularly detailed.

4.3 | Pattern-based approaches to shape digital platforms

In order to successfully complete the platform construction, more is required than mere knowledge of a corresponding procedure. Against this background, approaches have been incorporated into the analysis of the state of the art, which deal in detail with the design of individual platform elements by using patterns. Scientific literature has been dominated by approaches to the acquisition of participants—often also referred to as approaches to overcoming the chicken-and-egg problem. Leading works in this field come from Moazed and Johnson (2016), Hagiu and Altman (2017) and Evans and Schmalensee (2016). The authors describe different strategies to convince producers and consumers to use a platform. Another topic that is intensively discussed in the literature is the monetization of platforms. Leading works on this topic come from Alstyne et al. (2016) and Reillier and Reillier (2017). The focus of these works is on various strategies for the benefit-maximizing pricing of platform participants. The analysis of the state of the art has shown that the pattern approach is already being used in various domains and that initial work already exists in the context of digital platforms (Figure 9).

The mentioned and further approaches from the state of the art were examined for a possible utilization for the pattern-based development of digital platforms and were incorporated into the developed framework. The framework at hand was developed at the Heinz Nixdorf Institute using the design research methodology (DRM) according to Blessing and Chakrabarti (2009). In the first phase of the research, the goal has been clarified including the theoretical foundation and the state of the art. In the second phase, a first descriptive study consisting of 40 interviews with management personalities within the machine building industry has been conducted (Engels et al., 2017). This study lead to a deeper understanding of the mechanisms of digital platforms and of the problems companies face while establishing own platforms. Following the interviews, we conducted a literature analysis that led to potential platform patterns. The actual framework was developed in the third phase of the research within a prescriptive study. It is based on the findings of the first phase as well as further research (e.g. existing literature and best practices). The last phase of the work was a second descriptive study in which the developed methodology was evaluated.

5 | PATTERNS FOR THE DEVELOPMENT OF DIGITAL PLATFORMS

When setting up digital platforms, companies are confronted with recurring problems for which they need guidance. Platform patterns can provide such guidance. A pattern is a proven solution. The scientific literature on patterns in the context of digital platforms has so far been dominated by approaches to overcome the chicken-and-egg

Engineering



FIGURE 9 Patterns in different domains further developed from Amshoff (2016) [Colour figure can be viewed at wileyonlinelibrary.com] 420 WILEY-

problem (Evans & Schmalensee, 2016; Hagiu & Altman, 2017; Moazed & Johnson, 2016). Other approaches address the monetization of platforms (Reillier & Reillier, 2017). A collection of such patterns for building digital platforms does not exist (see Section 4). In the following, the cyclical procedure for creating a corresponding catalogue is presented (Figure 10). The procedure is based on the phases of pattern identification and documentation according to Kohls (2014).

5.1 | Deriving design fields for platform development

Starting point are design fields of digital platforms. These are homogeneous platform areas that can be designed separately from other areas. Existing approaches for the development of digital platforms are included in the derivation of the design fields (see Section 4). An examination of the existing literature on the development of digital platforms leads to seven possible design areas that can be addressed with the help of platform patterns. The value units of a platform and the acauisition of participants are undisputed design fields in the existing literature. The platform infrastructure and the transaction anatomy are not taken up by all approaches without restriction but are nevertheless mentioned by the majority. The design fields further ecosystem participants, monetization and access channels are controversially discussed. The application of the patterns in consulting projects has shown that access channels to a platform are relatively easy to select. Therefore, they will not be considered further. The six remaining design fields are shown in Figure 11.

5.2 | Identification of potential patterns for each design field

Potential patterns are identified for the above mentioned design fields. In order to accomplish this task, a deductive approach is chosen, in which the relevant literature is examined for platform-specific and pattern-similar approaches. Some of these approaches are already part of Section 4. Including further approaches, a total of nine sources describing potential patterns could be identified. The described possible patterns are transferred into a loose collection. A section of this collection is shown in Figure 12. The complete collection consists of 79 potential patterns. Approaches that deal with patterns for developing digital platforms, but cannot be assigned to any design field, are not considered. Potential patterns can be identified for all relevant design fields. The field *participant acquisition* dominates the scientific literature; 41 of 79 potential patterns can be assigned to this design field.

5.3 | Identification of relevant platform patterns

To determine relevant patterns, unsuitable candidates are eliminated first. Exclusion criteria are a lack of practical and content-related relevance as well as a too vague description. Based on these elimination criterions, 10 potential patterns are excluded from further analysis. To eliminate redundancies, similar potential patterns are bundled into clusters with the help of a design structure matrix (DSM) (see Lindemann, Maurer, & Braun, 2009). The underlying question is whether the compared potential patterns have a high degree of



FIGURE 10 Cyclical procedure for the creation of a catalogue with principles for the development of digital platforms; figure according to Echterfeld (2020) [Colour figure can be viewed at wileyonlinelibrary.com]

FIGURE 11 Design fields for developing digital platforms [Colour figure can be viewed at wileyonlinelibrary.com]

Acquisition of participants	Platform Infrastructure	Further participants of the ecosystem
Describes the measures of convincing producers and consumers to participate in a platform.	Contains all necessary tools to enable high quality and individual- ized transactions on the platform.	Describes which functions the provider outsources to partici- pants of the ecosystem and for which he himself is responsible.
Transactional anatomy The design of the transactional anatomy describes the way information, value units and compensations are exchanged on the platform.	Monetization In order to ensure long-term competitiveness, it is necessary to determine how activities on the platform can be monetized as part of the platform develop- mont process	Value unit The purpose of each trans- action is the exchange of a value unit. The design of this value unit is to be carried out while establishing the platform.

No.	Design Field	Name	Description	Source
1	Acquisition of participants	Certainty due to investment made in ad- vance	If a provider makes major investments prior to the platform launch, the producers are assured that participation in the platform is secure (e.g. Microsoft regarding Xbox).	[Moazed & Johnson 2016, P. 196]
2	Acquisition of participants	Cooperation with establis- hed companies	Instead of building a platform themselves, companies can join forces and use existing structures to promote the expansion of a platform (e.g. Google regarding Android).	[Moazed & Johnson 2016, P. 196f.]
3	Acquisition of participants	Act as a pro- ducer	Platform providers can themselves act as producers on their platform in order to convince first custom	[Moazed & Johnson 2016

FIGURE 12 Collection of potential platform patterns (excerpt) [Colour figure can be viewed at wileyonlinelibrary.com]

overlap. This analysis step leads to the formation of content homogeneous clusters, which are called platform patterns. With the help of the DSM, the remaining 69 potential patterns are bundled into 37 clusters. Each cluster corresponds to an actual pattern for the development a digital platform.

5.4 | Documentation of the platform patterns

Finally, the patterns are documented and transferred to a structured catalogue. The catalogue simplifies the selection of suitable patterns. The documentation enables a presentation of characteristic features, which form the basis for the externalization of the identified patterns. The notation scheme required for this is based on Alexander (1979). A documented principle consists of five elements: name (including the associated design field), classification, visualization, description and example. The name and the associated design field can be taken from the previous steps. A theoretical characterization of the pattern is given in the description. The example underlines the practical relevance and supports the application. In addition, the patterns are integrated into the process of developing a digital platform to provide users with an orientation guide. The process will be described in detail within Section 6. Figure 13 shows an example of a platform pattern. The patterns are documented in a card format to ensure their applicability in workshops (Gausemeier et al., 2017).

The patterns are structured according to the addressed design field and transferred to a catalogue (see Figure 14). The catalogue is of superordinate nature and can be used independently from the underlying task. Furthermore, new patterns can be added as soon as they are identified, making the catalogue a growing source of knowledge.

6 | METHODOLOGY FOR PATTERN-BASED DEVELOPMENT OF DIGITAL PLATFORMS

The pattern-based development of digital platforms follows a process consisting of three phases. The first phase is the ideation of ideas for a digital platform, the second phase is the conception of abstract platforms and the third phase is the development of a specific digital platform. The basic principle is shown in Figure 15. The different phases of the pattern-based development of digital platforms are explained below. This process must be conducted every time a new platform is initiated.

6.1 | Platform ideation

The developed patterns can be used as a creativity technique to generate new ideas for digital platforms. As stated by Csik, patterns have







FIGURE 14 Catalogue of consisting patterns with design field participant acquisition in front [Colour figure can be viewed at wileyonlinelibrary.com]

a positive effect on the results of creativity processes. The effect is based on the fact that patterns cause certain stimuli that promote creativity (Csik, 2014). We used our framework within various workshops and validated its applicability to generate new ideas for digital platforms. The validation was carried out as part of a project to initiate a digital within the manufacturing industry. We conducted workshops to generate ideas for such a platform. We found that the participants of the workshop understood the new concept of digital platforms much faster and easier than in workshops with a similar task but without using patterns. Moreover, the participants were enthusiastic



about the task and developed quite radical new ideas. The ideas were generated with 38 participants from research institutes and employees of machine learning companies. The participants used the platform patterns to directly generate ideas (see Figure 16). The patterns were randomly selected from the pattern catalogue in order to determine the greatest possible heterogeneity between the generated ideas.

The participants developed the idea of an artificial intelligence (AI) marketplace in the manufacturing industry. Within this industry, product innovations are crucial for business success. Although product development is a key to success, it is clear that the potential of digitization is far from being exhausted. The path from an initial product idea to the finished product requires the combined expertise of various disciplines along the product development process. Here, there are numerous potentials for the application of AI, for example, to improve quality, efficiency or the use of resources in product development. There are many examples of failed product developments. AI can help to better assess consumer needs and avoid expensive failures. To successfully bridge the gap between product development and AI, users from product development must meet with solution producers and AI experts and work together on new solutions. Against this background, the workshop participants developed an idea for a digital marketplace for AI applications in product development. The idea and its advantages as well as its challenges are depicted in Figure 17. Moreover, the receptiveness for digital platforms of the manufacturing branch and the protection of the branch are part of the idea profile. The profile results in a platformization mission, which states that a concept for an AI marketplace for product development should be elaborated.

Once the platformization mission is defined, an abstract concept needs to be developed. The following section shows how the patterns can be used to design such a concept.

6.2 | Platform conception

In the second phase, a platform concept is developed. The concept is based on the determined platformization mission. A superordinate process is used as an orientation framework for the development. The process must be conducted every time a new platform is initiated. It is based on the six design fields of digital platforms and systematizes the application of platform patterns. The starting point of the



FIGURE 16 Pattern confrontation to generate ideas for a digital marketplace. Al, artificial intelligence [Colour figure can be viewed at wileyonlinelibrary.com]

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development process is the key interaction as the platforms central promise of value. The key interaction is based on an exchange of value units between producers and consumers (see Figure 2). Besides the value unit and the platform participants, the anatomy of transaction is part of the key interaction. To determine a suitable anatomy of transaction, the exchange of information, value units and payments is worked out. After designing the key interaction, a developing company devotes itself to the mechanisms that enable key interactions between producers and consumers. Corresponding functions are grouped together in the platform infrastructure. Subsequently, the design of the monetarization of the platform is carried out with the

objective of ensuring the long-term viability of the platform. For this purpose, parts of the created values must be retained by the owner of the platform. The process ends with the decision as to how openly the platform owner will position the platform for further ecosystem participants. This sequence of a digital platform is shown in Figure 18. It is oriented towards key interaction and describes a platform development directed from the inside to the outside (Choudary, 2015).

The presented sequence enables companies to decide in which order they should implement the platform patterns. Each design field is characterized by guiding questions that help to decide which patterns are applicable for any given situation. The patterns are used to



FIGURE 18 Sequence of applying the platform patterns in accordance with Choudary (2015) [Colour figure can be viewed at wileyonlinelibrary.com]

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formulate a promising vision for a digital platform and to define the actual platform concept based on the patterns.

The presented process allows companies to decide in which order they should apply the principles. Each design field is characterized by guiding questions that help to decide which patterns are applicable for any given situation. For the acquisition of participants, for example, it has to be answered who the producer is and with what motivation he should join the platform or how the critical mass of participants should be reached in order to benefit from positive network effects. The pattern-based elaboration of each design field takes place in three steps. A distinction is made between an abstract and a specific area. The specific area describes the concrete view of a com-



FIGURE 20 Abstract concept for an artificial intelligence marketplace for product development [Colour figure can be viewed at wileyonlinelibrary.com]



FIGURE 21 Specific concept for an artificial intelligence (AI) marketplace for product development [Colour figure can be viewed at wileyonlinelibrary.com]

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pany that wants to realize a platform idea. The abstract area contains the generalization in the form of principles. The starting point is a specific idea for a platform (e.g. the AI marketplace for product development). First, the value unit is designed. For this purpose, the value unit to be offered is described using abstract platform patterns. An exemplary value unit could be physical goods (Pattern 1.3). Then an abstract subconcept is developed for the design field, which can contain several patterns, for example, a combination of physical goods and standardized services (Patterns 1.3 and 1.4). Finally, a specific subconcept is developed, for example, the sale of special machinery (physical goods) and accompanying AI services (standardized services) via the AI marketplace. The process is carried out for each design field and is shown in Figure 19.

By elaboration of each design field, an abstract concept is being developed. In the following, the abstract concept for the AI marketplace will be described. The AI marketplace connects producers of AI applications for the product development with manufacturing companies. For example, manufacturing companies can have existing design drawings optimized using an AI application (e.g. in terms of material consumption or stiffness). Virtual goods (AI applications) and standardized services (AI consulting) are the value provided by the marketplace (Level 1). The platform starts in a small region of Germany and uses an existing innovation ecosystem. The pattern micromarket was therefore used to attract initial participants. Further on, the patterns marketing push and acquiring participants were used to attract platform participants from whole Germany (Level 2). Producers of AI applications and manufacturing companies were already in contact before the AI marketplace came into existence. The AI marketplace should establish itself between these actors by facilitating exchanges and offering complementary value units. For the transaction anatomy (Level 3), the pattern complete ownership is used. Value unit, information and monetary consideration should be handled via the marketplace. Editorial curating and active filters are used for the platform infrastructure (Level 4). The AI marketplace charges transaction fees for the procurement of AI applications. In addition, a listing fee is charged for selected advertisements, and highlighting of offers is made possible in order to generate further revenues (Level 5). The AI marketplace is open for further owners, which will mostly be from the leading edge innovation ecosystem it's OWL. Therefore, the pattern ownership structure is used (Level 6). The resulting abstract concept for the AI marketplace is shown in Figure 20.

6.3 | Platform development

Once all design fields have been characterized and an abstract concept has been defined, a holistic concept for a specific digital platform can be worked out. To this end, the selected patterns are brought together, avoiding the combination of contradictory patterns and encouraging the selection of patterns that are favourable to each other. The resulting set corresponds to the core of the platform concept. Further elements of the concept are the defined key interaction, as well as an initial role concept (see Figure 2). The specific platform concept for the AI marketplace is shown in Figure 21. It contains a vision for the AI marketplace and its functionality. Moreover, the roles within the platform as well as the key interaction are part of the specific concept. Provides of AI solutions offer their services to manufacturing companies. These companies compensate the providers of AI solutions by payment and usage data. The last part of the specific concept includes the development strategy, which is based on the chosen patterns within the abstract concept.

7 | SUMMARY AND OUTLOOK

Nowadays, companies of the manufacturing industry have to face the challenges of the evolving platform economy. These platforms have been reshaping the structure of whole industries. Leading companies are stepping out of their core business and develop their own platforms. While the awareness of the economic potential of the platform model is growing, many established companies have considerable difficulties mastering the challenges of establishing own platforms. One of the main reasons is that the development of digital platforms exceeds the know-how of most of the manufacturing companies.

We introduced a methodology for the pattern-based development of digital platforms. Patterns represent proven principals and can thereby provide valuable know-how and reduce the risks of developing a platform. We identified 37 patterns and structured them in a catalogue, which makes the patterns useable. To do so, we provide a process model containing guiding questions that need to be answered to establish a digital platform. The patterns are a growing knowledge base and can be extended by new patterns once they are found. Moreover, we found several theoretic findings during our research: for example, (1) platform categories are often taken up in the scientific discussion, but a uniform differentiation does not exist yet; (2) besides technical knowledge gaps, companies often do not know how to earn money with platforms; and (3) the manufacturing industry is particularly concerned about the loss of consumer access due to digital platforms.

However, additional research is necessary to decide which companies should develop their own platform and which companies should join already existing platforms. Even though that first frameworks for platform business models exist, further research is needed in this field to help companies to monetarize their own platforms. Our patterns are a first step in this direction. Last but not least, the existing catalogue needs to be used in further projects to expand the already existing knowledge base.

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