Identifying Fields of Action for the Design of Circular Platform-based Business Models in the Manufacturing Industry Based on Phenotypes

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***Abstract*—Making the transition to sustainability is an important goal for companies. Sustainability has become increasingly critical for organizations to remain relevant and competitive in today's world. Much like digital transformation, driving sustainability requires organizations to transform every division of their business. Circular economy, in the form of cross-life cycle management of products and the closing of material flows, is the central instrument for manufacturing companies to implement sustainability economically. The complexity and interdependencies of circular economy mean that often no single company can implement it on its own. Ecosystem-wide orchestration beyond traditional company boundaries is necessary. In these circular business ecosystems, technical-economic platforms are the main reference point of value creation. To implement circular value creation on the organizational level, business models are a leverage. In recent years, a new method has been adopted by companies in the manufacturing sector as a means to introduce circular economy in the value chain. This method consists mainly of the adaptation of a circular platform-based business models. However, as there is a lack of a systematic theoretical frame of reference, companies are missing fields of action to reliably derive appropriate design approaches. A systematization based on phenotypes is needed to make relevant design knowledge accessible to companies and research. The following research approach is devoted to a systemization of the research field in question in order to enable further research initiatives and to support companies to develop circular platform-based business models.**

***Keywords*—sustainability, circular economy, circular strategies, business model, business ecosystem, structured literature research, taxonomy**

I. Introduction

Sustainability and digitalization mark megatrends and play a major role in today's business environment (Schuh & Dölle, 2021). The increasing signs of climate change, growing competition for scarce natural resources and an environmentally conscious society increase the pressure on companies to develop new products taking into account environmental, economic and social sustainability aspects. According to Scholz (2018), the development of sustainable products will be an essential prerequisite for a company to maintain its competitiveness in the future. National and international legislation requires companies to take responsibility for the entire product life cycle. For example, action plans like the European Green Deal (European Commission, 2020) embody legislative pressure. New opportunities for companies are also emerging to differentiate themselves from competition through sustainable product and process innovation (European Commission, 2023). This is to be understood as an expression of the need for concepts in innovation management, business development and engineering that systematically link companies and their value creation processes with their ecological and social environment in a success-oriented manner.

At the same time, digitalization is changing the macro-environment of manufacturing companies. It is primarily driven by the increasing networking of people, machines, products and the resulting data. There is increasing discussion regarding the interplay between sustainability and digitalization. Current research has shown that the combination of these two megatrends harbours enormous potential for sustainable corporate success (Oberländer *et al.*, 2023).

The principle of circular economy, in form of cross-life cycle management of products and closing of material flows, is the central instrument for manufacturing companies to operationalize sustainability economically (Schuh *et al.*, 2023). In order to operationalize a specific strategy, research approaches interpret the business model concept as the central design element of companies (Zott & Amit, 2010). Taking into account concrete demands for intensified research approaches the first goal of this research approach is to understand the implications of the phenomena of circular economy for the design of business models for manufacturing companies (Research Question (RQ)1: "What implications of the circular economy can be identified for the design of business models in the manufacturing industry?").

Since complex problems have to be solved in different life cycle phases for the circular management of products and extended competencies are required, value creation in circular economy no longer takes place exclusively within the traditional boundaries of the firm (Fontell *et al.*, 2017). Instead, value creation, in accordance with the pursuit of a circular product strategy, is situated in business ecosystems. These ecosystems are to be understood as networks in which several companies interact with each other to jointly provide a product or service that each company could not offer on its own (Tiwana, 2014). This phenomenon also implies a structural transformation. Classic and linear value creation processes are split off and replaced by network-like structures for collaborative value creation. These value creation processes mostly take place within ecosystems and via platforms. In this context, a platform serves as an intermediary to enable and facilitate the exchange or transaction of various services between different actors (Tiwana, 2014).

The transition to circular economy is in its early stages. In the course of circular economy, new products, value chains and platforms will emerge in all areas of life and business (Kanda *et al.*, 2022). Current research approaches agree that the transition to circular value systems often requires new types of skills (Parida *et al.*, 2019). Industry and academia must therefore continuously adapt methods, approaches, and structures to succeed in the age of sustainability transformation.

Business success depends on the ability to respond appropriately to changing conditions (Gimpel *et al.*, 2018). Although circular value creation logic is well known in both science and practice, it is not very conceptualized (Kirchherr *et al.*, 2017). For example, no design principles and blueprints can be identified that can enable the development of circular platform-based business models.

Classical approaches to business model development have so far not been geared to network-like forms of value creation and in most cases exclusively address economic target variables, without considering circular economy oriented targets. Consequently, the introduction of circular economy design principles into the development of business models in the manufacturing industry requires novel ways of aligning management, organization and value creating systems. A key factor is the use of engineering, information systems, business management and sustainability-oriented perspectives. In doing so, this approach addresses the second overarching research target, to develop a holistic, framework for the design of circular platform-based business models (RQ2: "How to develop a holistic framework for the design of platform-based business models for the circular economy?").

In order to answer the two research questions, this research approach first considers the theoretical background of sustainability, circular economy, business ecosystems, platforms and business model research. Building on this, the influence of circular economy on the design of platform-based business models is examined. Finally, the results of the associated systematic literature research are structured in a condensed conceptual taxonomy of circular platform-based business model. In addition, a brief description of corresponding dimensions and characteristics enables the derivation of fields of action for the design of phenotypes.

II. Theoretical Background

A. Sustainability

The concept of sustainable development was first addressed by the Brundtland Report. The Brundtland Commission's (1987) definition of sustainable development links two main perspectives, namely the intra- and intergenerational approaches to sustainability. These perspectives demand that the satisfaction of needs of present and future generations must be taken into account as equal weights in decisions-making on economic activities. Three general goals of sustainable development can be mentioned: securing human existence, preservation of the social production potential and preservation of the possibilities for development and action (Michelsen *et al.*, 2014).

Building on these principles, three key dimensions of sustainability can be identified. These are referred to as the "triple bottom line" (Potting *et al.*, 2017) and are classified into the ecological-, social- and economic dimension. The ecological dimension of sustainability characterises a biological ecosystem where humans depend on the functioning of the ecosystem and have access to natural capital to satisfy their needs. Natural resources may only be used without restricting future generations in the fulfilment of their needs (Zimmermann, 2016). The social dimension considers the role of social structure and human action in relation to the goal of sustainable development. The economic dimension of sustainability relates to economic activities. These economic activities should satisfy the needs of current generations and should not run counter to the interests and resource base of future generations (Morelli, 2011).

Sustainability is increasingly becoming a central issue in today's business environment, especially in the manufacturing industry. In view to the manufacturing sector this includes the pursuit of a circular economy (Kirchherr *et al.*, 2017).

B. Circular Economy

According to Ellen MacArthur Foundation (2013), circular economy can be understood as an industrial system characterized by a restorative and regenerative concept. The central goal of circular economy is to maintain products, components and materials at their highest use or value at all times, so that a minimization of resource use and generated waste is achieved. The essential means to achieve this are circular product strategies whose main benefit is to return products to the economic system for reuse at the end of their life (Geisendorf *et al.*, 2018).

A key concept of circular economy is the so-called systems perspective (Kirchherr *et al.*, 2017). This perspective describes the transformation to circular economy at three system levels. The micro level focuses on the individual company and the circular design of products and services. The meso level focuses on the role of so-called eco-industrial parks (UNIDO, 2023) as associations of several companies to jointly achieve more sustainable production. The aspect of cross-company cooperation to achieve circular economy is expanded by the macro perspective. This perspective considers entire industrial and cross-industrial composition and structure of systems (Kirchherr *et al.*, 2017).

Circular strategies are another key element of circular economy. These strategies are usually referred to as "R-strategies" (Kirchherr *et al.*, 2017). R-strategies aim at reducing the consumption of natural resources and minimizing negative environmental impacts. They can be considered as a basis for designing measures for slowing down, closing and narrowing technical, material cycles (Mast *et al.*, 2022).

In literature, different frameworks for the representation of R-strategies can be identified, which differ in the number of strategies considered. In the context of this research approach, a holistic coverage of existing R-strategies is focused. The analysis is therefore based on the highly subdivided “9R framework” according to Potting *et al.* (2017).

R-strategies can be arranged hierarchically depending on their degree of circularity. According to Potting *et al.* (2017), a higher degree of circularity implies that materials can be kept in circulation for a longer period of time and, after disposal, are reused if possible while retaining their original quality. As a result, fewer primary materials are needed to manufacture new products. R-strategies can be divided based on three guiding principles (Potting *et al.*, 2017).

The first and highest priority principle is to improve product use and manufacture. Products are to be saved or their use or manufacture should be designed more thoughtful. Strategies for realizing this principle contribute to the narrowing of resource flows by reducing the amount of raw materials required per product produced (Hoerborn *et al.*, 2022; Mast *et al.*, 2022). For example, minimizing resource requirements can be achieved by providing functionalities of individual products through other products or services, thus making certain products superfluous (Refuse-strategy). Another strategy is to increase the intensity of use of products. For example, several users can be granted access to a product so that its use is intensified. The usage scenario of the product is reconsidered in this way (Rethink-strategy). Resource savings can also be achieved by increasing the efficiency of product manufacturing processes through appropriate product design (Reduce-strategy) (Mast *et al.*, 2022).

The second guiding principle describes the extension of product life. This principle calls for individual products and their components to be used longer, achieving the slowing down of resource flows (Kirchherr *et al.*, 2017). The service life of a product can be extended by reusing the same product in its original function by another user without any adaptation (Reuse-strategy). If the product is in a defective condition, repair or maintenance must be carried out so that the product can continue to be used in its original function (Repair & Maintenance-strategy). In contrast to pure repair and maintenance, the so-called “refurbishment” of a product restores an outdated product, so that all critical product components are checked, repaired and, if necessary, replaced. “Refurbishment” achieves a higher quality of the product, which can ensure a higher warranty for the product (Refurbishment-strategy). Finally, “remanufacturing” can be seen as a process in which the components of an obsolete product are refurbished to such an extent, that the refurbished object achieves the quality of a new product and thereby exceeds the value of the original product (Remanufacturing-strategy). This upgrade circular economy established itself as the role model in the manufacturing industry (Schuh *et al.*, 2023 (b)). In contrast to these measures, the strategy of “repurposing” describes the integration of old products or its components into a new product with modified functionality (Repurpose-strategy).

The last guiding principle relates to the recycling of materials from products that can no longer be used. The goal is to recover raw materials or energy from these products (Recycling-strategy) (Mast *et al.*, 2022). The strategy of “Recovering” describes the energy recovery of materials and is applied when recycling is not economically or technically feasible (Recover-strategy).

Value creation in the context of the sustainability transition and consequently the implementation of the mentioned R-strategies, mostly takes place outside the traditional boundaries of the firm in business ecosystems (Kanda *et al.*, 2021). This systems perspective is briefly explained in the following.

C. Business Ecosystems

The basis for realizing a circular economy is cross-company and cross-industry collaborative value creation. “Value creation is not simply [monolithic or] dyadic; Instead, broader groups of [actors] shape value creation [in ecosystems]” (Tiwana, 2014). Current developments in the research area of circular economy in the manufacturing industry tend to focus less on value creation mechanisms along the classic, rigid value chain and increasingly refer to open networks with a focus on integration and collaboration. Within such business ecosystems the development of economic value has evolved from individual value creation within companies, to increasing partner involvement in the development process, to co-creation (Reichwald & Piller, 2014) of value in complex systems. Value creation is interpreted in this context as a collective activity of collaborating actors with the intention of creating new or improved value propositions for customers (Hoeborn *et al.*, 2022). Issues in the context of circular economy are usually so complex that they cannot be solved by a single company and its resource base alone (Mast *et al.*, 2022). In the context of circular value creation, for example, issues arise in the area of re-logistics or the processing of products. The classic “Business-to-Business (B2B)” or “Business-to-Customer (B2C)” perspective is evolving into an “Actor-to-Actor” perspective, from a company centric pipeline logic to an open platform design. It requires an ecosystem of partners, complementors (Brandenburger *et al.*, 1996) and suppliers to provide needed resources. As introduced by Brandenbueger *et al.* (1996) in addition to this vertical and horizontal integration of value chains, the phenomenon of coopetition emerges. Coopetition refers to a competitive structure characterized by both competitive influences and cooperative sequences with external actors. Creating value is a cooperative process. In contrast, value extraction and appropriation is characterized by competitive characteristics. Within this form of economic organization, platforms serve as intermediaries and orchestrators between organizations. The platform concept is briefly explained in the following.

D. Platforms

The term platform describes an infrastructure that acts as an intermediary to facilitate the exchange and transactions of various services between different actors and serves as a basis on which other companies develop complementary technologies, products or services. In the context of business ecosystems, Tiwana (2014) defines the function of a platform as a “blueprint that describes how the ecosystem is partitioned into a relatively stable platform and complementary set of [applications] that are encouraged to vary, and the design rules binding both”. Platforms create connections between individuals and organizations that share a common goal, or want to share a resource. Although platforms are an omnipresent phenomenon within modern industry structures, interpretations in publications diverge considerably. Consequently, a consensual definition is needed to ensure a uniform understanding for the following course of investigation.

Baldwin & Woodard (2008) define platforms as "a set of stable components that support a variety and evolvability in a system by constraining the linkage among the other components". This is extended by Constantinides *et al.* (2018), according to whom a platform represents "a set of digital resources-including services and content-that enable value creating interactions between external producers and consumers". Three main functionalities of a platform within ecosystems can be stated: providing interaction interfaces, value creation and network building. Platforms combine these functionalities and develop new principles of merging supply and demand. A platform can be understood as a set of generic components from which a stream of derivative products are created and published. Around this collection of standard components buyers and sellers coordinate themselves. Platforms often follow the design approaches of a marketplace and are to be considered in the regularities of a multi-sided market (Ewans & Gawer, 2020). According to Armstrong (2006), a multi-sided market involves two or more interest groups interacting through an intermediary, in this case the platform. Bringing together this market-based and technology-based operating principles, the platform emerges as a source of economies of scale and scope and as an enabler of substitution economies.

In view to the objective of integrating circular economy into the business activities of manufacturing companies a platform serves as a tool support and technological infrastructure for business models in order to implement the required system perspective and collaboration in ecosystems (Riesener *et al.*, 2024). In the following, the business model as a central element of the industry economic integration of circular economy into value creation principles of the manufacturing sector is explained in more detail.

E. Business Model

According to Osterwalder (2004), a business model can be understood as an instrument to describe the logic of value creation within a company. The business model consists of individual elements with relationships to each other. By describing these elements and their relationships, it is possible to capture the value creation mechanisms of a company.

Chesbrough and Rosenbloom (2002) describe the business model acting as an intermediary between technological input and economic output. In order for technological developments to be successfully transformed into economic output a company's business model must be suitably designed. In accordance, Gassmann (2013) emphasizes the importance of the business model for innovation capability for the long-term success of a company. Through innovations in various dimensions of the business model, new value creation potentials can be developed. Gassmann's approach emphasizes the need to question and continuously improve traditional business models in order to keep pace with constantly changing market conditions. In an integrative approach, Wirtz (2020) understands the concept of a business model to be the description of the mechanisms for creating value in the form of products, services or information. The overarching goal of the business model is to generate and maintain the profitability of the company.

In a consensual definition, the business model can therefore be understood as a model representation of the logical relationships between the implementation of a business strategy and the generation of added value for customers.

In view to the pursuit of circular economy within the manufacturing industry, business model issues not only relate to value chain relationships (Peppard & Rylander, 2006), but also highlight the need for alignment of interests and incentives between ecosystem actors (Parida *et al.*, 2015). Circular business models require manufactures to collaborate with service partners, third-party suppliers, customers and even other providers to profitably deliver circular value propositions (Parida *et al.*, 2019). Traditional industrial value chains incentivize players to achieve cost advantages through economies of scale. Current sustainable solutions often still have lower margins or fail, as their markets are too small (Lüdeke-Freund *et al.*, 2019). According to the Platform Industry 4.0 initiative (2022), business models based on platforms can counteract this phenomenon. They bundle providers, foster visibility and match demand requirements with supply. Platforms are therefore be seen as enablers of sustainability and circular economy in the manufacturing industry (e.g. Kanda *et al.*, 2021).

F. Interim Conclusion & Research Deficit

However, as shown, there is little conceptual guidance on which design principles and options manufacturing companies have to anchor circularity in their business model. To organize and guide entrepreneurial decisions, an appropriate ontology is required. Various research contributions have already applied taxonomies to structure emerging, fragmented research fields especially in business model research e.g. Täuscher & Laudien, 2018, Möller *et al.*, 2020 and Geske *et al.*, 2021. Recent research approaches have developed taxonomies for domain-specific business models in context of the circular economy, e.g. for business models in the plastics industry (Dijkstra *et al.*, 2020), building and construction industry (Nußholz *et al.*, 2020) or start-up business models in the field of reverse logistics (Mallick *et al.*, 2024). These taxonomies are either too general or too specific from the perspective of circular platform-based business models for the manufacturing industry. In particular, there is no integration of fundamental principles of circular economy. Especially the system perspective, which is essential in the context of circular economy, is not sufficiently taken into account. In particular, there is insufficient consideration of the role of business ecosystems and platforms. Existing approaches tend to argue from a single-view and specific use case perspective. This industry and domain focus makes it difficult to transfer and derive generally applicable design principles for manufacturing industry. The goal of this research approach is to provide an expanded, application-oriented conceptual framework for circular platform-based business models and to deliver an approach to systematize the research area.

III. Research Design

The motivation presented above and the resulting goal of this research approach focus on the need to solve a real-world problem to enable the development of practical knowledge for designing new approaches. Fig. 1 shows the underlying course of the investigation. Within this approach, a Systematic Literature Research (SLR) allows to pre-structure the research area (left part of the figure) before the application of a taxonomic analysis (middle part of the figure) reveals new insights regarding the implications of circular economy for the design of platform-based business models in the manufacturing industry. Fields of action for the design of corresponding business models can be identified using phenotypes based on basis of these preliminary steps (right part of the figure).

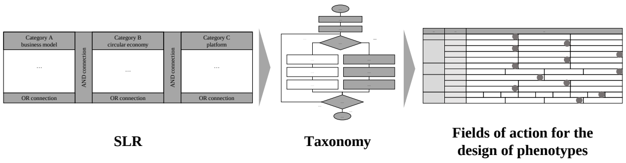

Fig. 1. Structure of the research approach.

A. Systematic Literature Research

The unclear characterization of circular platform-based business models limits the comparability and referenceability of future research. For analyzing and developing this missing link, this research approach employs the established guidelines, proposed by Webstar & Watson (2002) to conduct a SLR. The focus is on business model literature with special reference to circular economy in the manufacturing industry and in business ecosystems. In accordance with Riesener *et al.*'s (2023 (b)) approach, a strategy for searching extant literature and a set of study selection criteria was developed and a scheme for documenting, processing and analyzing selected studies was designed. To ensure that the literature relevant to the research approach was covered as comprehensively as possible, the literature analysis was systematized in both steps according to Webster and Watsons's (2002) approach, so that forward and backward-searching methods were applied (see Fig. 2). Figure 2 illustrates this methodology, which is based on steps defining of search categories, select database, define search string, identification of contributions, analysis of contributions.

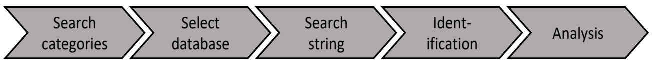

Fig. 2. Flow chart of the conducted SLR.

In order to pre-structure the research area, first the keywords "business model" AND "circular economy" AND "platform", as overarching keywords which are derived from the research questions, as well as associated synonyms and various combinations of terms ("categories" in Fig. 2), were used to search manually leading Information Systems research (IS) journals (e.g. the journals included in the "AIS Senior Scholars' Basket of Eight) and IS conference proceedings (ICIS and ECIS). Second, similar searches were carried out in popular databases (ScienceDirect and WebOfScience) to enrich the manual search by further sources, focusing on the manufacturing industry. Fig. 3 shows this methodical step of investigation. Category A contains keywords for the research area business models. Synonyms within this category are connected via an OR link. Category B focuses on aspects of circular economy. Category C involves aspects of platforms. Synonyms are also connected via an or link. The categories among each other follow an AND link.

The title and abstract were each examined for relevance and conformity with the research objective. In order to examine driving forces and phenomena at the corporate level, the first step is to take a closer look at the overall network of production and distribution relationships, the characteristic macro environment, as well as horizontal and vertical dependencies. Examining these elements helps to understand companies more precisely in their situational environment.

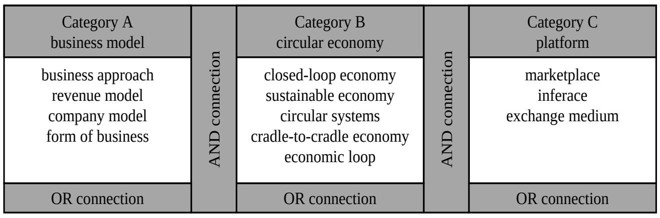

Fig. 3. Summary of keywords for SLR.

B. Taxonomy

In the sense of the multidisciplinary and multidimensional research approach the next step of the investigation is found in a systematization of the field of action, connected with the identification of investigation artifacts.

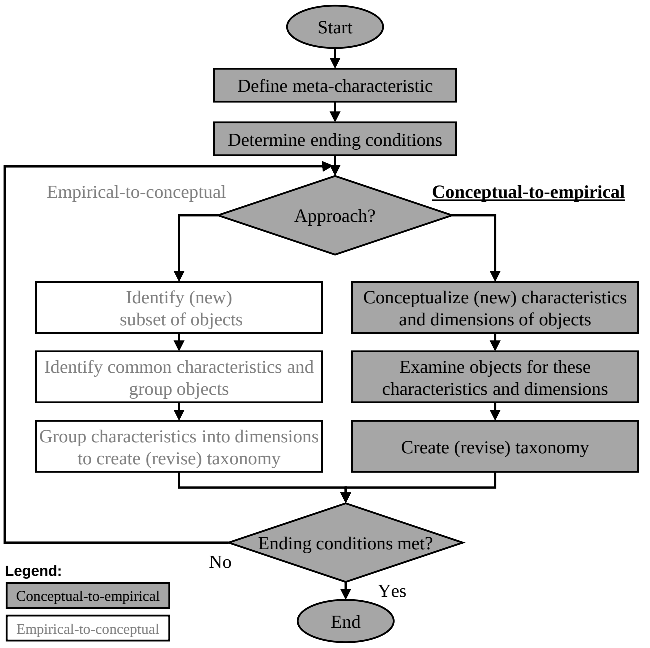

Fig. 4. Taxonomy development according to Nickerson *et al.* (2013).

The goal of this step is to develop a topology of the scientific landscape. Thus, the elaboration uses a bibliometric analysis to create a bibliometric network (Zupic & Čater, 2013). For this a "co-word analysis technique" (Callon *et al.*, 1991) was conducted. Afterwards, a cluster analysis (van Eck & Waltman, 2010) was executed. Then the tool VOSviewer was used (Van Eck & Waltman, 2010), which is the most widely used information visualization software to select the top most keywords used by authors in their papers. To analyze the identified contributions, Nickerson *et al.*'s (2013) method for taxonomy development was employed (see Fig. 4). Taxonomic analysis begins with the establishment and definition of meta-characteristics of the object of study. These meta-characteristics represent the central comprehensive features of the object of study and act as a reference point for developing further resulting characteristics. Exemplarily, their choice can be based on central theories. The meta-dimensions of value proposition, value delivery, value creation and value skimming were initially selected in accordance with the research approaches by Osterwalder *et al.* (2002) and Gassmann *et al.* (2014). In addition to these basic business model levels, platform architecture was added as another meta-dimension, in accordance with the research approach by Twiana (2014) and Riesener *et al.* (2023 (b)). Building on these Meta-Dimensions (MD), further Dimensions (D) and Characteristics (C) are identified and grouped. Since the method is characterized by an iterative approach, ending conditions have to be defined. From an objective point of view, the investigation is to be terminated if no new features or dimensions have been added, split, or merged during the last iteration and each dimension and feature is unique. Subjective ending conditions are found in the conciseness and completeness. The actual development of the taxonomy is either through an "empirical-to-conceptual approach", "conceptual-to-empirical approach" or from a combination of both mechanisms. The method of procedure is to be chosen according to data availability and the objective of the analysis (Nickerson *et al.*, 2013).

Along its meta-theoretical approach and the representation of a research-in-progress issue, this elaboration exclusively follows the "conceptual-to-empirical" (highlighted in Fig. 4, grey boxes) method and builds on the results of the previous literature review. Going through the research approach iteratively leads to a first and a multitude of revised taxonomy proposals. The development process of the taxonomy is constantly continued until the ending conditions are reached.

Specifically, a first iteration was dedicated to the harmonization and synthesis of existing research approaches. The following iteration steps incorporated the findings of the elaboration on current developments in engineering, technology- and innovation management, in business model theory and sustainability research.

C. Extension of the Taxonomy towards Circular Economy

To further develop the taxonomy of platform-based business models for the conditions of circular economy, two additional iteration steps were carried out according to the "conceptual-to-empirical" approach. These iteration steps included the literature on the circular economy. In a first iteration step, central dimensions for circularity orientation (DC) and characteristics were derived. In order to holistically capture the conditions of circular business models, supplementary dimensions and characteristics had to be added, particularly within the MD of value offering and value creation. The second iteration step served to check and validate the supplemented dimensions and characteristics against the literature identified in the SLR. Analogous to the procedure for the development of the taxonomy for platform-based business models, the objective and subjective end conditions according to Nickerson *et al.* (2103) also had to be checked after each iteration step. The final presentation of the taxonomy takes the form of a creative heuristic representation based on the principle of the morphological box (Zwicky, 1962).

D. Identifying Fields of Action for the Derivation of Phenotypes

The derivation of fields of action for the design of phenotypes is based on a process and analytical structure in accordance with Zweifel *et al.* (2013). The process consists of the development of a taxonomy of platform-based business in the context of circular economy and the subsequent implementation of four framework principles. These are collecting, reviewing, investigating and documenting key findings. In the case of this research approach, inputs for these steps are the literature review, which is detailed in Section IV. A and the taxonomy, which is detailed in Section IV. B and IV. C. Following the approach by Van Der Pijl *et al.* (2016) and Hosseini (2018), effects in terms of changing, renewing, expanding, replacing and rebuilding are detailed by taking the fields derived in the literature review and applying them to the developed taxonomy. Building on this methodical approach, design options for phenotypes of circular platform-based business models in manufacturing industry can be identified. The overall methodological approach is shown in Fig. 5.

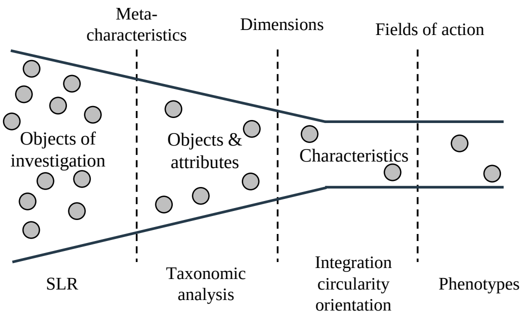

Fig. 5. Overall methodological approach.

IV. RESULTS

The following section presents the results of the research approach based on the methodology presented above. First the results of the SLR are introduced (Section A). Then, the dimensions and characteristics of a platform-based business model are presented in the form of a taxonomy (Section B). This taxonomy is extended by the identification of additional dimensions and characteristics according to the effects of the circular economy (Section C). The morphological representation consists of MDs, Ds and Cs. Elements of each aspect will be introduced in detail, starting with MDs. Finally, fields of action for the design of corresponding phenotypes of platform based business models for circular economy are identified (Section D).

A. SLR

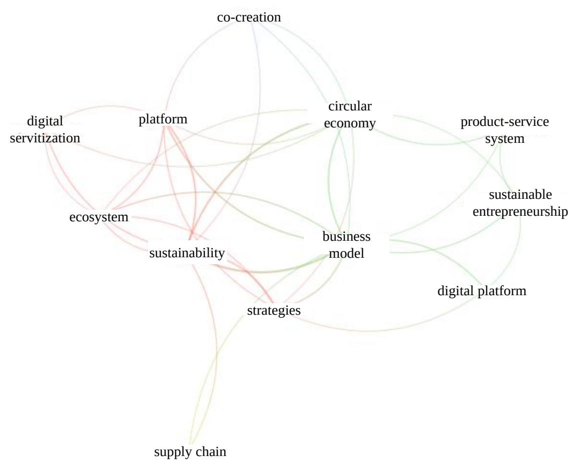

Fig. 6. SLR-Cluster analysis.

Fig. 6 shows the connected network of the most common keywords regarding the overarching keywords "business model", "circular economy" and "platform" in the database "ScienceDirect". 138 relevant contributions were identified.

Within the contributions, 12 relevant keywords were selected, according to their connection to the research questions. These keywords can be grouped into four clusters. The red cluster focuses on publications dealing with the introduction of sustainability in manufacturing firms, especially in the context of a strategically and ecosystem perspective. The papers associated with the green cluster include issues of the design principles of business models, especially in connection with the circular economy. The blue cluster aggregates publications dealing with co-creation as a principle for organizing economic activities. Lastly, the yellow cluster represents contributions considering supply chains. These clusters served as a starting point for the taxonomic analysis.

B. Taxonomy of Platform-based Business Models

In a first step, the dimensions and characteristics of platform-based business models are identified in the form of a taxonomy based on the conducted SLR (Table 1). In particular, the first iterations of the taxonomy development included publications of the clusters "design of business models" (green), "co-creation" (blue) and "supply chains" (yellow). The results are presented in the following.

Table 1. Taxonomy of platform-based business models

<table>
<tr><th>Metadimensions</th><th>Dimensions</th><th colspan="12">Characteristics</th></tr>
<tr><td>Value Proposition (MD1)</td><td>Core functionality (D11)</td><td colspan="4">product transaction</td><td colspan="4">service transaction</td><td colspan="4">product and service transaction</td></tr>
<tr><td rowspan="4">Value Delivery (MD2)</td><td>Customer segment (D21)</td><td colspan="4">company-specific</td><td colspan="4">industry-specific</td><td colspan="4">cross-industry</td></tr>
<tr><td>Channel (type) (D22)</td><td colspan="4">physical</td><td colspan="4">digital</td><td colspan="4">physical and digital</td></tr>
<tr><td>Channel (marketplace) (D23)</td><td colspan="4">internal marketplace</td><td colspan="4">external marketplace</td><td colspan="4">no marketplace</td></tr>
<tr><td>Customer relationship (D24)</td><td colspan="4">neutral</td><td colspan="4">cooperation</td><td colspan="4">collaboration</td></tr>
<tr><td rowspan="2">Architecture (MD3)</td><td>Openness (provider) (D31)</td><td colspan="4">open</td><td colspan="4">access requirements</td><td colspan="4">selection</td></tr>
<tr><td>Rating system (D32)</td><td colspan="3">by buyer</td><td colspan="3">mutual evaluation</td><td colspan="3">by platform</td><td colspan="3">no evaluation</td></tr>
<tr><td rowspan="3">Value Creation (MD4)</td><td>Key activity (D41)</td><td colspan="6">matching</td><td colspan="6">matching and additional services</td></tr>
<tr><td>Key resource (D42)</td><td colspan="4">tangible resources</td><td colspan="4">intangible resources</td><td colspan="4">multiple resources</td></tr>
<tr><td>Key partners (D43)</td><td colspan="4">infrastructure providers</td><td colspan="4">data analysts</td><td colspan="4">other/multiple partners</td></tr>
<tr><td rowspan="2">Value Skimming (MD5)</td><td>Revenue source (D51)</td><td>transaction</td><td>usage-oriented</td><td colspan="2">subscription</td><td>fixed price</td><td colspan="2">license</td><td>advertising</td><td colspan="2">additional services</td><td>freemium</td><td>multiple revenue sources</td></tr>
<tr><td>Revenue partner (D52)</td><td colspan="3">provider</td><td colspan="3">buyer</td><td colspan="3">third-party provider</td><td colspan="3">multiple revenue partners</td></tr>
</table>

The derived taxonomy consists of five MD: "value proposition", "value delivery", "platform architecture", "value creation" and "value skimming" and 19 derived dimensions, with a minimum of two and a maximum of nine characteristics. The 19 dimensions show the key characteristics of circular platform-based business models in the manufacturing industry. Along the bottom-up approach and incorporating the results of the previous approaches not every characteristic of the taxonomy is new to the existing research landscape.

Value Proposition (MD1)-The "value proposition" MD is the "starting point for any business model" (Bouwan *et al.*, 2018). The value proposition describes the benefits generated for actors within the platform. Platform-based business models are characterized by the fact that benefits for a large number of organizations that participate in the platform's services are created. To further specify the value generated by the platform, it is necessary to describe the core functionalities (D11) of a platform. Platforms can be differentiated for this purpose on the basis of their transaction content. Accordingly, "product transactions", which focus exclusively on the transfer of a physical product, "service transactions", which are based on the transfer of an intangible service or "product and service transactions", which contain a mixture of material an intangible transaction components, can be identified.

Value delivery (MD2)-This MD focuses on the market addressed by the platform. The customer segment (D21) represents the customers of a platform including all organizations participating in the platform. Platform-based business models can be offered either company-specific, with focus on one company only, "industry-specific", with a focus on one branch of the industry only, or "cross-industry", with focus across industry boundaries (Täuscher *et al.*, 2018; Hodapp *et al.*, 2019).

The dimension "channel (type)" (D22) is used to define whether the value proposition is delivered "physical", on the basis of a tangible pure product, "digital", as an intangible digital artefact, or "physical and digital", as a mixture of tangible and intangible components (Staub *et al.*, 2021).

The availability of a marketplace for exchanging physical or digital products and services within a platform is described by the "channel (marketplace)" (D23) dimension (Hodapp *et al.*, 2019). While an "internal marketplace" is integrated into the platform, an "external marketplace" relies on additional external infrastructure to support the exchange of products and/or services. Accordingly, the marketplace functionality is developed internally by the platform company. Alternatively, the platform company can only provide the infrastructure on which the marketplace is operated itself and the actual marketplace functionality must be supplemented by an external provider. In this case, the infrastructure would serve as a boundary resource (Ghazawneh & Henfridsson, 2010) for integrating the marketplace functionality.

The customer relationship (D24) dimension describes the relationship between the platform provider and the customer. The customer relationship in platforms that merely mediate between different user groups and no specific bond exists between platform providers and customers can be characterized as "neutral". In contrast, the customer relationship on platforms which orchestrate an ecosystem of different actors for collaborative value creation is categorized by the characteristic of "collaboration". The term "coopetition", characterized by Brandenburger and Nalebuff (1994), describes as a third possible customer relationship. This relationship is characterized by the simultaneous occurrence of cooperation and competition among the organizations of the platform.

Architecture (MD3)-Platform architecture describes the extent to which the regulatory framework and the technical structure of a platform allow organizations, solutions to be integrated into the platform and enable interactions between these objects. A central dimension is the "openness" (D31) of the platform. The openness of a platform can be controlled by the regulatory and legal framework (Täuscher *et al.*, 2021). In case, that actors are granted unrestricted access to the platform and participation in transactions is not subject to any restrictions, the platform is considered to be "open". Access to a platform can also be restricted by "access requirements" or a "selection" of actors made by the platform company (Wortmann *et al.*, 2019).

The platform architecture also includes a rating system (D32) that helps to create transparency about the quality of the products and services provided on the platform and to generate trust for the transaction between sellers and buyers. The evaluation can be carried out by the "buyers" or alternatively by the "platform provider", which can evaluate transactions based on previously defined criteria. The evaluation can be also based on a "mutual evaluation". There is also the possibility that the platform provides "no evaluation" (Täuscher *et al.*, 2018).

Value creation (MD4)-The key activity (D41) for value creation within a platform is the "matching" between supply and demand enabled by the platform. This matching function can be enhanced by additional services. Such services can be provided on the basis of transaction data and are intended to facilitate transactions (BDI, 2021). The key resources (D42) of a platform are the assets traded within the platform. Depending on whether it is a marketplace for physical products or digital services a distinction has to be made between "tangible resources" or "intangible resources". "Tangible and intangible resources" as a combination of tangible and intangible resources may also be required for value creation. A central key partner (D43) of platforms is the role of the "infrastructure provider", who provides the technical infrastructure required to operate the platform. Such infrastructure includes, for example, the software for managing the platform. One other key partner of a platform can be the role of "data analyst" who analyse the transaction data and enable additional services (BMWi, 2021). Lastly, the characteristic "other/multiple partners" describes the integration of multiple roles for value creation.

Value skimming (MD5)-The MD describes the mechanism of value absorption. The different revenue

generation models are described by the revenue source dimension (D51). A platform provider can either focus on a single revenue model or the use of multiple revenue sources. The revenue source of "transaction" describes that the platform provider charges percentage fees or alternatively a predefined fixed amount for each successful transaction and thereby generates revenue (Curtis *et al.*, 2020). Alternatively, revenues can be generated depending on the "usage" of a platform. An example for usage-based revenue generation are fees charged per request for a specific service (Hodapp *et al.*, 2019). The "subscription" revenue model describes that platform users have to make continuous payments to use the platform services. Alternative revenue sources are the sale of "licenses" to use a platform, the generation of revenue through "advertising" by third-party providers, or "fixed prices". In addition, the provider of a platform can sell "additional services" that go beyond the core functionalities of the platform. In the case where individual groups of actors are granted free use of the platform, in form of a free basic product or service as well as chargeable extensions, is referred to as a "freemium" model (Täuscher *et al.*, 2018).

Due to the fact that several actors participate in the platform, the revenue partners (D52) must also be described when examining value extraction. Within a platform, revenues can be generated by "providers", "buyers", "third-party providers" or by "multiple revenue partners".

C. Integration of Circular Economy Design Principles

In a further iteration step, the impact of the circular economy on the dimensions and characteristics of the platform-based business model was examined. The dimensions and characteristics of the original taxonomy were supplemented accordingly. These iteration steps include, in particular, publications from the "sustainability in manufacturing firms" (red) cluster. The results (see Table 2) are briefly presented in the following.

Value Proposition (MD1)-Within the MD value proposition, the dimension circular strategy (DC11) was added. By adding the dimension, strategies are described that can be pursued within an ecosystem to implement circular economy. Depending on the circular economy strategy pursued, the benefits for different actors within the platform system vary. The circular strategies are derived, based on a conducted literature review, in accordance with R-strategy frameworks by Lacy & Rutqvist (2015), Kirchherr *et al.* (2017), Geissdoerfer *et al.* (2018), Esposito *et al.* (2020) and Ellen Mac Arthur Foundation (2024). Business models for circular economy can implement one or several of these circular strategies. The arrangement of the circular strategies within the taxonomy is implemented on the guiding principle that the degree of circularity of the strategies decreases from left to right, so that the "Refuse" strategy has the highest degree of circularity and the "Recycle" strategy the lowest. The characteristics of the circular strategy dimension are briefly explained in the following.

Table 2. Taxonomy of circular platform-based business models

Metadimensions	Dimensions	Characteristics								
Value Proposition (MD1)	Circular strategy (DC11)	refuse	rethink	reduce	repair and maintain	reuse	recycle	several		
	Core functionality (D11)	product transaction	service transaction	product and service transaction						
Value Delivery (MD2)	Customer segment (D21)	company-specific	industry-specific	cross-industry						
	Channel (type) (D22)	physical	digital	physical and digital						
	Channel (marketplace) (D23)	internal marketplace	external marketplace	no marketplace						
	Channel (return) (DC21)	direct	indirect	direct and indirect	no return					
	Customer relationship (D24)	neutral	cooperation	collaboration						
Architecture (MD3)	Openness (provider) (D31)	open	access requirements	selection						
	Rating system (D32)	by buyer	mutual evaluation	by platform	no evaluation					
Value Creation (MD4)	Key activity (D41)	matching	matching and additional services							
	Key resource (D42)	tangible resources	intangible resources	multiple resources						
	Key partners (D43)	infrastructure providers	data analysts	other/multiple partners						
	Key activities (circular economy) (DC41)	virtualization/ dematerialization	increasing the intensity of use	increase the efficiency	repair and maintenance	return	remanufacturing	recycling	several	
	Key resource (circular economy) (DC42)	virtualized products and services	PSS	sharing products	efficiency-enhancing technologies	repaired and maintained products	remanufactured products	recycled products	multiple resources	
	Key partner (circular economy) (DC43)	repair and maintenance companies	return partners	remanufacturing companies	recycling companies	none	other/multiple partners			
Value Skimming (MD5)	Revenue source (D51)	transaction	usage-oriented	subscription	fixed price	license	advertising	additional services	freemium	multiple revenue sources
	Revenue partner (D52)	provider	buyer	third-party provider	multiple revenue partners					

The "refuse strategy" includes measures that help to avoid the use of physical materials. This can be achieved by either completely dispensing with certain products or providing functionalities of the products through other products or services (Potting *et al.*, 2017). The "rethink strategy" describes measures that increase the intensity of use of products by transforming the economy and changing consumer behaviour (Potting *et al.*, 2017). The "reduce strategy" describes the reduction in physical resources achieved by increasing efficiency in the production process or reducing material requirements. This strategy involves measures to optimize products and production processes as well as decisions to replace old technologies and materials with new technologies and materials to minimize resource requirements by increasing efficiency.

While the first three circular strategies contribute to the narrowing of resource flows, the "repair & maintain strategy" describes repair and maintenance services that contribute to an extended lifetime of products and promote the slowing down of resource flows (Potting *et al.*, 2017). For example this strategy can focus on a product-life-extension, emphasizing that repairs and maintenance contribute to extending product life and can thus save primary materials in the long term.

Another closing-the-loop strategy included is the "reuse strategy". This strategy describes measures in which individual or several products, product components or other materials are returned for reuse within the technical product cycles, so that this strategy also contributes to slowing down resource flows. This category includes both measures in which products are returned without further reprocessing operations ("direct reuse") and measures that require additional reprocessing or restoration services ("refurbishment", "remanufacture", "repurpose", "resynthesize").

The “recycling strategy” describes measures in which products and their components are recovered at the end of their service life in such a way that secondary materials or recycled substances, known as recyclates, can be recovered and be used to manufacture new products (Potting *et al.*, 2017). “Several” of the listed strategies can also be pursued simultaneously.

Value delivery (MD2)-Within the MD of value delivery, the dimension “channel (return)” (DC21) has been added in the course of analysing the influences of circular economy. This dimension describes the channels for the return of products, components and secondary raw materials. The channels can be “direct” and/or “indirect”. While direct channels describe the direct return of physical resources by the end-user, indirect channels require intermediate entities that mediate the return from the end-user to repair, remanufacturing or recycling complementors. Channels to return products, components and secondary raw materials are required to realize the “reuse” and “recycle” strategy (see DC1). Circular economy business models that do not require recycling of products, product components, or other physical resources, do not require a channel for return. Accordingly, the characteristic “no return” has been added to the taxonomy.

Architecture (MD3)–Within this MD no further dimensions and characteristics resulted from analysing the influences of circular economy. The literature analysis showed that especially the dimensions describing the openness of a platform are relevant for circular economy. By controlling the degree of openness of a platform, it is possible to regulate which complementors are allowed to participate. This has a regulating influence on whether the implementation of a circular economy is conducted at the micro, meso or macro level (Kirchherr *et al.*, 2017).

Value creation (MD4) - Within this MD, key activities (DC41), resources (DC42), and partners (DC43) of circular economy were added as additional dimensions.

The key activities (DC41) for implementing circular economy can be derived from the identified circular strategies. In the following, the identified characteristics are briefly related to the underlying circular strategy.

The key activity for the implementation of the “refuse strategy” is the “virtualization or dematerialization” of products or services (Ellen Mac Arthur Foundation, 2024). In contrast, the implementation of the “rethink strategy” is mainly achieved by “increasing the intensity of use” of products and services. The activity relevant to the “reduce strategy” relates to “increasing the efficiency” of production processes and product design. “Repair and maintenance” are key activities for the implementation of the similar called strategy. Activities for remanufacturing and recycling of products at end of life become relevant for the “reuse-” and “recycle strategy”. These two strategies also require activities to “recycle” products, components or secondary raw materials. If several circular strategies are implemented at the same time, “several key activities” are consequently required.

The dimension of circular key resources (DC42) describes tangible and intangible resources for enabling circular economy. “Virtualized products and services” are the key resources for implementing the “refuse strategy”. In contrast, “sharing products” are central resources for implementing a “rethink strategy” (Sihvonen & Ritola, 2015). Sharing products refer to those products that have not fully reached their maximum usage capacity and can therefore be made available to other users via a platform for a certain period of time for example on the basis of a subscription model (Ellen Mac Arthur Foundation, 2024). So-called “Product Service Systems (PSS)” represent another key resource. According to Tukker (2004), PSS are to be understood as a combination of tangible products and intangible services which together contribute to satisfying the needs of the customer. PSS are divided into product-oriented, use-oriented and result-oriented PSS based on the degree of material products involved. Due to the fact that PSS can increase the usage intensity of products on the one hand and provide complementary virtual services on the other hand, business models based on PSS are mainly related to the “refuse-” and the “rethink strategy”. To implement a “reduce strategy”, “efficiency-enhancing technologies” in particular are needed (Circular Economy Initiative, 2021). Other key resources of circular economy are “repaired and maintained-”, “remanufactured-” as well as “recycled products”, which are needed to implement the “repair & maintain-”, the “reuse-” and the “recycle strategies”. Strategies that require the return of physical materials also require “return systems” as another key resource. When multiple strategies are implemented to realize a circular strategy, “multiple resource” are needed accordingly (Geissdörfer *et al.*, 2020).

The key partners (DC43) added to the taxonomy with reference to circular economy are “repair and maintenance companies”, “remanufacturing companies”, “recycling companies” and additional “return partners”. These companies carry out, as complementors, value-adding steps that are required to manage products in cycles. Through the dimension “other/multiple” the cases are described that either several key partners are required at the same time or other complementors have to be involved for circular economy activities. In the case no other key partner is required, the characteristic “none” is assigned.

Value skimming (MD5) – Within this MD no additional dimensions and characteristics are added. The central value extraction mechanisms described in the dimensions of the taxonomy for platform-based business models also apply to the circular economy.

D. Derivation of Identifying Fields of Action for Circular Platform-based Business Models Based on Phenotypes

Based on the structured literature research (Section A), the developed taxonomy for platform-based business models (Section B) and the integration of influences of circular economy (Section C), fields of action for the design of business models based on corresponding phenotypes can be derived. In the following, the MDs identified will be run through suggestively to derive phenotypes and show fields of action per MD. In Table 3, these phenotypes are each assigned their own colour. The assignment of the colours takes place within the presentation of the fields of action in the first MD in the following section. Correspondingly, coloured dots mark fields of action based in phenotypes across the entire taxonomy. According to Bradley *et al.* (2018), the strategies of rethink, repair and maintain, reuse and recycle are particularly relevant for the manufacturing industry. For this reason, only these strategies are used as a reference point in the following.

Table 3. Fields of action for the design of phenotypes within the taxonom

Meta-dimensions	Dimensions	Characteristics								
value proposition (MD1)	circular strategy (DC11)	refuse	rethink (blue)	reduce	repair and maintain (orange)	reuse (green)	recycle (yellow)	several		
	core functionality (D11)	product transaction (yellow, blue)	service transaction	product and service transaction (green, orange)						
value delivery (MD2)	customer segment (D21)	company-specific	industry-specific (orange, blue)	cross-industry (yellow, green)						
	channel (type) (D22)	physical (yellow)	digital	physical and digital (green, orange, blue)						
	channel (marketplace) (D23)	internal marketplace (yellow, green, orange, blue)	external marketplace	no marketplace						
	channel (return) (DC21)	direct (yellow, green)	indirect	direct and indirect (yellow, orange)	no return (blue)					
	customer relationship (D24)	neutral (orange, blue)	collaboration (yellow, green)	coopetition						
architecture (MD3)	openness (provider) (D31)	open	access requirements (yellow, orange, blue)	selection						
	rating system (D32)	by buyer	mutual evaluation (yellow, green, orange, blue)	by platform	no evaluation					
value creation (MD4)	key activity (D41)	matching	matching and additional services (yellow, green, orange, blue)							
	key resource (D42)	tangible resources (yellow, blue)	intangible resources	tangible and intangible resources (green, orange)						
	key partners (D43)	infrastructure providers	data analysts	other/multiple partners (yellow, green, orange, blue)						
	key activities (circular economy) (DC41)	virtualization/ dematerialization	increasing the intensity of use (green, blue)	increase the efficiency	repair and maintenance (orange)	return	remanufacturing	recycling (yellow)	several	
	key resource (circular economy) (DC42)	virtualized products and services	PSS	sharing products (blue)	efficiency-enhancing technologies	repaired and maintained products (orange)	remanufactured products	recycled products (yellow)	multiple resources (green)	
	key partner (circular economy) (DC43)	repair and maintenance companies (orange)	return partners (green)	remanufacturing companies	recycling companies (yellow)	none	other/multiple partners (blue)			
value skimming (MD5)	revenue source (D51)	transaction	usage-oriented	subscription	fixed price	license	advertising	additional services	freemium	multiple revenue sources (yellow, green, orange, blue)
	revenue partner (D52)	provider	buyer (orange, blue)	third-party provider	multiple revenue partners (yellow, green)					

Legend: (blue) rethink (orange) repair and maintain (green) repair and maintain (yellow) recycle

The MD value proposition (MD1) forms the basis of every business model (Osterwaler, 2004). Consequently, it is the central point of reference for any circular platform-based business model. Accordingly, the phenotypes that reflect a specific circular purpose can also be rooted here. The selection of a "circular strategy" is, as the initial field of action, decisive for the establishment of phenotypes. It determines the objective pursued and the purpose of the business model and is therefore the reference point for further fields of action.

Addressing the phenotype of the "rethink" circular strategy (blue dots) shared use of underutilized machinery or equipment increases the intensity of use of these goods, saving resources and energy to produce new machinery and equipment. An increase of the utilization intensity of machinery and equipment is focused. A platform can be also used for the phenotype "repair & maintain activities" (orange dots). Such a platform can serve to mediate service transactions between providers of repair or maintenance services and owners of machinery equipment. By mediating product and service transactions for the purpose of repairing and maintaining, the life of products can be extended, achieving a slowdown in resource flows. Another phenotype is a platform for "reuse" (green dots) activities. This phenotype can also be used simultaneously to broker product and service transactions. In order to collect relevant information to enable transactions, the platform must enable owners of used or defective machinery or equipment to transmit data about these products to the platform. Based on this data, the platform can connect owners of these machines

or equipment with complementors that either offer relevant services to recondition the defective products or, alternatively, purchase the used or defective goods. Buyers of used components can reuse them directly if they still have functionality. Alternatively, it is possible for defective products to be purchased, remanufactured and sold again via the platform to corresponding buyers (Circular Economy Initiative Germany, 2021). This type of platform enables the networking of a variety of different organizations that can contribute to different "reuse" circular strategies. Such strategies can include direct reuse, refurbishment, remanufacturing, repurposing and resynthesizing (Ellen Mac Arthur Foundation, 2024). A comparable phenotype is the platform for "recycling" (yellow dots) activities. This phenotype enables product and service transactions that address the "recycling" circular strategy. Such platforms can provide the functionality of suggesting suitable recycling processes and available recycling complementors to providers of machinery or equipment to be recycled based on a data-based algorithm. The platform can link suppliers of recyclates with potential buyers. This type of platform enable the optimization of recycling activities and the return of recycled materials to technical material cycles (Niemietz *et al.*, 2022).

Further fields of actions can be identified within the MD value delivery (MD2). In its intermediary role, the platform acts as a neutral entity to mediate product and service transactions and enables the exchange of information relevant for circular economy. The customer segment of a platform can basically be, as shown, industry-specific or cross-industry. Platforms for the phenotypes of "sharing" (blue dots), "repair & maintain" (orange dots) and "reuse" (green dots) activities are very likely to have an industry-specific customer segment. This is because machinery and equipment are specified for the manufacturing sector. Platforms in connection with the phenotype "recycling activities" (yellow dots) have a cross-industry customer segment. This is due to the fact that recycling companies often operate across industries boundaries and recyclates can be reused in different industries. Regarding the field of action "channel (type)" within this MD, it can be stated that platforms use both digital and physical channels to promote circular economy. The exchange of physical goods and the provision of repair, maintenance, remanufacturing or recycling services require physical channels. At the same time the exchange of circularly economy relevant data and information is critical to the implementation of circular strategies (Parida *et al.*, 2019; Kanda *et al.*, 2021). Such data and information exchange takes place through digital channels of a platform. For the description of the requirements within the field of action "channel (return)", a distinction must be made between different platform types. With regard to phenotypes concerning sharing-strategies (blue dots) it can be stated that these do not require a channel for return. Whereas phenotypes for "reuse" (green dots) or "recycle" (yellow dots) activities require a channel for return. When platforms act as broker services between end-users and reuse or recycling companies, the return can be characterized as "indirect". Also direct return of products by end users can occur. In this case, platforms does not act as an intermediary for repatriation, but are necessary for the distribution of remanufactured or recycled products and materials. Platforms need to be considered also for phenotypes of "repair & maintain" (orange dots) activities. If there is no take-back of machinery or equipment by the original equipment manufacturer the platform can act as an intermediary between end-users and repair or maintenance complementors. Alternatively, machines and equipment are returned to manufacturing companies, repaired and afterwards sold via the platform.

In order to promote phenotypes of circular platform-based business models the platform architecture (MD3) must be designed in such a way that mechanisms for screening and evaluating platform actors are integrated into the platform. These mechanisms should ensure that suitable players can operate via the platform and positively influence the circular system. Within the field of action "openness" of a platform, the openness should be restricted for both suppliers and buyers either through access requirements or a criteria-based selection of platform participants by the platform provider. This can ensure that only companies that generate actual benefits for the circular economy participate in the platform. The platform provider must therefore establish a governance structure that ensures that trustworthy companies interact within the platform and that misuse of the platform services is avoided (Krom *et al.*, 2022). The additional integration of a rating system within the platform can contribute to this purpose. A system for the mutual evaluation of suppliers and buyers within the platform generates benefit, as transparency can be created on both sides of the market. The mutual evaluation can take place after each transaction within the platform. Alternatively, it would also be conceivable for suppliers and buyers to be evaluated automatically by the platform provider (Łękawska-Andrinopoulou *et al.*, 2021). An assessment can be used to optimize the matching between suppliers and buyers in such a way that users are brought together who have a high degree of similarity in their plans to promote the circular economy and whose collaboration contributes to the realization of sustainability goals (Łękawska-Andrinopoulou *et al.*, 2021).

Within the MD of value creation (MD4), fields of action for the cycle-oriented design of key activities, resources and partners are focused, in order to promote phenotypes of circular platform-based business models. Key activities, resources and partners may differ depending on the core functionalities of platforms elaborated in the value proposition MD. Value creation via a platform depends on the functionality to enable successful matching between suppliers and buyers. In order to use this functionality for the implementation of circular economy, additional information about machines and equipment is needed. For example information concerning the quality or availability of machinery is necessary (Täuscher *et al.*, 2018). The key activity of a platform is to enable matching between suppliers and buyers and to supplement this with additional services for integrating cycle-relevant data. The integration of data can be achieved, for example, by linking machines from manufacturing companies directly to the platform via appropriate hardware, thereby transmitting cycle-relevant data to the platform (BDI, 2021). The field of action "key resources of a platform" can be of different types. While platforms for the phenotype "sharing" (blue dots) primarily require tangible resources in the form of machinery or equipment and intangible resources in the form of data, platforms for the phenotype "repair & maintain" (orange dots), "reuse" (green dots) or "recycle" (yellow dots) often additionally require human resources for corresponding repair, maintenance, remanufacturing or recycling services. Within the field of action "key partners", partners for the operation of a circular platform are infrastructure providers and data analysts. They contribute to the optimization of the matching algorithms based on data standing in connection with circular value creation activities. The key circular activity within a platform for the phenotype "sharing" (blue dots) is to increase the intensity of use of resources. The key resources offered on such a platform are machines and equipment with an underutilized capacity. In contrast, the key activity within a platform for the phenotype "repair & maintain" (orange dots) is to promote repairs and maintenance. Accordingly, the key resources are repaired or maintained products. Additional key partners required are repair and maintenance complementors, return partners, as further key partners, are companies that are called upon by the platform provider to support the return of defective machinery or equipment. The cycle-oriented key activities of a platform for the phenotype "reuse" (green dots) activities are remanufacturing and return of defective machines, plants or their components. The remanufactured products and return systems are the key resources of the platform. A comparable configuration of cycle-oriented key activities, resources and partners can be seen in case of phenotypes of platforms for "recycle" (yellow dots) activities. The cycle-oriented key activities of these platforms are recycling and return of machines, systems or their components. Return systems and recycled products are needed as key resources.

Within the MD value skimming (MD5) it can be assumed that the fundamental type of revenue generation for a provider of platforms is largely independent of the area of application of the respective platform (Tiwana, 2014). Accordingly, the application context of phenotypes of platform-based business models will leave the systematics of revenue generation for the provider of a platform largely unchanged (Lüdeke-Freud *et al.*, 2019). Subscription models are seen as a central mechanism within the circular economy (Riesener *et al.*, 2023 (a)). Within the field of action "cost structures" it should be taken into account that these structures may change due to additional platform services set up for the purpose of circular economy. These should be considered on a case-by-case basis and analysed in greater depth from a business and economic perspective (Krom *et al.*, 2022), outside the scope of this research approach. Revenue structures of the organizations participating in the platform may also change in the context of circular economy. In this field of action, in the long term it must be ensured that all companies participating in the platform can generate revenues or that companies are offered other incentives to participate in the system (Circular Economy Initiative Germany, 2021). Within the field of action "value extraction" various revenue sources and partners are available to the provider of a platform to ensure value extraction within a circular platform-based business model. Platform providers can use transaction-based, subscription-based or advertising-based revenue sources. In addition, a platform provider can generate revenue by selling additional services, such as the analysis and visualization of cycle-relevant data (Täuscher *et al.*, 2018). The revenue partners of a platform can be suppliers, buyers or third-party providers, depending on the revenue model pursued. Platform companies can use several of these parties as revenue sources.

V. Conclusion and Derived Need for Research

A. Summary

Based on the application of the method by Nickerson *et al.* (2013), a taxonomy for platform-based business models with focus on circular economy in the manufacturing industry is presented. This approach serves as a reference architecture that provides guidance for the description of circular platform-based business models. It provides consistent definitions of systems, decompositions and design mechanisms, as well as a common vocabulary to discuss specifications of implementations. Based on this descriptive approach, phenotypes and fields of action for the design of platform-based business models for circular economy could be identified. In summary, this taxonomy of circular platform-based business models represents a meta-theoretical framework in order to systematize the research area. For ease of understanding, the model contains a limited number of terms and characteristics and can consequently be described as concise and practicable.

B. Implications and Outlook

From the results several implications for theory and practice can be drawn. Regarding scientific contributions, the research approach addresses the lack of systematic tools for platform-based business model development in the circular economy (e.g. Lewandowski, 2016; Geissdörfer *et al.*, 2020). This research approach confirms existing business model frameworks take insufficient account of the complexity and specific characteristics of circular economy (Riesener *et al.*, 2023 (a)). In this regard, Lambert (2015) refers to the importance of appropriate classifications for business model research and calls for further research approaches. "A good classification scheme [forms] the basis of theory development". Similarly, this work notes that current business model concepts are based on dividing the business model into certain components (e.g. Osterwalder *et al.*, 2005; Gassmann *et al.*, 2013). Building on the high level of abstraction of generic business model definitions (e.g. Gassmann *et al.*, 2013) this research approach develops a contextual reference model in the form of a taxonomy of circular platform-based business models. This taxonomy provides the research area with the required "common ground" for focusing further research initiatives (e.g. Berg & Wilts, 2019; Eastwood 2023, Riesener *et al.*, 2023 (b)). Based on this "common language", the taxonomy facilitates the comparability and synthesis of existing and future research results and serves in this context as an instrument for reducing complexity.

As for managerial contributions, the developed taxonomy addresses the lack of guidance for realizing business strategies and business model development in circular economy. The developed taxonomy shows fields of action for the design of platform-based business models which pursue, for example, a circular product strategy and delivers generic components that characterize such a business model. As a simplified representation of reality, the model is intended to help minimize the cognitive demands on decision makers and overcome application difficulties with regard to the missing structuring of the field of action.

As noted by Nickerson *et al.* (2013), taxonomies are never perfect, but exist to provide an appropriate solution in a given context. The approach is, naturally, limited by a number of limitations that must be taken into account when interpreting the results. Due to the meta-theoretical approach of this elaboration, the present taxonomy development exclusively uses a "conceptual-to-empirical approach" and thus derives inductively knowledge. The dimensions, characteristics and phenotypes identified can be explained in depth, verified, validated and, if necessary, expanded deductively through further research initiatives in the form of an "empirical-to-conceptual approach". Theoretical classifications can thereby be enriched, for example, through the investigation of empirical case studies.

The structured literature research, in conjunction with the development of a taxonomy and the identification of fields of action for the design of phenotypes fundamentally strengthens the conceptual basis for further investigation of the realization of value-enhancing circular economy in the manufacturing industry. Classifications open up the possibility of organizing abstract, complex concepts. Extensive taxonomies are the basis for theory development (Doty & Glick, 1994). Consequently, the present research approach provides a solid and promising basis for conducting further qualitative and quantitative research initiatives.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

G. Schuh, M. Riesener, M. Kuhn, and

S. Schümmelfeder conducted the research and analyzed the data; S. Schümmelfeder wrote the paper; all authors had approved the final version.

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