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Mapping Order Processing In Circular Production: Development Of A Systematic Literature Review-Based Morphological Box

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Abstract

Increased resource scarcity and sustainability regulations urge manufacturing companies to shift from linear to circular value creation. Circular production facilitates the dissociation of resource consumption from the provision of high-value products. Circular production is implemented by R-strategies, representing various strategies to circulate a product's material. Introducing R-strategies implies changes for the configuration of companies' order processing.

This paper examines the constitutive features and their respective specifications for order processing in circular production. Based on an extension of linear order processing to include sub-processes relevant to circular production, a systematic literature review (SLR) is carried out. The features and specifications identified in the SLR are then clustered, refined and completed. The developed morphological box provides an overview of the main design decisions and options available to companies for designing order processing in circular production.

Keywords

Circular Economy; Order Processing; Process Management; Production Management; Remanufacturing

1. Introduction

The necessity for reducing greenhouse gas emissions and adopting sustainable resource management is becoming increasingly important for businesses worldwide [1]. Beyond environmental considerations driven by regulatory requirements and customer demands, significant economic opportunities exist in reducing resource consumption within industrial operations. Transitioning from a linear economic model to circular production systems can unlock these potentials [2]. Circular production aims at closing product and material loops, shifting focus from resource extraction to retaining value within existing materials and products. While recycling remains a critical aspect, product-centric strategies such as remanufacturing and refurbishment are gaining traction for manufacturing companies in implementing circular value creation models. However, these changes require significant adjustments in traditional organizational structures, posing various challenges for companies [3].

Order processing, as a core process of a company, is strongly affected by the need for adaptation, as it encompasses the process of value creation. Additional sub-processes and process steps must be integrated to address aspects unique to circular production. For instance, the reverse logistics required for returning used products to the company becomes a fundamental part of circular order processing [4].

The complexity of these challenges varies across industries and demands tailored solutions [3]. Consequently, organizations require guidance in configuring their order processing systems to align with

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circular production principles. Identifying the constitutive features and their specifications is an essential step in enabling this support.

This paper is structured as follows: Section 2 provides a theoretical background on circular production and order processing. Section 3 reviews related work. Section 4 outlines the systematic literature review conducted to identify constitutive features of order processing in circular production and their respective specifications. Section 5 details the development of a morphological box derived from these features and specifications. Finally, Section 6 presents conclusions and suggests avenues for further research.

2. Theoretical Background

This section outlines the foundational concepts of circular production, order processing, and the morphological box as a methodological approach.

2.1 Circular Production

Circular production is a regenerative approach designed to minimize resource consumption and waste generation by implementing strategies to slow, narrow, and close material loops [5]. It contrasts sharply with the linear economy's "take-make-waste" paradigm by embracing a "reduce, reuse, recycle" philosophy [6].

Within the circular economy, products are retrieved after use, and their materials and components are systematically recovered for new production cycles. To achieve this, businesses adopt various "R-strategies", such as refurbishing and remanufacturing, which are particularly relevant for manufacturing companies [7]. These strategies enable companies to create additional revenue streams while reducing resource demands compared to linear production. Moreover, they allow firms to deliver high-quality products that compete effectively with new offerings.

Key processes in circular production include:

- **Refurbishment**: Comprehensive product overhaul to restore original performance, resulting in a fully functional, high-quality used product [8].
- **Remanufacturing**: Combining new and used components to create products that meet or exceed the functionality of the original. This includes functional upgrades and re-assembly [9].
- **Recycling**: Returning materials to industrial production when reuse or remanufacturing is not viable, typically for components without further utility [10].

This paper focuses on processes beyond recycling, emphasizing strategies that retain product value through component-level interventions.

2.2 Order Processing

Order processing represents a core operational function for producing companies, covering the end-to-end activities required to fulfill customer demands [11]. Technical order processing includes production scheduling, execution, and logistics, as well as auxiliary functions such as sales and procurement [12]. These sub-processes interact across various organizational domains, illustrating the cross-functional importance of order processing [13]. The shift to circular production introduces additional complexities, such as reverse logistics and reconditioning activities, requiring the integration of new processes into traditional workflows.

2.3 Morphological Box

Morphological and typological approaches effectively address complex, multi-dimensional problems [14]. A morphological box abstracts a system by identifying its core features and the possible specifications for each feature [15]. This approach enables the systematic representation of diverse configurations, aiding in the understanding and differentiation of complex systems. Configurations within a morphological box represent unique combinations of specifications of features, making this method particularly valuable for solving qualitative and multi-dimensional challenges [16]. Its application in this paper facilitates the structured analysis and depiction of order processing in circular production.

3. Related Work

This section reviews existing research relevant to the morphological description of order processing and systematic literature reviews in the context of circular production.

3.1 Morphological Description of Order Processing

Several studies have explored morphological frameworks to describe and differentiate order processing in production systems. For instance, GROßE-OETRINGHAUS developed a typology for manufacturing companies based on features and their specifications [17]. SCHOMBURG introduced a morphological framework specifically for linear production order processing, identifying eight core features such as product range, order release type, and production structure [18]. This framework emphasizes the end-to-end nature of order processing and its cross-functional relevance within organizations. Building on this, BÜDENBENDER expanded the framework by incorporating additional features, such as customer change requests and assembly organization [19]. This enriched framework supports the categorization of companies into order processing types like engineer-to-order, make-to-order, assemble-to-order, and make-to-stock.

However, these frameworks predominantly address linear production. For circular production, NOVOSZEL [20] proposed a reference model for reverse logistics, identifying eight types of manufacturer involvement in product returns. The author focusses on the derivation of reference process models using a morphology of initial features and performance features to differentiate reverse logistics types. This approach focuses on reverse logistics rather than the complete order processing cycle including use phase and the relevance of the underlying business model. Similarly, DIAZ ET AL. developed a morphological approach for analyzing circular product design strategies but limited their scope to product development patterns [21]. This approach is focused on very strategic features with only limited relevance for order processing configuration.

A comprehensive morphological framework capturing the full scope of order processing in circular production is notably absent, creating a gap that this work aims to address.

3.2 Systematic Literature Reviews in Circular Production

Systematic literature reviews (SLRs) have addressed various aspects of circular production, laying the groundwork for understanding its challenges and opportunities. GUNASEKARA ET AL. emphasized the importance of effective circular supply chain implementation, highlighting acquisition, sorting, and disposition as critical processes [22]. KE ET AL. developed a twelve-step remanufacturing process, underlining the significance of reverse logistics in enabling successful circular production systems [23].

Decision-making processes in remanufacturing have also been explored extensively. RIZOVA ET AL. investigated strategic, tactical, and operational decision-making in remanufacturing, addressing the hierarchical nature of decisions essential for managing circular production [24]. AKANO ET AL. identified key decision factors for remanufacturing implementation, focusing on incorporating stakeholder and customer requirements into the process [25]. In parallel, LIU ET AL. examined challenges in remanufacturing assembly, identifying opportunities for efficiency improvements through advanced robotics and automation technologies [26].

Collaboration among stakeholders in circular production has been another area of focus. BEHNERT AND ARLINGHAUS studied the role of open-source frameworks in fostering cooperation, highlighting their importance for achieving effective collaboration across entities [27]. In addition, KIM ET AL. applied morphological analysis to circular economy business models, particularly in the electrical and electronic equipment sector [28]. Their study demonstrates how morphological methods can be used to identify systemic design options for circular business models.

Despite these efforts, no SLR has fully translated its findings into a morphological framework for order processing in circular production. This paper addresses this gap by systematically identifying and categorizing the constitutive features and their specifications.

4. Systematic Literature Review

This section outlines the methodology used to conduct the systematic literature review (SLR) and the results obtained. The review aimed to identify the constitutive features and their respective specifications of order processing in circular production.

4.1 Scope and Objectives

The primary goal of the SLR was to investigate order processing in manufacturing companies within the context of circular production. Companies focusing solely on recycling or operating as pure remanufacturers were excluded to maintain a targeted perspective. To achieve a comprehensive view, the relevant sub-processes of order processing in circular production were identified and distinguished from those in linear production. Building on previous work by HOMMEN ET AL., the following sub-processes were determined as central to circular production: use, reverse logistics, pre-/post-disassembly, disassembly, reconditioning, sales, product engineering, procurement, part manufacturing, assembly, and shipping [29].

4.2 Methodology

The SLR followed a structured, transparent, and replicable approach as outlined by Xiao et al. [30]. Two rounds of literature review were conducted: the first to identify constitutive features and the second to determine their associated specifications. The initial review also extracted specifications when available, reducing the need for further investigation. The second review was conducted only when gaps in feature specifications were identified.

Search strings were developed based on the relevant sub-processes identified earlier, and queries were conducted in databases such as Scopus, ScienceDirect, and Web of Science. To ensure comprehensive coverage, search strings were prepared in English and German and adapted to database-specific syntax requirements. These sub-processes formed the basis for the search strings used in the literature review, ensuring alignment with the research focus. The process-step-specific search strings were expanded by general search strings. An overview on search strings is given in Figure 1.

	Search-Strings used for the SLR
1	(„Circular Economy“ OR Circular) **AND** („order fulfillment“ OR „order processing“ OR „order handling“ OR „end-to-end process“ OR „decision framework“ OR „decision guideline*“) **AND** (production)
2	(„Circular Economy“ OR Circular) **AND** („production organization“ OR „production characteristic*“ OR „production feature*“)
3	(„Circular Economy“ OR Circular) **AND** („order fulfillment“ OR „order processing“ OR „order handling“ OR „end-to-end process“ OR „decision framework“ OR „decision guideline*“) **AND** („manufacturing“ OR „processing“ OR „business model*“ OR „reverse logistic*“ OR „core acquisition“ OR „distribution“ OR „procurement“ OR „design“ OR „*assembly“ OR „usage“ OR „sale“)
4	(„Re*manufactur*“ OR „Re*purpos*“ OR „Re*assembl*“ OR „Re*furbish*“) **AND** („order fulfillment“ OR „order processing“ OR „order handling“ OR „end-to-end process“ OR „decision framework“ OR „decision guideline*“) **AND** (production)
5	(„Re*manufactur*“ OR „Re*purpos*“ OR „Re*assembl*“ OR „Re*furbish*“) **AND** („production organization“ OR „production characteristic*“ OR „production feature*“)
6	(„Re*manufactur*“ OR „Re*purpos*“ OR „Re*assembl*“ OR „Re*furbish*“) **AND** („order fulfillment“ OR „order processing“ OR „order handling“ OR „end-to-end process“ OR „decision framework“ OR „decision guideline*“) **AND** („manufacturing“ OR „processing“ OR „business model*“ OR „reverse logistic*“ OR „core acquisition“ OR „distribution“ OR „procurement“ OR „design“ OR „*assembly“ OR „usage“ OR „sale“)

Figure 1: Applied Search Strings in the SLR

4.3 Screening, Selection and Result

The initial search yielded 52,632 results across the three databases. After removing duplicates, the remaining entries underwent a title screening phase, followed by abstract screening to assess their relevance. The shortlisted articles were subjected to full-text screening to confirm their suitability for the study. This systematic process reduced the dataset to 92 relevant articles. Figure 2 illustrates the statistics of the screening and selection. These sources provided a comprehensive basis for identifying the features and specifications of order processing in circular production. A total of 763 features from 77 of the full-text screened articles and 6 articles from the section related work were initially identified and organized into a longlist.

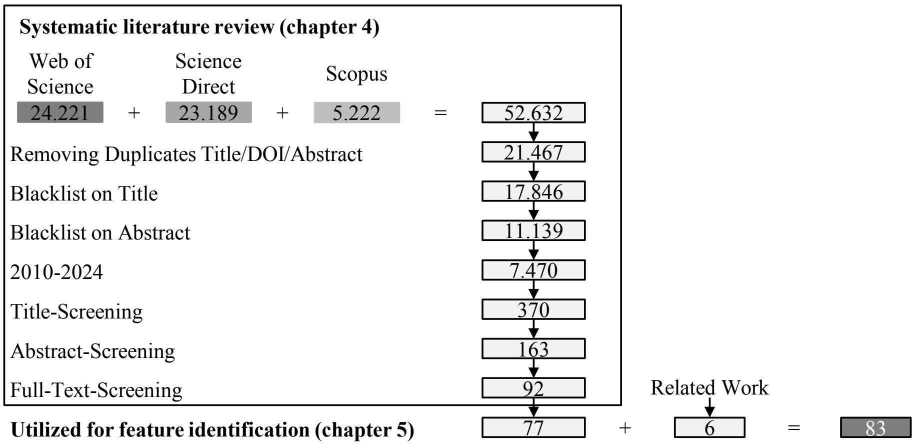


Figure 2: Results of the Conducted SLR

5. Derivation of a Morphological Box

This section outlines the process for deriving a morphological box to structure the design of order processing in circular production. Foundation is the conducted SLR in section 4. The derivation is split into two key phases: the identification of constitutive features and the identification of their associated specifications. Finally, the morphological box is constructed based on these elements.

5.1 Identification of Constitutive Features

The identification of constitutive features followed a systematic six-step process, beginning with the extensive dataset generated from the systematic literature review (SLR). The process is illustrated in Figure 3.

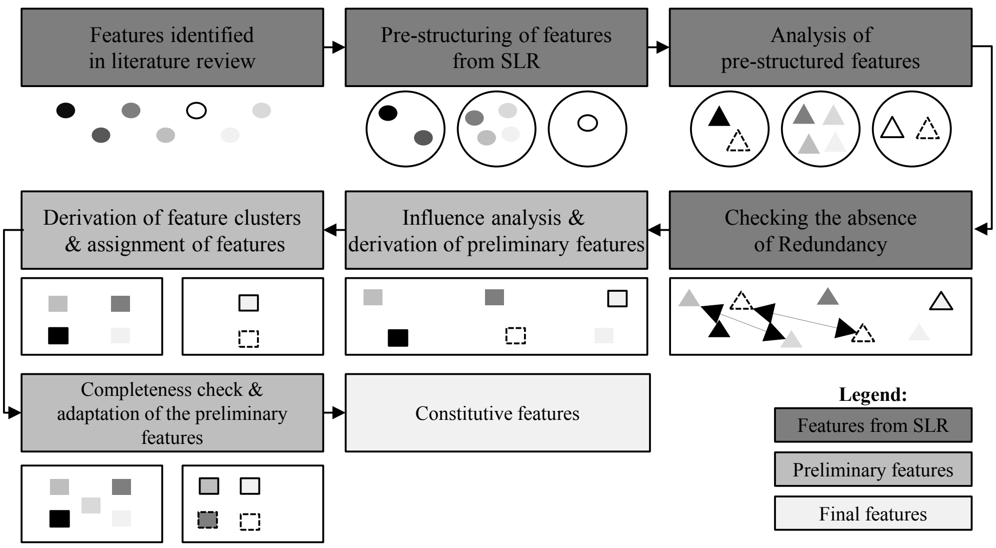


Figure 3: Process for the Identification of Constitutive Features

In the first step, the 763 features identified during the SLR were preliminarily structured to provide an organized overview. Features with identical labels or meanings were consolidated, resulting in a reduced list of 309 features. This step was crucial for eliminating straightforward redundancies and preparing the dataset for further analysis. The second step focused on clustering the features based on similarity using a matrix that systematically compared their descriptions and contexts. Features with overlapping scopes were grouped in clusters. After this, the resulting clusters were analyzed one by one, allowing for a detailed analysis of a small group of features on each cluster. This step leads to a reduction of the dataset to 117 features. After this, the clusters established to support this analysis step, were abandoned again.

The third step involved a detailed redundancy analysis. Here, the features were arranged in a pairwise comparison matrix (117x117) to identify overlaps and redundancies. Through this step, the number of features was reduced to 95 unique features, ensuring clarity and eliminating duplication. In the fourth step, an influence analysis was conducted to examine the relationships and dependencies between features. Features deemed non-essential or highly dependent on others were removed, further refining the dataset to 59 features. This analytical process ensured that the remaining features were critical for describing order processing in circular production.

The fifth step organized the remaining 59 features into feature clusters. Each group was aligned with specific sub-processes of circular production, such as reverse logistics, disassembly, and reprocessing. Additional clusters were created with the overarching cluster "Production (general)" for all general features describing the production and "Customer and market". The sixth and final step addressed completeness. By conducting targeted literature searches and utilizing intuitive research, 11 additional features were identified and added to the framework. This process brought the total number of constitutive features to 70, forming a robust foundation for constructing the morphological box.

5.2 Identification of Feature Specifications

The identification and specification of feature specifications were essential to ensure the configurational richness of the morphological box. This phase involved a structured four-step process, illustrated in Figure 4.

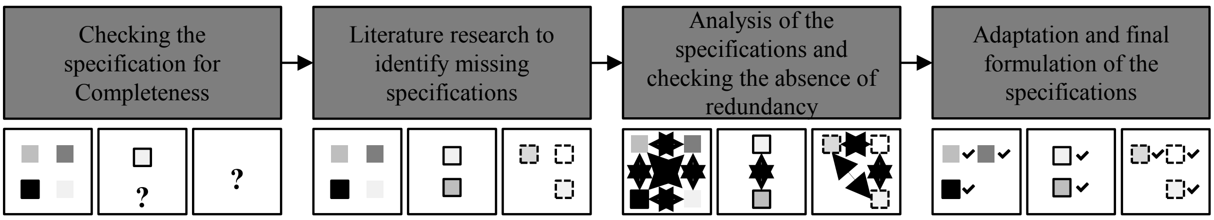


Figure 4: Process for Identification of Feature Specifications

The first step focused on extracting specifications directly from the SLR. For each feature, relevant specifications were documented, capturing possible options or manifestations. For instance, the feature "reverse logistics" was associated with options such as "centralized collection" and "decentralized collection." These initial specifications were comprehensive but required further refinement. The second step addressed gaps in the initial dataset by conducting additional targeted literature searches. Using feature-specific keywords, searches were performed across databases like Scopus and Google Scholar. This process uncovered specifications not initially captured, such as "hybrid collection systems" for reverse logistics, enriching the configurational space. The third step ensured that the identified specifications were unique and non-overlapping. A redundancy analysis was applied to the specifications, consolidating similar ones and clarifying distinctions. Features with only one identified specification were expanded by logical complements or derived alternatives, ensuring that each feature was described comprehensively. Figure 5 illustrates the procedure for the feature "Type of Business Model". In a first iteration "Rent" and "Rental" were identified as describing the same specification and were therefore consolidated.

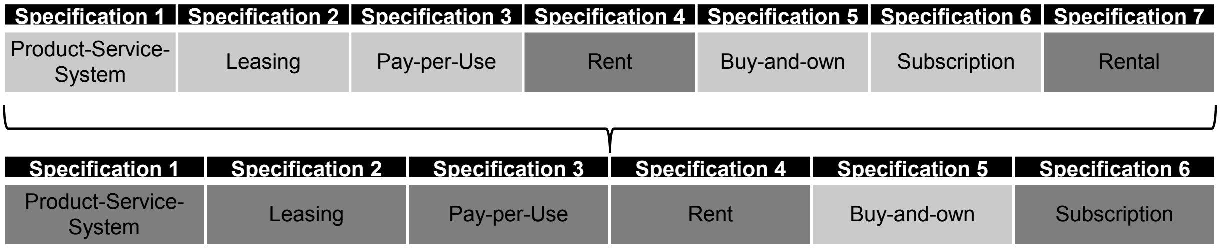
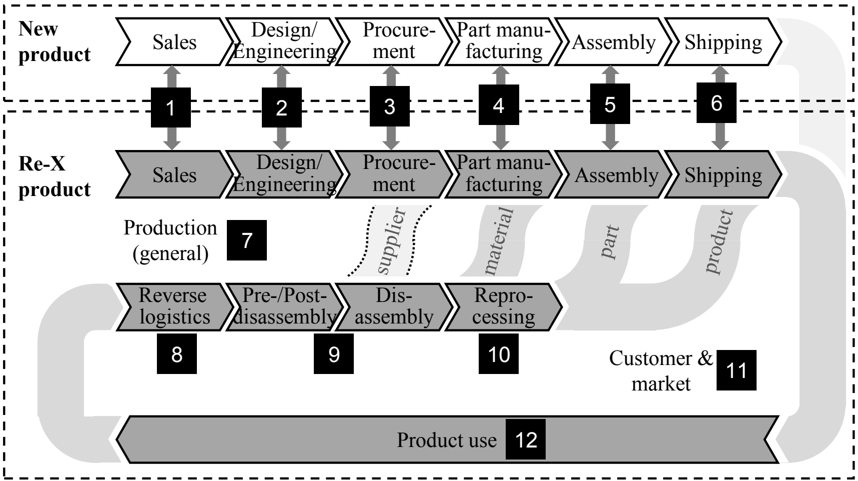


Figure 5: Exemplary analysis of specifications and reduction for the feature "Type of Business Model"

In the final step, the specifications were finalized to align with the requirements of the morphological box. They were formulated to be distinct, clear, and practically applicable, allowing for straightforward integration into the final framework.

Construction of the Morphological Box

The morphological box integrates the constitutive features and their specifications into a structured representation. The features that constitute the morphological box and are illustrated in Figure 6.



1 Sales
Order initiation type (4) [35, 47, 48, 62-66]
Type of business model (2) [32, 54, 67-69]
Execution of distribution (2) [49, 52, 56]
Legal restrictions for distributing Re-X-products (3) [70-72]
Synthesis of distribution channels (2) [61, 73, 74]
Product differentiation (2) [A]

2 Design and engineering
Product type (2) [87, 102]
Product range (4) [31, 35, 63, 78, 103]
Product structure (3) [25, 26, 32, 41, 46, 60, 67, 78, 79, 87, 93, 95, 104 - 109]
Product scope (3) [A]
Product value (3) [A]

3 Procurement
Triggering of secondary requirements (3) [18, 19]
Procurement type (new products/components) (3) [18, 19]
Stocking type (new products/components) (2) [31]
Determing core, product and component demand (3) [18, 19]

4 Part manufacturing
Process type in production (4) [18, 19]
Manufacturing structure (3) [18, 19]

5 Assembly
Reassembly mode (4) [18, 19]
Reassembly type (3) [A]
Type of exchanged components (3) [26, 35]
Legal requirements for reassembly (2) [35, 37, 48]
Origin of exchanged components (2) [44]
Reassembly structure (3) [39, 41]
Integration in new product assembly (2) [A]
New product assembly process (4) [18, 19]

6 Shipping
Synthesis of shipping channels (2) [61]

7 Production (general)
Production type (3) [18, 19]
Production structure (2) [37, 42, 75]
Production strategy (3) [34, 47, 52, 54, 62, 75 - 80]
Production site structure (2) [A]

8 Reverse logistics
Initiation of reverse logistics (2) [4, 32, 35]
Execution of reverse logistics (4) [35, 50 - 57]
Transport complexity (3) [31, 35, 53, 56, 58]
Return agreement (8) [32, 54]
Timing of return agreement (3) [A]
Timing of core condition check (5) [22, 60]
Location of core condition check (4) [A]
Procurement type of cores (3) [49]
Grade of staggering of reverse logistics (3) [A]

9 Disassembly
Disassembly mode (4) [33, 38 - 40]
Disassembly type (3) [37]
Disassembly depth (2) [4, 37, 41 - 46]
Manual complexity of disassembly (3) [36, 39, 41, 46]
Disassembly structure (3) [41, 47]

10 Reprocessing
Reprocessing mode (3) [32 - 34]
Reprocessing type (3) [4, 32, 35]
Reprocessing focus (2) [A]
Reprocessing structure (3) [35]
Reprocessing scope (3) [36]
Upgradability by reprocessing (2) [37]

11 Customer and market
Customer-product relationship type (3) [56, 81, 82]
Customer-company relationship type (3) [56, 81 - 84]
Technological innovation type (3) [85 - 87]
Customer type (4) [35, 54, 88, 89]
Customer budget (4) [32, 59, 61, 62, 71, 74, 85, 90]
Customer purchasing behavior (3) [51, 59, 61, 74, 86, 91]
Target market (2) [47, 57, 73 - 76, 92 - 94]

12 Product use
Duration of product use phase (4) [87, 98, 99]
Dominant cause of end of use (4) [57, 87]
Type of product wear (2) [63, 95]
Variation of duration of use (3) [A]
Determinability core condition (2) [44, 54, 96, 97]
Condition monitoring (3) [54, 69, 97, 101]
Frequency of condition transmission (3) [54, 69, 97]
Maintenance/service intervals (3) [A]
Customer relation during product use (4) [A]
Mobility of the product (4) [A]
Value development of the product (3) [100]
Customer relation during product use (5) [A]
Evaluation criterium of product use (4) [A]

Notation:
feature (number of specifications) [reference]

Abbreviation:
A: added by authors to improve cluster completeness

Figure 6: Overview on the resulting features of the morphological box

Figure 6 illustrates the assignment of features to the clusters. The clusters represent sub-processes of order processing in circular production and two additional clusters “Customer and market” and “Production (general) for features that did not fit into the other sub-processes. Figure 6 furthermore highlights the number of distinct specifications for each feature in brackets.

The developed morphology comprises a variety of features along the sub-processes of order processing in circular production. The granular resolution of the features differs from the morphology introduced by Novoszel. There is a strong focus on the consideration of the perspective of the order in circular production and the connection between new and Re-X product is reflected. Furthermore, the importance of the product use phase and the business model are given greater consideration, while NOVOSZEL places a greater focus on initial features for the identification of process model types. Other morphology approaches, such as DIAZ ET AL., focus on strategic aspects of the design of circular production and differ accordingly in the selection of characteristics. When looking at the identified features, the perspective on the structure of the production network is lacking, from the structure of locations within reverse logistics and reprocessing to the interaction of new production network and the networks for circular production. Here, the morphology must be expanded accordingly.

The designed morphology comprises 70 features. The high number of features is due to the holistic approach and allows the use of operational features. However, it hinders the application in practice. Therefore, in future work, the identification of the most relevant features and the application of the morphology in practice should lead to a reduction of the morphology to the most essential features. The morphology will subsequently be used to describe characteristic types for order processing in circular production. Features that are not relevant for type formation can be removed from the morphology. This approach systematically reduces the SLR-based morphology to the essential features

6. Conclusion And Further Research

This paper examines the transformation of order processing in circular production by developing a morphological box based on a systematic literature review (SLR). Circular production requires a reconfiguration of traditional processes to include new sub-processes such as reverse logistics, reprocessing, and disassembly. A structured six-step process identified and refined 70 constitutive features, while a four-step methodology defined their specifications. These efforts culminated in a morphological box that systematically represents the configurational options for order processing in circular production. This framework supports businesses in exploring tailored configurations and highlights the complexity of circular production processes. It provides a foundation for decision-making and further research.

The morphological box requires iterative refinement to enhance its practical relevance. Specifications must be operationalized to help companies map latent or unclear features, particularly when these features are not directly identifiable without support (e.g. manual complexity of disassembly). Structured expert interviews are to be conducted to check for completeness and identify the most relevant features. Future work will focus on applying the morphological box in practice. This will help identify potential adjustments to features and specifications while revealing opportunities to define representative order processing types for circular production. These types could serve as benchmarks for companies, enabling them to assess and align their configurations with established types.

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