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Design Options for Sustainable and Open Business Models: A Taxonomy-Based Analysis

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Abstract: The imperative for decarbonization forces businesses to transform their business models (BMs) and to adopt Sustainable Business Models which focus on creating value sustainably. In the context of Sustainable Business Model Innovation, maintaining close relationships within ecosystems is crucial to ensure a sustainable transformation while preserving competitiveness. As corporate boundaries become more transparent, the importance of external resources increases, leading to a shift from closed to open business models (OBM). In OBMs, stakeholders, including customers, actively co-create innovation and value creation. Our research investigates how integrating these approaches can shape BMs that effectively address decarbonization drivers and tackle the required business model innovation. We conducted a structured literature review to develop a taxonomy that outlines 64 design options across nine dimensions for sustainable, open BMs. In conclusion, this study provides sustainable and open design options, classified into detailed taxonomies. The practical applicability of this taxonomy was demonstrated through a use case classification, providing a foundation for companies and further research into designing and implementing these BMs in the context of decarbonization.

Keywords: sustainability; business model; sustainable business model; open business model; open innovation; taxonomy; sustainable transformation; decarbonization

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1. Introduction

The current research examines the urgent challenge of climate change and the resulting need to sustainably transform social and economic systems. Today, sustainable development is seen as a guarantee for lasting success on an economic, ecological and social level [1]. Thus, manufacturing companies are faced with the task of reconciling economic stability with profitable business [2]. The creation of sustainable added value, and thus the extension of the value chain, helps improve the company's image and opens up new market opportunities. It thus promotes company growth and development [2]. Energy-intensive manufacturing industries (EIMI), in particular, are faced with the challenge of achieving climate neutrality in accordance with the Paris Agreement and the European Green Deal [3,4].

In response to increasing sustainability challenges, leaders recognize the opportunity to shape markets and society by addressing these challenges [5], often in cooperation with, but occasionally with greater influence than, regulators and non-governmental organizations [6,7]. In this dynamic context, it is essential for entrepreneurs to develop adaptable business models (BMs) that allow them to quickly and efficiently adjust their strategic orientations to market requirements [8]. Nowadays, sustainable innovations must go beyond technology and research and development and also include the BM [9].

A Sustainable Business Model (SBM) describes how companies create, deliver, and maintain value while considering the interests of various stakeholders, the environment, and society [6,10,11]. To remain competitive and continuously generate sustainable value for customers, partners and the company, it is necessary to reconsider existing BMs or implement new, sustainable ones [12,13]. Companies must actively participate in sustainable business model innovation (SBMI) to successfully navigate the transitions to a sustainable economy [14]. This challenge requires a new approach to sustainable innovation, one far beyond conventional practices [8].

In the context of decarbonization, openness through symbiotic exchange offers a solution approach for the necessary innovation of BMs by enabling the use of openness at different levels as a source of both profit and the reduction of risks, which is particularly relevant, as the independent development of new BMs requires extensive investments in research, market development and process optimization by companies and is therefore often risky and costly. Maintaining close relationships with business partners is crucial to transforming sustainably and remaining competitive in the market [15]. Today's organizations cannot ignore the growing importance of their dependence on their business partners and stakeholders [16]. Through collaboration with stakeholders and inter-organizational connections within the ecosystem, the importance of external resources is increasing due to the increasing accessibility and transparency of corporate boundaries in innovation [17]. For example, customers become part of the change and have active relationships with the company's transformation towards sustainability. Moving away from a traditional, closed innovation model requires companies to adopt an open business model (OBM) [18]. OBMs have gained in importance, particularly through the work of Chesbrough [9], which heralded a new era of innovation strategies. Compared to traditional BMs, which may include collaborative value creation and capture, OBMs are explicitly based on these principles and shift the focus from a company-centered to a network-centered perspective [19,20]. These models recognize customers and other stakeholders not only as recipients of value propositions, but also as active co-creators of the value creation process [21].

The combination of elements from OBMs and SBMs [22,23] leads to an innovative approach, which we will call the "sustainable open business model" (SOBM) in the following. This concept reflects the ambition to merge the strengths of both models to meet today's challenges in terms of sustainability and innovation. This merging creates a framework that recognizes and emphasizes the need for a collective effort to solve complex sustainability problems [24,25]. A key aspect of the SOBM is the role of an open innovation culture that encourages collaboration between different stakeholders [24], the sharing of knowledge and expertise, experimentation and risk-taking [24,26–29]. Furthermore, the diverse perspectives and competencies create a basis for the joint development and implementation of solutions that are economically as well as ecologically and socially sustainable [24,26]. By integrating the principles of openness and sustainability, SOBMs offer a promising perspective for tackling the complex challenges of our time [30,31] and promote a sense of shared responsibility for sustainable transformation within an ecosystem [10].

Recently, the research community has shown an increased interest in SBMs, OBMs and their combination (referred to as SOBM here), with various studies highlighting different facets of these topics (see Figure 1). The research community [32] has identified the fact that the openness-oriented innovation process contributes within the context of BMI. Companies and non-profit organizations are increasingly researching the OBM, but academic research has also responded to this trend [33]. Initial typologies in the field of OBMs have been developed in research papers [34]. SBM research has focused on identifying BMs that address specific sustainability challenges and on classifying and analyzing different types of SBMs [10,11]. Still pending is the investigation of collaborations and partnerships that connect the different stakeholder groups and constitute BMs [15]. It is to be mentioned that [35] identifies the need to analyze the role of multi-stakeholder collaboration as both an opportunity and a barrier for business model innovation (BMI) in achieving sustainability goals. These efforts reflect the growing awareness that the application of the SOBM offers the opportunity not only to capture and share value in innovative ways but also to effectively address complex sustainability issues [22].

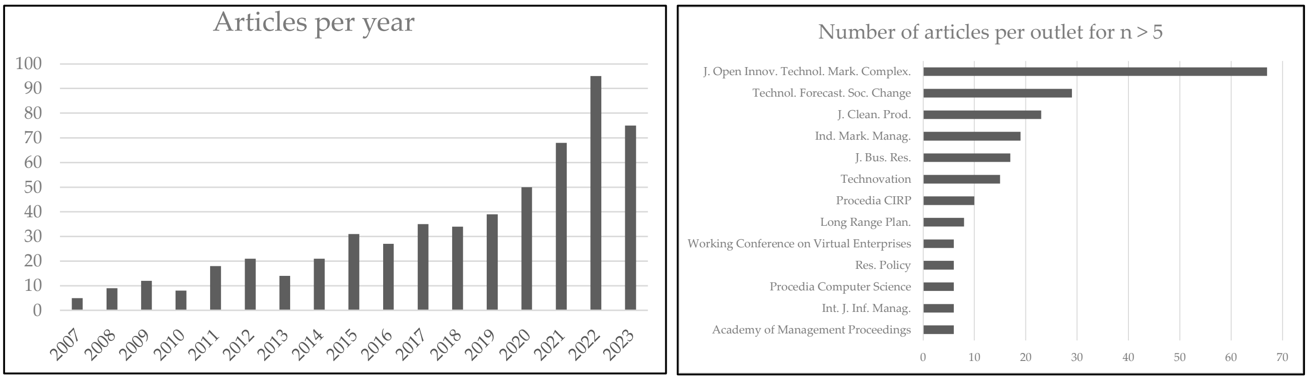

Figure 1. Distribution of articles across years (left-hand side; collection ended December 2023) and outlets (right-hand side).

Despite the increased interest in SBMs and OBMs and the awareness that the combination of openness and sustainability in BMs offers innovative ways to generate and capture value, the question of how to design SOBMs remains largely unanswered. The development of SOBMs that fulfill multiple requirements, from the need for ecosystem-wide orchestration [36] to risks and costs in BMI [12] and the transition to a circular economy [10], represents a central but still largely unsolved research problem.

The motivation of this analysis is to utilize the academic literature of the SBM and OBM to extend the literature relevant to the combination of both research streams. A deep understanding of this combination allows for the analysis and classification of the design options associated with the SOBM. The aim is to answer the research question and thus close the research gap: which design options for sustainable and open business models can be derived from the developed taxonomy to support EIMI companies in overcoming decarbonization drivers? In this paper, the answer to the question is provided by a detailed examination of the design options of BM (SBM, OBM and SOBM). We find 41 characteristics for OBM, 39 for SBM and 64 for SOBM, distributed across four meta-dimensions and nine dimensions. Then, we present a typology for the SOBM(f). The results are checked for validity via use case classifications and expert interviews.

2. Materials and Methods

As part of the research work's general objective to provide an overview of SOBMs and their design options, four phases are carried out. In the first step, (1) the literature is reviewed to derive a selection of conceptually derived BM characteristics in the area of openness and sustainability in the EIMI. Subsequently, (2) the taxonomies for the OBM, SBM and SOBM are constructed. In the following section, (3) the identified taxonomies of OBM and SBM are consolidated within SOBM(f). Finally, (4) the options for the design of an SOBM(f) are examined.

2.1. Phase 1: Structured Literature Review

We conducted a structured literature review for the data collection, which was focused on the characteristics of BMs in the context of openness and sustainability (see Appendix A for details). Following the Prisma model, this explicit systematic method unfolded across five phases in November 2023 [37,38]. Below, the procedure and results are shown in Table 1.

The first step serves for the identification of relevant titles by a keyword-based search in various scientific databases. The search term is entered as ((“open business model”) OR (“industry ecosystem”)) AND (“innovat*” AND “sustain*”). The literature's preselection in the second phase excluded publications that did not correspond to the application area. The scope of the research work is at the BM level and includes the EIMI. The selection of articles was limited to the BM and articles dealing with the conceptual theories or those presented in the application context.

Table 1. Overview of the literature search.

Search String	Database	Results	Included
TITLE-ABS-KEY((“open business model”) OR (“industry ecosystem”)) AND (“innovat*” AND “sustain*”)	Scopus	29	6
	IEEE Xplore	10	1
	EBSCOhost	47	10
	ScienceDirect	374	27
((“open business model”) OR (“industry ecosystem”)) AND (“innovation” AND “sustainability”)	SpringerLink	114	4
	Final Sample (no duplicates, filtering, forward backward search)		$\sum = 81$

In further course, keywords were identified, and the relevance of the titles was assessed. In the penultimate step, we evaluated the availability and suitability of the literature by reviewing the full texts. Finally, all relevant papers were identified in the integration phase. After carrying out a forward and backward search, we identified 81 relevant papers. We used databases commonly used for BM research, i.e., Scopus, SpringerLink, IEEE Xplore, EBSCOhost, and ScienceDirect. A comprehensive sample minimized the obvious limitation of having overlooked an article. Web of Science was not included due to its limited accessibility in our institution. The following selection criteria were taken into account. We only considered papers that presented BM in a non-trivial way and provided sufficient, transparent information about the characteristics of BMs. When selecting the articles, attention was paid to the concept of BM being in focus and being placed above the concepts of openness or sustainability. We limited our scope to articles with a successful peer-review process. Table 2 provides an overview of the databases, search strings and the final sample from the forward and reverse searches. The search was terminated when no new articles were identified in the selected databases. Figure 1 shows each publication outlet and the corresponding number of publications relevant to this study. Most articles (n = 66) originated in an Open Innovation outlet. The articles identified indicate a rapidly growing trend in research on the topic. The first publications are from as early as 1996, subsequent to which the increased frequency of publications, i.e., the increased interest in the research field, is clearly recognizable in the increasing number of publications from 2007 onwards. The number of annual publications has risen steadily since 2007, and increased by a factor of 9 per year until 2023. From 2021 to 2022, an exceptionally high increase in publications per year was recorded, compared to the rest of the duration. The data collection was conducted at the end of 2023.

Table 2. Overview of taxonomy-building iterations.

Iteration	Approach	Sample per Iteration	Explanation
1	Conceptual-to-Empirical	20	The literature already contains knowledge about business models in general and about sustainable and open business models. For this reason, it is appropriate to first incorporate the conceptual knowledge from the underlying literature in order to achieve both a high degree of rigor and sufficient reference to theory.
2	Conceptual-to-Empirical	20	
3	Conceptual-to-Empirical	20	Further iteration was aimed at recognizing relevant characteristics. The in-depth investigation of possible design options fulfils the requirements for conciseness and completeness.
4	Empirical-to-Conceptual	21	An empirical-to-conceptual iteration is necessary to test the finding from the 3rd iteration and refine dimensions and characteristics.

2.2. Phase 2: Taxonomy Building for OBM, SBM and SOBM

Taxonomies are a widely used tool in business administration. They make the complexity of the objects of study, such as BMs, more tangible by categorizing them into groups based on their similarities, structuring the complex field of interest [39–41]. This article uses the taxonomy development method described in [42], which is often considered the de facto standard for taxonomy design [43]. This method follows an iterative process approach that comprises seven development steps and integrates a conceptual-to-empirical approach (deductive) and an empirical-to-conceptual approach (inductive), which are applied iteratively to develop the taxonomy [42]. On this basis, the sample was subdivided according to the approaches used to create a taxonomy (i.e., iterations from conceptual to empirical or from empirical to conceptual) (see Table 2).

The process begins with the definition of a meta-characteristic that reflects the overall purpose of the taxonomy and serves as a guiding authority throughout the process. In this study, the meta-characteristic is as follows: providing design options that guide the future development of SOBM (purpose); the target group comprises designers of SBM, practitioners, and academics interested in the classification of BMs in the context of sustainable transformation. Following the taxonomy creation method proposed by [42], the authors of this research systematically developed a taxonomy for SBM, OBM and SOBM for the EIMI. This method allows the combination of the theoretical findings on SBM, OBM and SOBM with the results of the literature review. This taxonomy is directed toward researchers in the field of sustainability and also those engaged in OBM research, as well as practitioners in the EIMI area, for whom it aims to provide guidance in reconceiving BMs toward sustainability. To start the taxonomy development, each characteristic in every dimension must be a "logical consequence of the meta-characteristic" [42].

In the second step, subjective and objective end-conditions are defined. Work [42] recommends five subjective and eight objective end-conditions. The proposed end-conditions are adopted in our creation process, with five subjective and five objective end-conditions each. Researchers can then choose between the conceptual-to-empirical or the empirical-to-conceptual approach. The conceptual-to-empirical approach is based on conceptually derived dimensions that are tested against a sample of empirical objects to create or revise the taxonomy. Finally, the final conditions are checked to decide whether a new iteration round is required in the case that the final conditions are not met or whether the process can be terminated [42]. The study required four iterations to reach saturation in the design of the taxonomy. The first three iterations were conceptual–empirical. Only the last one was empirical–conceptual. Based on the literature generated by the research work, the data set consisting of 81 articles was randomly compiled within iterations 1–4. The first iteration served as a conceptual starting point and provided a general overview of the OBM, SBM and SOBM. The purpose of this research is to identify the dimensions and characteristics of SBMs, OBMs and SOBMs for the EIMI. The selection of metadimensions (MD) was based on the results and recommendation of [44], according to which a comprehensive view of the BM should include four MD when designing a taxonomy. Subsequently, Value Delivery, Value Proposition, Value Chain and Value Creation were defined as MD for the OBM, SBM and SOBM [45]. The dimensions were introduced and named in the process of creating the taxonomy, based on the understanding of business model components (BM components) according to [46]. Accordingly, a combination of the work of [45,46] was used for the conceptual design of the MD and dimensions. Furthermore, this provides an initial basic requirement for subsequent comparability at the MD level of the OBM, SBM and SOBM. Further details of the MD and dimensions follow in the results chapter (for an overview of the OBM and SBM, see Appendix B). The possibility to extend and reduce dimensions per taxonomy was given. Further iterations identified relevant characteristics. Through the in-depth investigation of possible design options, the fourth round fulfills the requirements for completeness and sufficient differentiability (Figure 2). Additionally, in the last iteration, we introduced the notion of exclusivity of characteristics, which we determined for every dimension.

	end conditions	1st	2nd	3rd	4th
Objective	All objects were analyzed. No object was merged with a similar object in the last iteration				X
	At least one object is classified under each characteristic of each dimension		X	X	X
	No new dimensions or features were added in the last iteration				X
	Each dimension is unique and is not repeated. Each characteristic is unique within its dimension			X	X
	Each combination of characteristics is unique and is not repeated			X	X
Subjective	Conciseness: Is the typology understandable and not overcrowded?			X	X
	Robustness: Are the dimensions differentiated enough?			X	X
	Completeness: Can all dimensions and characteristics be classified?			X	X
	Expandable: Can a further dimension be added?		X	X	X
	Explainable: Is the content explainable?		X	X	X

Figure 2. End conditions in accordance with [42], shown per iteration.

2.3. Phase 3: Synthesis and Interpretation of SOBM(f)

Based on the detailed development of the taxonomies for SBMs, OBMs and SOBMs, we focused on the extension of the SOBM(f)-final taxonomy. In addition to the SOBM, the extension using the SBM and OBM taxonomies serves as the basis for this. It is important to emphasize that the SOBM taxonomy, similarly to the taxonomies for OBM and SBM, was already outlined with characteristics and dimensions as part of the taxonomy development. Through this phase, we wanted to expand the design options for a SOBM(f).

The preliminary SOBM taxonomy has the attribute of extensibility required by [47]. This ultimately allows a comparison of the existing SOBM taxonomy with the characteristics of the SBM and OBM (see Appendix C for details) and the subsequent building of the SOBM(f) by integration and extension [48]. The aim was to determine which specific characteristics were possibly insufficiently represented in the SOBM taxonomy. Characteristics that were present in both the OBM and the SBM taxonomies but missing in the SOBM were included in the SOBM(f) taxonomy based on a group decision [49] of the research team through discussion and consensus building. The iterative approach enabled the comprehensive expansion and refinement of the SOBM(f) taxonomy.

Figure 3 schematically visualizes the merging process. Within the first merging (1), the SOBM characteristics were compared with the OBM characteristics and confirmed by, e.g., the recurrence of a characteristic or an extension by new characteristics. The second merging (2) consisted of the SOBM and SBM taxonomies. The procedure was identical to that in (1). In the final merge (3), OBM characteristics and SBM characteristics that were not yet in the SOBM were merged into one characteristic and included in the SOBM(f).

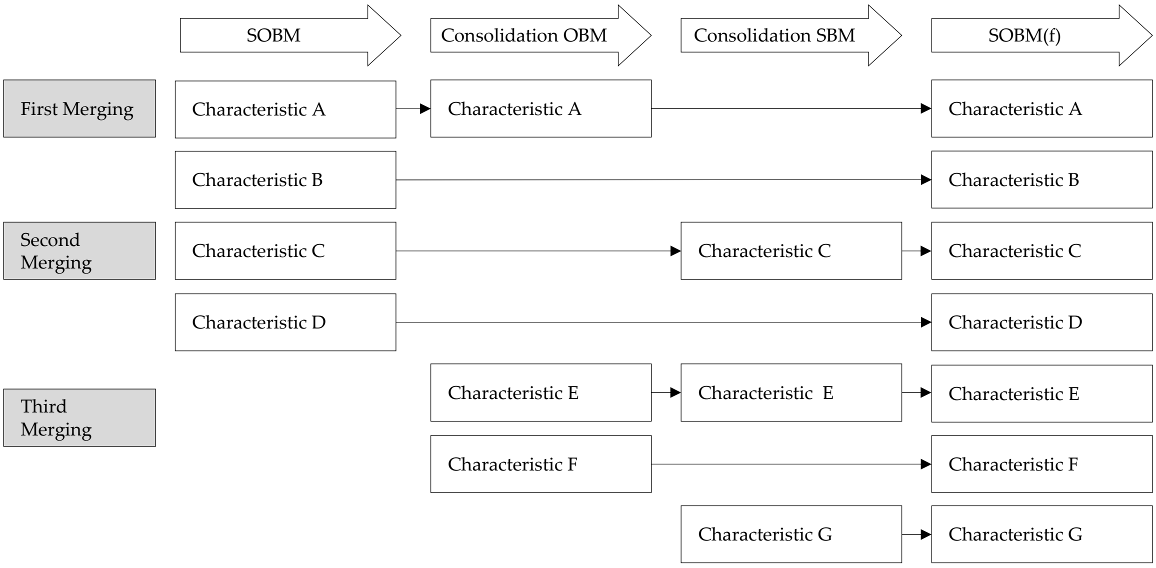

Figure 3. Schematic representation of the merging process.

2.4. Phase 4: Taxonomy Evaluation

To verify the validity and applicability of the identified characteristics, use case classifications validated them in a next step. The classifications were based on the publications identified in the research in the literature, thus establishing a direct link between the theoretical foundation and practical application. This method made it possible to confirm the relevance and necessity of each individual characteristic for the SOBM(f) taxonomy. Additionally, the SOBM(f) results were discussed with three EIMI experts to allow further verification of the results. This served to evaluate the specific characteristics within each dimension. The experts used a multiple-choice selection to confirm which characteristics were relevant as a potential design option for an SOBM in their company. The results of this survey were carefully analyzed, which not only gave the taxonomy a theoretical basis but also validated it in practice.

3. Results: Design Options for SOBM

3.1. MD of SOBM(f)

The final taxonomy is as follows: We structured the design options by means of superordinate theoretical lenses, so-called metadimensions (MD_n). The MDs and their Dimensions (D_n), as well as the identified characteristics ($C_{Dn,\, n}$), are presented below for each dimension.

Ts_{OBM} = {

MD_1 (Value Creation) {

D_1 (Strategic Collaboration) | C_1 (Inbound-Exchange, Coupled-Exchange, Outbound-Exchange) | EX = {N}},

D_2 (Key Partners) | C_2 (Political Decision Makers, Competitors, Customers, Research Institutions, Stakeholder Ecosystem, Suppliers, Industrial Symbiosis, Organization) | EX = {N}},

D_3 (Key Activities) | C_3 (Crowdsourcing, Customer Integration, Social Networking, Sharing Economy, Material Substitution, Reduction, Recycling, Collaboration, Open Innovation, Standardization, Reuse, Awareness for Sustainability) | EX = {N}},

D_4 (Key Resources) | C_4 (Open Data, Renewable Energies, Waste and By-Products, Value-Enhancing Exchange Resource, Knowledge, New Skills, Biogenic Raw Material, New open and/or sustainable Technologies, Financial Resource) | EX = {N}},

MD_2 (Value Proposition) {

D_5 (Value Proposition) | C_5 (Technological Progress, Maximizing Customer Benefit, Personalization, Personalization, Positive Social Value, Maximizing Material and Energy

Efficiency, Reducing Negative Environmental Impacts, Mass Customization, Product Responsibility across all Stakeholders) ∣ EX = {N}},

MD_3 (Value Delivery) {

D_6 (Customer Relationship) ∣ C_6 (Customer-Centric, Actively Communicate and Network, Inclusive, Awareness-Raising, Transparent, Trustworthy) ∣ EX = {N}},

D_7 (Customer Segments) ∣ C_7 (Community, Conventional, Health-Conscious, Ecologically Conscious, Financially Conscious, Innovation-Oriented,) ∣ EX = {N}},

MD_4 (Value Capture) {

D_8 (Cost Structure) ∣ C_8 (Investment Costs, Operating Costs, Personnel Costs, Development Costs, Production Costs, Maintenance Cost, Costs of Environmental Pollution or Protection) ∣ EX = {N}},

D_9 (Revenue Stream) ∣ C_9 (Customer Service Fees, Licensing Fees, Product Sale, Leasing, Sharing Model) ∣ EX = {N}}}

3.1.1. MD_1: Value Creation

The BM components of value creation describe how value is created. These activities include the development, production, marketing and delivery of products and services. In addition, the MD includes resources and relationships with strategic partners [45]. In addition, forms of cooperation and the flow of exchange between companies and stakeholders are analyzed. Value creation includes the dimensions of strategic cooperation (D_1), key partners (D_2), key activities (D_3) and key resources (D_4).

Strategic Cooperation (D_1): Inbound exchange ($C_{1,1}$) allows the inflow of ideas, technologies and knowledge from outside into the company [2]. Practices are, for example, participation in development alliances, crowdsourcing, or the establishment of joint ventures [50]. Coupled exchange ($C_{1,2}$) is characterized by collaboration between companies and external partners [51], whereby knowledge, skills and ideas are combined, and risks and costs are shared [22]. Outbound exchange ($C_{1,3}$) is the process in which a company provides its own innovations externally to enable collaboration with other organizations [52,53].

Key Partners (D_2): Through constructive dialog and cooperation with political decision-makers ($C_{2,1}$), companies can contribute to the development of framework conditions that promote innovation and support sustainable business [54]. By sharing and pooling resources, companies can realize efficiency advantages and reduce costs through cooperation with competitors ($C_{2,2}$) [55]. Customers ($C_{2,3}$) are not just recipients of products, but essential partners in the innovation landscape [7,56]. Their diversity enriches the pool of ideas, promotes the development of inclusive offerings and motivates companies to integrate sustainability into their core strategies [30]. Cooperation between companies and research institutions ($C_{2,4}$) such as universities is a key performance factor in the context of ecological innovation [30]—from technology transfer to the co-creation of knowledge [24]. The stakeholder ecosystem ($C_{2,5}$) is defined by the connection that is created through the exchange of materials and energy between the different actors [57]. The circulation of resources takes place within the ecosystem, as it offers considerable advantages to the participating stakeholders and makes it attractive to participate in a certain ecosystem [58]. The integration of suppliers ($C_{2,6}$) through cooperation or bilateral dialog is essential, as they are often directly involved in the value chain and thus have a direct influence on the sustainability of products and services [59] and the effective implementation of sustainability goals [60]. The concept of industrial symbiosis ($C_{2,7}$) is characteristic of the EIMI and describes the development of symbiotic relationships, for example, the exchange of waste and by-products, such as that between industrial partners and stakeholders [56]. Organizations ($C_{2,8}$), whether NGOs or industry associations, have specialized knowledge, networks and resources that companies can use to achieve their goals more effectively [30].

Key Activities (D_3): Crowdsourcing ($C_{3,1}$) allows companies to draw on externally available, open knowledge, whereby they rely on the input of a broad and heterogeneous pool of knowledge providers such as customers, experts, or suppliers [53]. Through customer integration ($C_{3,2}$), companies can develop their products and services to meet the needs and expectations of consumers and thus adapt the value proposition of the company [61]. Companies increasingly rely on open platforms to create and maintain an innovative ecosystem [62]. Social networking ($C_{3,3}$) contributes to the development of innovations with a variety of external resources in the sense of collaborative value creation [53]. The sharing economy ($C_{3,4}$) entails using products from third parties by exchanging, lending, or renting them without any change of ownership [63]. Material substitution ($C_{3,5}$) involves the replacement of non-finite resources with renewable and/or natural substitutes [10]. Reduction of resource consumption ($C_{3,6}$) refers to activities in which the amount of material resources required for product manufacture or service production is reduced [64], and the environmental impact is subsequently reduced [10]. In recycling ($C_{3,7}$), the product development process already ensures that the products are composed of reusable materials, thus reducing waste [65]. Companies usually assume extended responsibility for the product over the entire product life cycle [63]. Collaboration ($C_{3,8}$) represents an opportunity to multiply the sources of value creation [66] through working with partners, suppliers, customers and other stakeholders [59] and can enable long-term corporate growth [24]. Open innovation ($C_{3,9}$) is considered an effective innovation approach [67], in which companies combine internal and external knowledge to develop new ideas that can be shared and implemented with other companies [68]. According to [36], standardization ($C_{3,10}$) is one of the mechanisms within an ecosystem that is used to achieve the goals of the circular economy. In terms of the circular approach, 'reuse' ($C_{3,11}$) means that products are designed to be used for several consumption cycles [63]. Creating awareness for sustainability ($C_{3,12}$) as a company among its stakeholders promotes sustainable innovation, and, as a result, the successful marketing of sustainable products [69].

Key Resources (D_4): Companies use open data ($C_{4,1}$) and the publication of their intellectual property to promote competition, develop a market and strengthen their position as market leaders, with open data helping to drive innovation and transparency [33]. Renewable energy ($C_{4,2}$) becomes more accessible due to the increasing affordability of technologies and systems [10], while open exchange and collaborations drive the development of new solutions for renewable energy production [14]. Using waste and by-products ($C_{4,3}$) increases resource efficiency and reduces waste by using by-products from agriculture or other industries as input products [58]. Value-enhancing exchange resources ($C_{4,4}$) create additional value for companies through the circular exchange of assets, information, or monetary resources, which promotes sustainable and innovative value creation [68,70]. Knowledge ($C_{4,5}$) enables companies to increase the sustainability of their offerings and intensify their innovation activities through collaboration [71]. The partners' knowledge helps to promote innovative capability and effectively address market failures [30]. Companies acquire new capabilities ($C_{4,6}$) from outside [72], understood as additional knowledge and competencies gained through collaborations and dynamic exchange in ecosystems [73], to increase the potential for sustainable value creation and innovation [74]. Biogenic raw materials ($C_{4,7}$) are used in various industries and vary depending on the location in the form of biomass, such as organic waste, crops, sewage sludge or field biomass [58]. New open and/or sustainable technologies ($C_{4,8}$) are innovative solutions that are publicly available and aim to reduce environmental impact and improve resource efficiency [74]. Financial resources ($C_{4,9}$) are essential for companies to make investments, drive sustainable innovation, and support operations [68].

3.1.2. MD_2: Value Proposition

The value proposition (D_5) describes a company's intended product or service offering and specifies the value provided to target customers. In addition, the BM components constitute the basic statement of the company's strategy on how to compete by emphasizing the specific value that the company offers compared to the competition, thus defining the unique advantage customers receive by selecting this company [45].

Value Proposition (D_5): Technological progress ($C_{5,1}$) describes a company's promise to create significant added value for customers [75] using the latest technologies [76], to make processes more efficient and to achieve a competitive advantage [77]. Maximizing value ($C_{5,2}$) for the customer describes a company's commitment to delivering innovative features [76] and the highest possible value through pricing in order to meet customer needs and expectations optimally [73]. Personalization ($C_{5,3}$) refers to a company's promise to offer significant added value and strengthen customer loyalty through customized products and services that are directly tailored to individual customer needs and wishes [73]. Positive social added value ($C_{5,4}$) is created through contributions to social development and the companies' commitment to the environment, society and social and ethical values [78]. Maximizing material and energy efficiency ($C_{5,5}$) describes a company's efforts to offer cost-effective [79] and sustainable products and services that both minimize environmental impacts and create competitive advantages through resource-efficient production methods, innovative manufacturing techniques [10] and a circular economy [10]. Reducing negative environmental impacts ($C_{5,6}$) emphasizes a company's commitment to minimizing environmental and social impacts through innovative, environmentally friendly processes and products, resulting in a healthier, more economical and environmentally friendly experience for customers [59]. Mass customization ($C_{5,7}$) aims to address individual customer needs through customizable standard products, offering both cost efficiency and product diversity and promoting long-term customer loyalty [73]. Product responsibility across all stakeholders ($C_{5,8}$) emphasizes the shared commitment of all stakeholders in the value chain to minimize environmental and social impacts and promote sustainable development, creating value for customers and other stakeholders [59].

3.1.3. MD_3: Value Delivery

Value delivery describes the process by which a company provides and delivers the promised value to its customers [45]. The MD_3 comprises the interaction and communication with the customer and is described by the customer relationship (D_6) and customer (D_7) segments.

Customer Relationship (D_6): Companies focus on understanding and implementing the needs and requirements of customers and ensure an improved customer relationship through a customer-centric ($C_{6,1}$) approach [80]. They communicate actively ($C_{6,2}$) with customers at an early stage [79] and exchange information to create a sense of community and thus strengthen customer loyalty. To overcome the seller–buyer relationship [81], they ($C_{6,3}$) integrate customers into development, production and product life cycle processes [63]. The BMs of companies and corporate responsibility for their environmental impact can actively contribute to raising awareness ($C_{6,4}$) of sustainability issues in the value network [10,59]. Transparency ($C_{6,5}$) towards customers promotes openness and simplifies access to feedback to identify optimization potential and adjust strategic decisions. Creating credibility and trust ($C_{6,6}$) for sustainable products is crucial, especially through high integration and interaction with stakeholders, as environmental and social characteristics are often invisible [59].

Customer Segment (D_7): Communities ($C_{7,1}$) have a high potential as a driver for joint value creation and give companies access to external resources [73]. Conventional customers ($C_{7,2}$) prefer standardized products and services that can be selected from a catalog [82]. By adapting the companies' product portfolio with regard to health and sustainability, health-conscious ($C_{7,3}$) customers can be addressed [10]. Ecologically conscious ($C_{7,4}$) customers prefer to buy from sustainability-conscious companies and are often willing to pay a price premium for sustainable products [14]. Customers who pay great attention to a good price–performance ratio and thus infer product quality from the price [83] are referred to as financially aware customers ($C_{7,5}$). Innovation-oriented ($C_{7,6}$) customers help to drive innovation, improve products and develop new solutions to challenges [53].

3.1.4. MD_4: Value Capture

Value capture describes how a company earns money and creates other forms of value. This includes the revenue stream (D_9), which shows the different sources of revenue and options for how the company can generate financial resources for its products. In addition, the BM components include the cost structure (D_8), which captures the total costs, profit margins and costs of operating the business model [45].

Cost structure (D_8): Within a stakeholder ecosystem, individual companies can bear investment costs ($C_{8,1}$) to support the entire ecosystem. The results of the work of [14] show that by engaging in a network with other companies, with the aim of BMI, companies can achieve reductions in operating costs ($C_{8,2}$) in the long term [14]. Personnel costs ($C_{8,3}$) include expenses, such as salaries, social and additional benefits, costs for equipping workplaces, or personnel development costs [69]. Development costs ($C_{8,4}$) [69] are required to drive innovation and sustainability processes forward. Production costs ($C_{8,5}$) are incurred during the creation of products or services, including costs for raw materials, energy, and disposal [2]. Access to low-cost power supply options can make a significant difference to production costs. Maintenance costs ($C_{8,6}$) are expenses for the proper functioning of machines and buildings [2]. Costs of environmental pollution or protection ($C_{8,7}$) are incurred through compliance with sustainable norms and standards and are paid in the form of taxes or subsidies [2].

Revenue Stream (D_9): Revenue can be generated by offering service and maintenance packages for customers [69] via customer service fees ($C_{9,1}$) [56]. Licensing ($C_{9,2}$) generates income on the basis of a technology transfer (e.g., product licenses) for which the customer must pay a fee [84]. The classic product sale ($C_{9,3}$) is that of assets or services [25]. In leasing ($C_{9,14}$), exclusive usage rights to the product are leased for a certain period, while the ownership relationship remains with the provider [85]. In the sharing model ($C_{9,5}$), several customers can use the product or service jointly, and [2] the functionality is provided by the provider instead of ownership [10].

Figure 4 illustrates the final taxonomy for the design of SOBM(f) as a morphological field [86]. We chose this type of visualization because it gives an intuitive insight into how such taxonomies work.

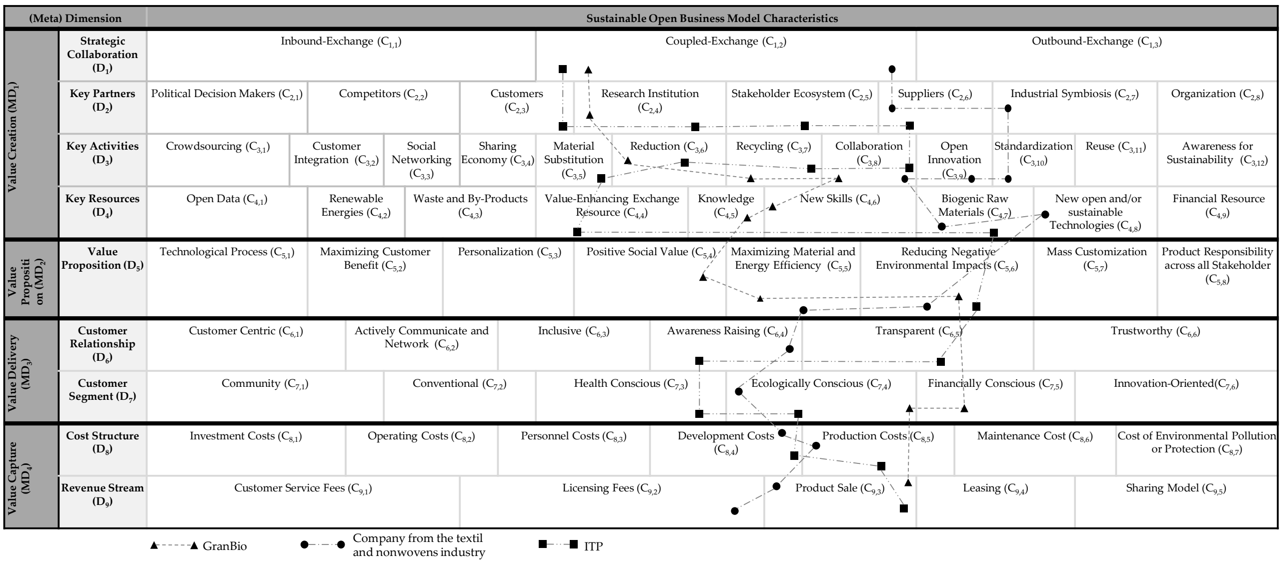

Figure 4. Design options for SOBM(f) and three exemplary applications.

3.2. Evaluation of SOBM(f)

Figure 4 shows an overview of the SOBM(f) taxonomy with the classification of specific case companies. The applicability of the taxonomy can be confirmed by the classifications of the case studies. In the following, the design options of an SOBM are examined in more detail using the three case studies and their BMs.

The case study of GranBio [87,88], a Brazilian company, illustrates the integration of sustainability and innovation in the BM to produce bioethanol from waste and by-products from sugar cane fields. By converting previously discarded and burned sugarcane bagasse and straw into biofuels, GranBio addresses not only environmentally conscious but also economically oriented customer groups by offering one of the lowest prices for biofuel product sales worldwide. This approach is reflected in GranBio's extensive international collaborations and research communities, through which the company continuously develops new solutions to reduce negative environmental impacts by recycling input products. Since 2013, GranBio has been working with the US clean-tech company American Process Incorporated (API) and is part of international projects exploring further solutions. These partnerships not only expand the company's knowledge and capabilities in the field of biomass utilization but also contribute to the reduction of resource consumption. GranBio, which was ranked among the world's most sustainable companies in 2013, aims to create sustainable solutions for a better world through innovation. This strategic focus enables GranBio to generate both ecological and social added value, making the company a leading example of the successful combination of ecological awareness and financial efficiency.

The selected company in [89] specializes in the production of staple fibers for the textile and nonwoven industries. By using its efficient production processes and biogenic resources, it minimizes environmental impact and sets new standards in material and energy efficiency. Collaboration with international partners enables scaling and open innovation, strengthens the supplier ecosystem and promotes the development of sustainable production chains. In addition to direct product sales, the company explores flexible BMs, including licensing its technology and establishing joint ventures, such as a potential partnership with another company to establish a jointly operated fiber production company. These collaborations help optimize the cost structure, especially in terms of development and production costs, enabling the company to price its products competitively. The company takes a leading role in ecological responsibility by transparently communicating its sustainable practices and thus addressing ecologically aware consumers.

The company ITP [90] specializes in producing and marketing collection films for secondary packaging, focusing on the preservation of food and protecting products such as bathtubs, furniture and caravans. The aim is to significantly reduce the material used by reducing the layer thickness and using biogenic raw materials. These efforts not only contribute to recycling but also promote the replacement of conventional plastic with sustainable alternatives. In collaboration with leading partners such as packaging solutions manufacturer Dow Chemical, printing and laminating technology specialist Proteco and pouch-making machine manufacturer Elba, the company has created an ecosystem encompassing the entire value chain. These collaborations make it possible to use biogenic raw materials to add value and develop innovative packaging systems that optimize production and development costs while minimizing environmental impact. The company acts transparently by openly communicating its commitments and achievements, such as the ISO 14001 certification for its environmental management system. The company sets new standards in the packaging industry by developing and marketing packaging solutions that respond to market trends, new forms of social and ethical awareness, environmental protection, and pollution reduction, enabling it to attract a wide range of customers.

In summary the selected use case examples from the EIMI can be classified very well in the SOBM(f) based on their BMs, thus confirming the applicability of the taxonomy.

To build on the theoretically oriented validation of the use case results, a practice-oriented validation was carried out with three experts from EIMI. In the beginning, the experts were introduced to the topic of SOBM. The experts were asked to give their assessments of each characteristic based on its practicability and how it could be integrated into an SOBM in the corporate context. The experts made their assessments via a multiple-choice selection by choosing applicable characteristics per dimension. The results were validated carefully, with analysis of agreements and deviations among the experts' assessments. This analysis made it possible to identify characteristics associated with each dimension where there was broad agreement, as well as areas where differences of opinion might indicate the need for further investigation or adaptation. The consistent confirmation of certain design options across different experts and industries highlights their relevance and applicability for developing SOBMs.

In the context of the strategic cooperation dimension, all experts confirmed that $C_{1,1}$-$C_{1,3}$ could be possible design options for an SOBM in their company. The importance of key partnerships, particularly with customers and suppliers, in the context of industrial symbiosis, was highlighted. Collaboration with competitors was generally rated as less conceivable. In terms of key activities, recycling, open innovation and collaboration were clearly preferred, while social networking and sharing-economy models were considered less relevant. Confirmations of characteristics within the key resources dimension included renewable energy and new open and/or sustainable technologies. It should be noted that financial resources were not mentioned as a key resource for the SOBM. According to the experts, the value proposition of SOBMs focuses on product responsibility across all stakeholders, technological progress and reducing negative impacts on the environment. Less focus was given to personalization and mass customization. According to the experts, the customer relationship could be designed to be customer-oriented and transparent, whereas the active involvement of customers is rather inconceivable. In the future, ecologically conscious customer segments should be addressed in order to have buyers for sustainable products. The experts agreed that manufacturing, investment and operating costs are key aspects of an SOBM. As sources of revenue, product sales and performance-based models, as well as licensing, were preferred. Sharing was not considered a relevant source of revenue for SOBMs.

The second validation approach links the theoretical foundation and practical application. This link is crucial to ensure the relevance and feasibility of the theoretically identified characteristics in real business contexts. However, the results of the validation show that despite the general confirmation of the majority of the characteristics by the experts, there are specific differences of opinion regarding the applicability and importance of individual aspects. Of the 64 characteristics examined, 55 were confirmed as relevant by all experts or by individual mentions. This finding makes it clear that all experts consider certain characteristics indispensable for implementing an SOBM(f), which highlights the universal importance and acceptance of these characteristics. At the same time, there are characteristics that were only considered relevant by some of the experts, indicating different perspectives and possibly company-specific contexts. The fact that the expert survey confirmed a significant number of characteristics speaks for the validity of the current design of the SOBM(f). Accordingly, the current design of the SOBM(f) can provide a solid basis for the development and implementation of SOBMs and can be considered validated, with the identified differences of opinion providing valuable starting points for future research and adaptation.

4. Discussion and Conclusions

This research significantly contributes to the scientific discussion on the BM, particularly regarding sustainable and open design options and their classification in taxonomies. Expanding the existing knowledge base has created a reference point for companies, simplifying future BM designs in the context of decarbonization. Using the developed taxonomy SOBM(f), it was possible to answer the research question of how companies from the EIMI can manage the drivers of decarbonization through SBMI. The SOBM(f) can serve as a basis for discovering and unlocking the potential of BM's SBMI by integrating specific characteristics.

The developed SOBM(f) taxonomy has made it possible to recognize and integrate the strengths and similarities of the investigated models (SBM and OBM), thus merging two streams of research and expanding the research space. Nonetheless, deciding which options should be chosen according to the specific drivers of decarbonization remains a question to be explored from an entrepreneurial perspective. Future research could focus on how decision-making can be performed strategically regarding the design of a BM to address decarbonization drivers in companies.

Future research directions could include the introduction of weighting factors to better assess and prioritize the different design options within the SOBM(f). Developing decision-making models that guide companies in structuring and implementing SOBMs in alignment with decarbonization goals is another promising area. These models can incorporate multi-criteria decision analysis (MCDA) techniques. Additionally, investigating the impacts of various BM configurations on sustainability outcomes could provide valuable insights. Examining how these configurations influence environmental, social and economic aspects can help identify the most effective strategies for SBMI.

The application of the search string and the specific focus on the EIMI implied that additional relevant literature was not considered in the development of the SOBM(f). When selecting the articles, particular attention was paid to the concept of the BM and its priority over the concepts of openness or sustainability. To address this, a backward search was carried out to expand the coverage. The methodological focus of the taxonomy creation on the defined meta-characteristic, as well as the purpose and target group, led to the exclusion of potential design options for SOBM that did not meet these criteria. The restricted number of researchers involved in the taxonomy consolidation process limited the diversity of perspectives. Furthermore, the evaluation of the taxonomy could be carried out in comparison with existing BMs in practice to validate and deepen the results beyond the published use cases in the science.

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Appendix A. Details of the Structured Literature Review

To illustrate and summarize the process of our systematic literature search, we have created an overview based on [37] (Figure A1). This overview shows how many articles were identified in the systematic review, pre-selected and then integrated into the analysis in the qualifying review.

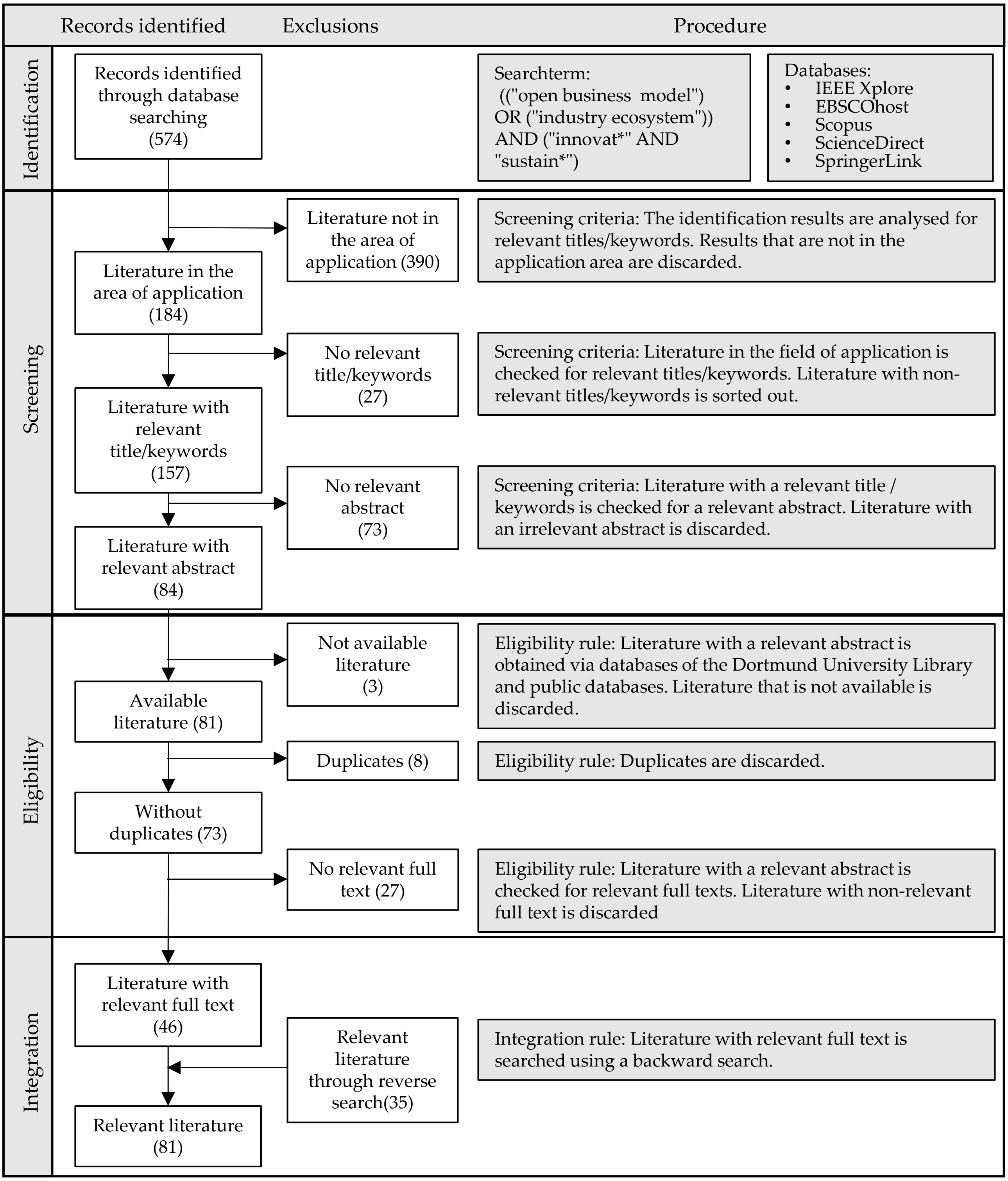

Figure A1. The literature review process.

Appendix B. Taxonomy Development of OBM and SBM

The taxonomies of the OBM and SBM, which serve as the basis for the extension of the SOBM(f) taxonomy, are shown below.

T_{OBM} = {

MD_1 (Value Creation) {

D_1 (Strategic Collaboration) | C_1 (Outbound-Exchange, Inbound-Exchange, Coupled-Exchange) | EX = {N}},

D_2 (Key Partners) | C_2 (Research Institutions, Political Decision Makers, Competitors, Suppliers, Customers, Industrial Symbiosis) | EX = {N}},

D_3 (Key Activities) | C_3 (Crowdsourcing, Collaboration, Customer Integration, Open Innovation) | EX = {N}},

D_4 (Key Resources) | C_4 (Knowledge, Value-Enhancing Exchange Resource, Financial Resource, New Skills, New Technologies, Open Data) | EX = {N}},

MD_2 (Value Proposition) {

D_5 (Value Proposition) | C_5 (Technological Progress, Maximizing Customer Benefit, Personalization, Mass Customization, Ecological Benefit, Positive Social Value) | EX = {N}},

MD_3 (Value Delivery) {

D_6 (Customer Relationship) | C_6 (Inclusive, Integrating Customer Feedback, Customer-Centric, Actively Communicate and Network, Transparent) | EX = {N}},

D_7 (Customer Segments) | C_7 (Community, Conventional, Innovation-Oriented) | EX = {N}},

MD_4 (Value Capture) {

D_8 (Cost Structure) | C_8 (Development Costs, Production Costs, Personnel Costs, Investment Costs, Operating Costs) | EX = {N}},

D_9 (Revenue Stream) | C_9 (Licensing Fees, Customer Service Fees, Leasing, Product Sale) | EX = {N}}}

T_{SBM} = {

MD_1 (Value Creation) {

D_1 (Key Partners) | C_1 (Stakeholder Ecosystem, Customers, Suppliers, Industrial Symbiosis, Political Decision Makers) | EX = {N}},

D_2 (Key Activities) | C_2 (Reduction, Reuse, Recycling, Collaboration, Open Innovation, Material Substitution, Standardization, Awareness for Sustainability) | EX = {N}},

D_3 (Key Resources) | C_3 (Waste and By-Products, Renewable Energies, Biogenic Raw Materials, Energy-Efficient Technologies, Water-Efficient Technologies) | EX = {N}},

MD_2 (Value Proposition) {

D_4 (Value Proposition) | C_4 (Maximizing Customer Benefit, Product Responsibility across all Stakeholders, Fulfilling the Needs of the Value Chain, Social Value and Justice, Maximizing Material and Energy Efficiency, Reducing Negative Environmental Impacts) | EX = {N}},

MD_3 (Value Delivery) {

D_5 (Customer Relationship) | C_5 (Actively Communicate and Network, Inclusive, Awareness-Raising, Trustworthy, Reverse Logistics) | EX = {N}},

D_6 (Customer Segments) | C_6 (Health-Conscious, Financially Conscious, Ecologically Conscious, Conventional) | EX = {N}},

MD_4 (Value Capture) {

D_7 (Cost Structure) | C_7 (Operation Cost, Maintenance Cost, Costs of Environmental Pollution or Protection) | EX = {N}},

D_8 (Revenue Stream) | C_8 (Sharing Model, Leasing) | EX = {N}}}

Appendix C. Illustration of Merging Steps 1–3 According to the Business Model Components

Providing more detail, Figures A2–A10 show the merging of the characteristics within the interpretation and synthesis step. The presentation is specific to the business model component. Starting with the component, the initial basis of the SOBM is shown, and then, via (1), (2) and (3), the extension of the characteristics up to the SOBM(f).

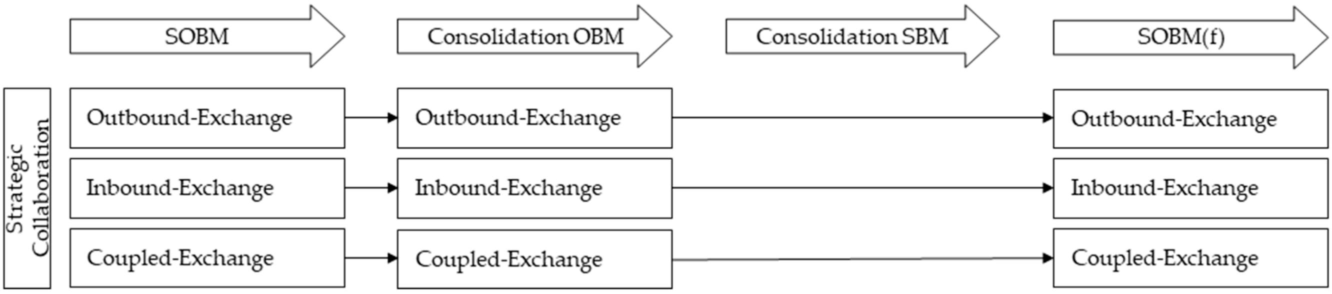

Figure A2. The merging process for Strategic Collaboration.

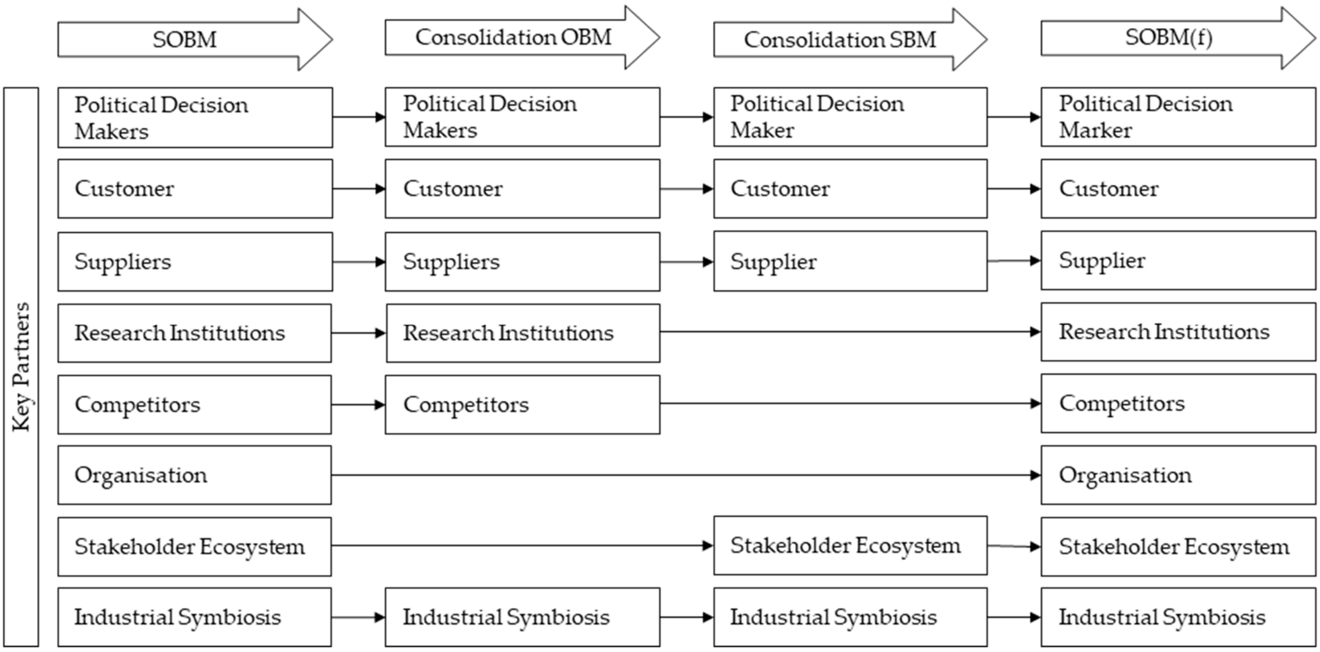

Figure A3. The merging process for Key Partners.

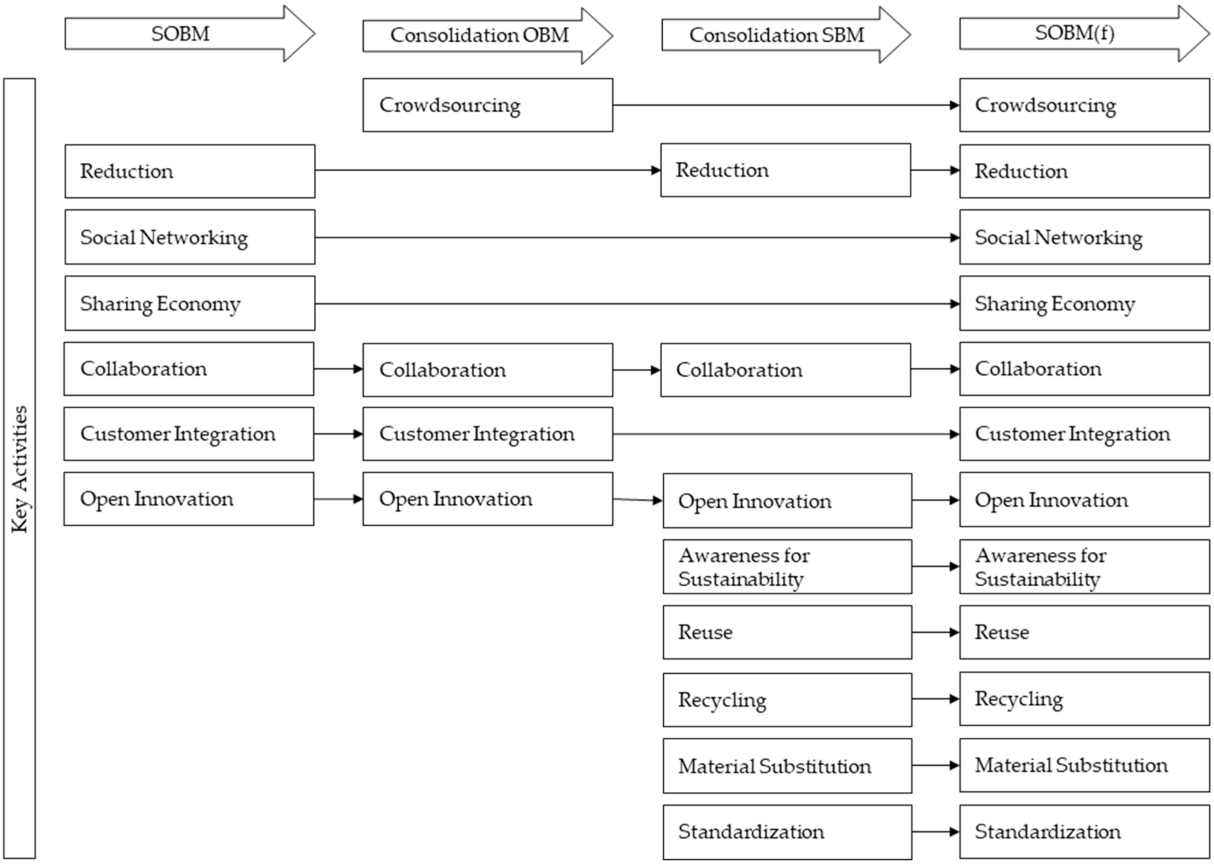

Figure A4. The merging process for Key Activities.

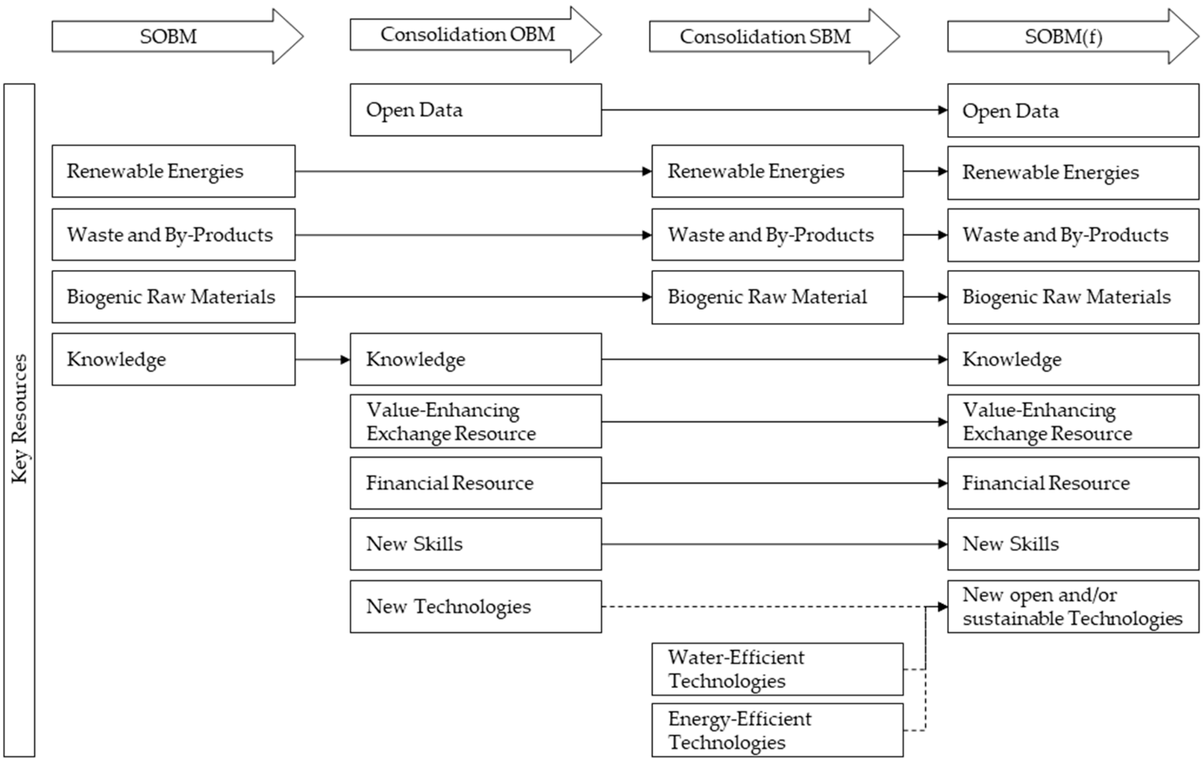

Figure A5. The merging process for Key Resources.

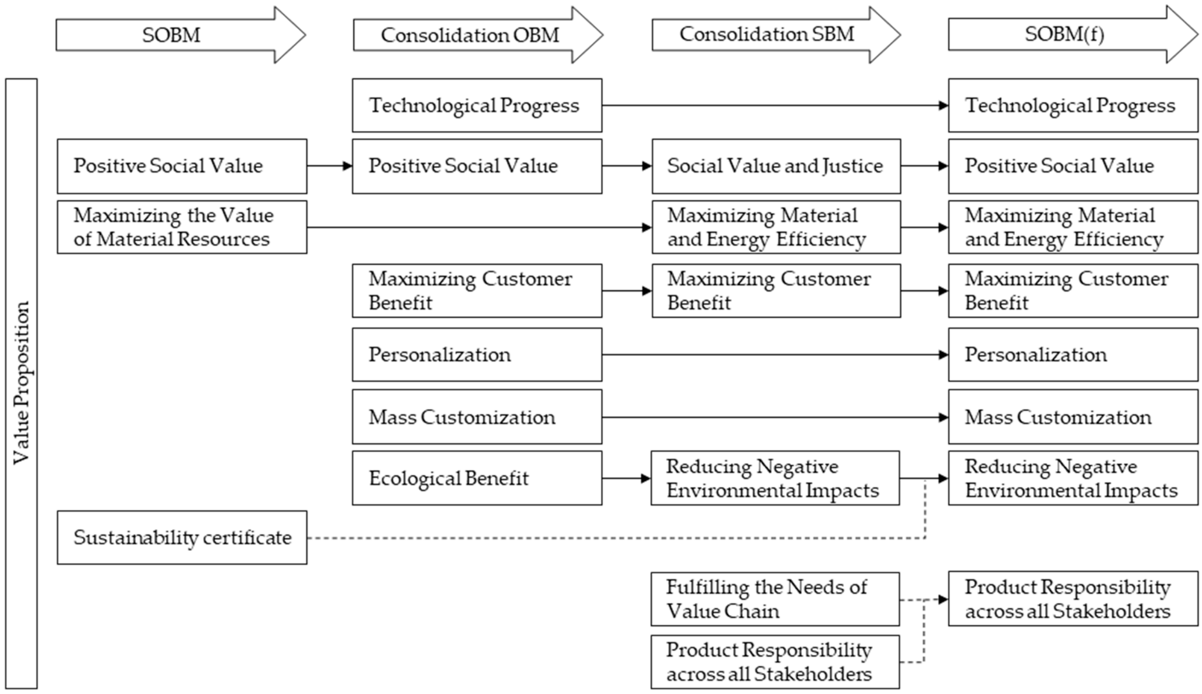

Figure A6. The merging process for Value Proposition.

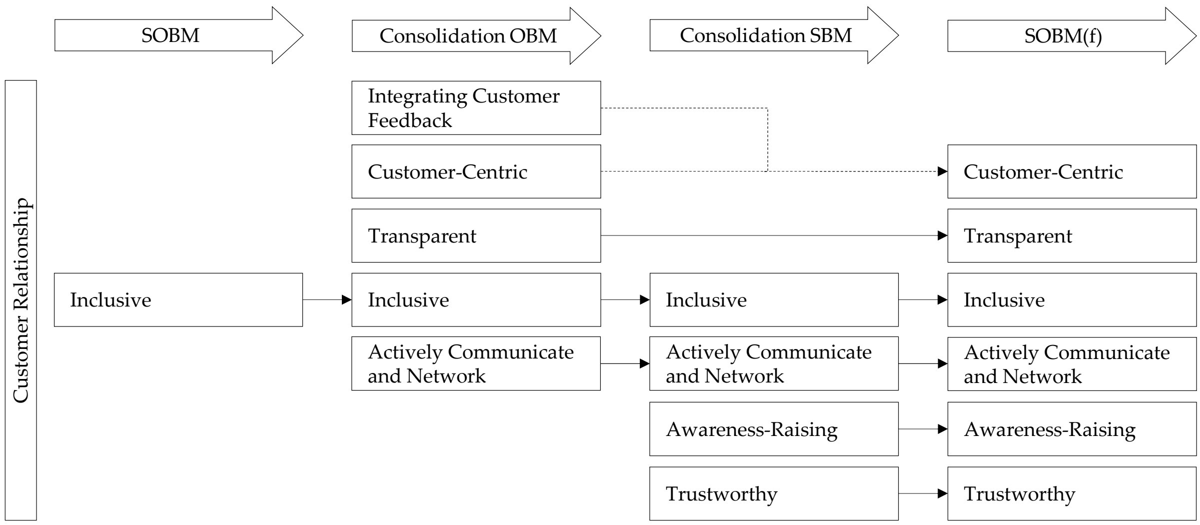

Figure A7. The merging process for Customer Relationship.

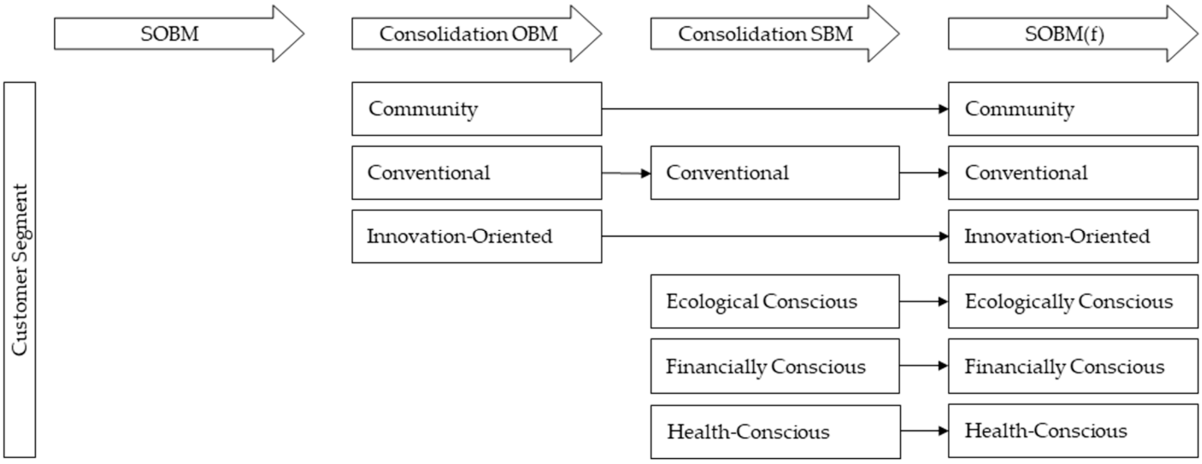

Figure A8. The merging process for Customer Segment.

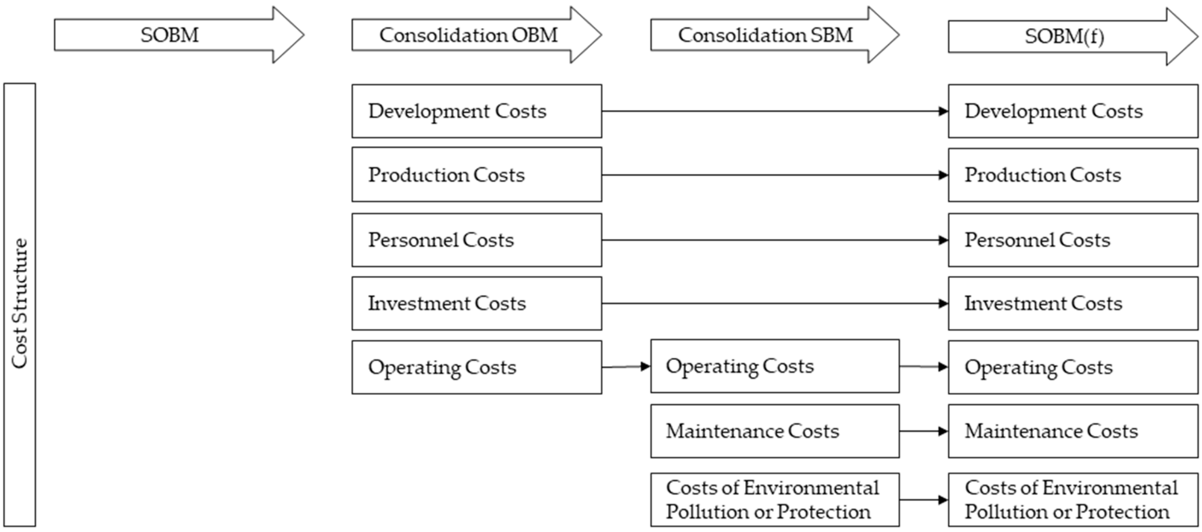

Figure A9. The merging process for Cost Structure.

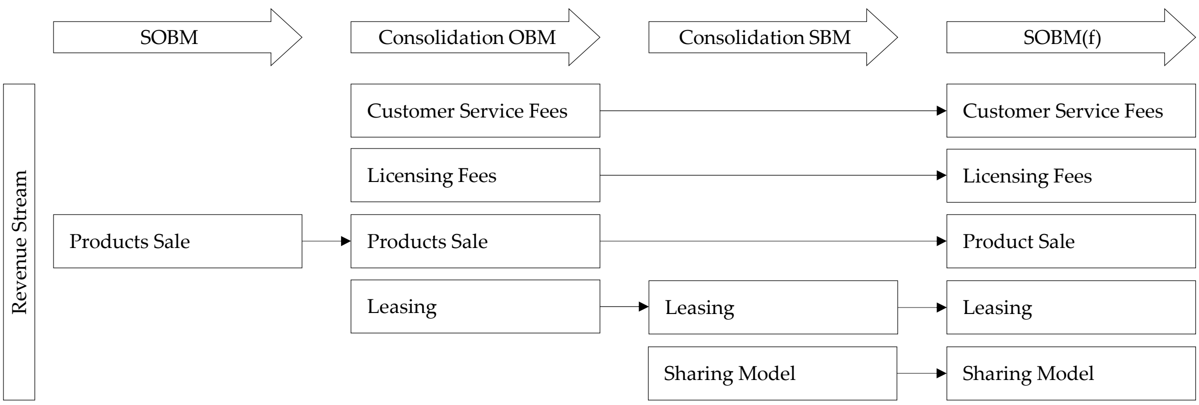

Figure A10. The merging process for Revenue Stream.

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