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Business model patterns of sustainability pioneers - Analyzing cases across the smartphone life cycle

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ABSTRACT

The production and consumption of smartphones have been associated with a wide range of sustainability issues throughout the life cycle. While the dominant industry practices and resulting social and ecological problems have been discussed in depth in the extant literature, it has not been investigated so far how sustainability pioneers alleviate unsustainability in the smartphone industry through their business models. Addressing this gap, this exploratory multiple case study analyzes sustainable business models of 16 sustainability pioneers along the entire smartphone life cycle. Based on a variety of business model designs in the sample, the findings reveal seven sustainable business model patterns that are explained in terms of their value proposition, value creation and delivery, and value capture. One key finding is that most patterns extend beyond a single life cycle phase into other phases, which allows them to develop more comprehensive solutions than single-phase sustainable business models. This article furthermore discusses how sustainable business models of pioneers address sustainability issues of the smartphone industry. Comparing empirical insights with the emerging sustainable business model concept shows that the 'ideal' sustainable business model suggested in academic literature could not be observed. This article concludes with implications for sustainable business model research and practice. First, solving the industry's sustainability issues comprehensively requires a combination of pioneering sustainable business models and collaboration of actors. Second, the sustainable business models explored in this study provide design options for pioneer and conventional smartphone companies alike.

1. Introduction

Since their commercial breakthrough in the late 2000s, smartphones have become a key communication device. Despite the economic and consumer value created by the industry, smartphone production and consumption lead to several negative social and ecological consequences (Bridgens et al., 2017). Analyses of the impact of a smartphone throughout its physical life cycle (LC) have detailed many issues such as severe ecological and health impacts of resource extraction or human rights violations related to conflict minerals (Wilhelm et al., 2015). Life cycle analyses suggest that addressing sustainability issues of smartphones requires a lens that accounts for all life cycle phases, i.e. from resource extraction through end-of-life (Moberg et al., 2014). Together, these problems call for significant improvements in terms of cleaner production, sufficient consumption and effective recycling of smartphones. This study therefore adopts the perspective of the physical product life cycle (Suckling and Lee, 2015) covering resource extraction and processing, design and manufacturing, distribution and network provision, usage, and end-of-life. Other life cycle perspectives in marketing (Anderson and Zeithaml, 1984), organizational change (Benn et al., 2006) or business model evolution (Muzellec et al., 2015) are not closely related to cleaner production, consumption, and recycling of a physical product in general, and smartphones in particular.

Moreover, this article adopts a business model perspective that expresses "the business logic of a specific firm" (Osterwalder et al., 2005: 10) and helps explaining how firms integrate sustainability into their core business (Bocken et al., 2014). This is necessary because the sustainability problems throughout the life cycle are to a large extent shaped by the industry's dominant business models,

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which focus on selling high numbers of smartphones that are replaced after a short use phase (Boons and Lüdeke-Freund, 2013). While these industry-leading companies are highly innovative (Wilhelm et al., 2015), their business models are primarily driven by an economic rationale with insufficient consideration of social and ecological impacts (Wernink and Strahl, 2015). The transformation of the smartphone industry towards sustainability, therefore, calls for radically different sustainable business models (SBM; Schaltegger et al., 2012). These SBMs explicitly and systemically address impacts on stakeholders and the natural environment (e.g. Stubbs and Cocklin, 2008; Freudenreich et al., 2019).

Hockerts and Wüstenhagen (2010) argue that sustainability-oriented innovations with the potential to induce transformation of unsustainable industries are frequently initiated by pioneering companies. Sustainability pioneers develop proactive sustainability strategies which entail "systematic patterns of voluntary practices that go beyond regulatory requirements" (Aragón-Correa and Rubio-López, 2007: 258) and which are realized through their business models (Casadesus-Masanell and Ricart, 2010). Given their transformational role in other industries such as textiles, energy or mobility (Schaltegger et al., 2016b), pioneers represent a promising subject of study. Indeed, sustainability pioneers in the smartphone industry such as Fairphone (Akemu et al., 2016) have started to develop SBMs that integrate social and environmental considerations into their core business (Stubbs and Cocklin, 2008).

In this regard, the literature presents several research gaps. First, previous studies have mostly focused on the exemplary case of Fairphone (e.g. Wernink and Strahl, 2015). However, the existence of other pioneers with viable SBMs that improve the sustainability of smartphones in different ways or LC phases calls for a multi-case research method to capture the breadth of possible approaches. Second, several conceptual solutions have been proposed in the literature such as modular designs and product-service systems (Bridgens et al., 2017; Suckling and Lee, 2015). The number of failed modular smartphone projects (e.g. Hankammer et al., 2018) illustrates that many solutions do not necessarily create enough customer value to be viable in practice. If a sustainability innovation fails in the market due to an unsuitable business model, it will not contribute to a sustainability transformation (Boons and Lüdeke-Freund, 2013). Due to this, "products have to be seen in the context of their specific business models" (Proske and Jaeger-Erben, 2019: 65), which is missing in the smartphone-related literature. This requires more empirical research into how SBMs in the smartphone industry create social and environmental value in an economically viable way. Third, studies tend to focus on one specific LC phase, for instance usage (e.g. Riisgaard et al., 2016). In order to understand how the sustainability of smartphones can be improved comprehensively, however, SBMs need to be analyzed across all life cycle phases.

This paper, therefore, addresses the research gap of how different SBMs can address socio-ecological issues of the smartphone life cycle in practice. The research is guided by the following questions: *What kind of sustainable business models have been developed by sustainability pioneers in the smartphone industry to address sustainability issues? How do these sustainable business models create value from addressing sustainability issues?*

This study contributes to the debate about the sustainability of smartphones in several ways. Extending the scope to multiple cases renders a more elaborate empirical picture of how different SBMs shape a more sustainable (smartphone) life cycle (Hansen et al., 2009). The analysis reveals seven smartphone-related SBM patterns focusing on different stages in the life cycle, which are discussed with regard to how they create value by addressing sustainability issues. These patterns can provide guidance for others – especially sustainability laggards – in the smartphone industry for their own sustainability transformation endeavors (Schaltegger et al., 2016b). Beside the industry-focused analysis, we also contribute more broadly to the "emerging field" of SBMs (Lüdeke-Freund and Dembek, 2017: 1674).

The remainder of this paper is organized as follows. The literature review in Section 2 describes sustainability issues along the smartphone life cycle and introduces the concept of sustainable business models. Section 3 explains the research methodology. The results are presented in Section 4 and discussed against extant literature in Section 5. The paper concludes in Section 6 with a summary, contributions to sustainable business model research and managerial implications, limitations and suggestions for future research.

2. Literature review

2.1. Sustainability issues throughout the smartphone life cycle

Smartphone production, consumption and disposal have various adverse social and ecological consequences (Bridgens et al., 2017) which require consideration of all life cycle phases (Moberg et al., 2014). Table 1 provides an overview of the life cycle phases of a smartphone (based on Frey et al., 2006; Suckling and Lee, 2015) and sustainability issues.

Resource extraction and processing: Primary raw materials are often sourced through artisanal and small-scale mining in resource-rich emerging countries, which is characterized by rudimentary extraction processes (Shen and Gunson, 2006). If managed poorly, it has significant impact on workers, ecosystems and local communities (Hofmann et al., 2018). Recycled materials are accessible from, for example, urban mining (Jones et al., 2013) of valuable resources in disused devices accumulating in urban areas (Sun et al., 2016). Raw materials and recycled resources differ in aspects such as footprint (Jones et al., 2013) or potential yield per ton (Roos, 2014).

Design and manufacturing: Design choices have a large influence on other life cycle phases. First, material or component choices affect which resources need to be extracted. Second, device design affects usage and end-of-life aspects such as reparability, upgradeability, durability and recyclability (van Nes and Cramer, 2005). Currently, smartphone designs do not emphasize these eco-design aspects. For instance, rather than being mounted with screws, components are often fixed with strong adhesives to reduce size (e.g. Cook and Jardim, 2017). These design choices, together with the proprietary and closed product strategy (Cecere et al., 2015), make conventional smartphones more difficult to upgrade or maintain (Bridgens et al., 2017) or make it harder to recover materials at the end-of-life (Li et al., 2012). Additionally, most smartphone manufacturers regularly release new generations (Bridgens et al., 2017) whose novel features accelerate smartphone turnover by making older devices obsolete (Wilson et al., 2017). Smartphones and smartphone components are produced mainly in Asian countries with low social and ecological standards (Welfens et al., 2013).

Distribution and network provision: To enable the full functionality of a smartphone, users require both a device and a network contract. From a strategic marketing perspective (Anderson and Zeithaml, 1984), manufacturers commonly introduce new generations before the market decline of the preceding one, which in effect creates overlapping product (marketing) life cycles. To maintain affordability of increasingly expensive smartphones, network operators bundle their contracts with subsidized access to devices (Riisgaard et al., 2016). Together, these aspects promote more frequent replacement by users (Boons and Lüdeke-Freund, 2013), thereby exacerbating sustainability issues in other phases.

Table 1
Sustainability issues at different LC phases of a smartphone.

Life cycle phase	Sustainability issues	References
Resource extraction and processing	-**Illicit operations** and harmful sourcing of hazardous or **conflict minerals** -**Poor working conditions** (e.g. child and forced labor, excessive working hours) -**Environmental degradation** through mining and processing (e.g. high land use, soil contamination)	Bleischwitz et al. (2012); Frey et al. (2006); Hofmann et al. (2018); Shen and Gunson (2006); Silva and Schaltegger (2019); Young (2015)
Design and manufacturing	-Energy and **resource intensive** manufacturing -**Poor working conditions** (e.g. low wages and standards, long working hours) -Potential of human and environmental exposure to **toxic substances** -**Poor product design** choices (e.g. proprietary, non-reparable)	Bridgens et al. (2017); Cecere et al. (2015); Li et al. (2012); Welfens et al. (2013); Wilhelm et al. (2015)
Distribution and network provision	-Transport **emissions** -**Fast replacement business model** accelerating device replacement	Boons and Lüdeke-Freund (2013); Moberg et al. (2014)
Usage	-**Short** average operating **lifetime** -**Electricity consumption** -**Stockpiling** of **functional devices** as barrier to reuse	Moberg et al. (2014); Suckling and Lee (2015); Welfens et al. (2016); Wilhelm et al. (2015)
End-of-life	-**Stockpiling** of **defect devices** prevents recycling -Electronic waste **illicitly imported** to emerging countries -**Informal recycling** sector for valuable materials -Poor **working conditions** -**Toxic substances** in discarded electronics causing environmental **pollution** and health problems	Li et al. (2012); Ongondo et al. (2011); Wilhelm et al. (2015); Wilson et al. (2017)

Usage: In this phase, sustainability impacts largely depend on user behavior (Makov et al., 2019) and the network infrastructure (Suckling and Lee, 2015). Smartphones are commonly replaced earlier than their potential life expectancy (Wieser and Tröger, 2018) and then stored in households for years, which reduces the value of a smartphone for secondary markets (Suckling and Lee, 2015). Additionally, because of user carelessness, a smartphone may prematurely turn into electronic waste (Wieser and Tröger, 2018). On the network side, the energy consumption that contributes to greenhouse gas emissions is controlled by network operators (Suckling and Lee, 2015).

End-of-life: Once the operating lifetime of a smartphone has expired (Wilson et al., 2017), they are often withheld from the recycling system, which increases the need for primary resources (Welfens et al., 2016). Waste electrical and electronic equipment (WEEE) is often illegally exported to countries with unsafe landfilling and informal recycling that cause severe pollution and health problems for workers and communities (Ongondo et al., 2011).

Concluding, a large body of literature highlights sustainability issues along the smartphone life cycle. As sustainability issues of smartphones are largely driven by the industry's dominant business model, more sustainable alternatives need to be empirically investigated. Transforming the linear business model of selling, using and discarding (Bocken et al., 2016) towards sustainability is a key lever to reduce the environmental and social problems of the smartphone industry. The following section discusses SBMs that integrate sustainability principles into the core business and consider social and environmental problems throughout the life cycle (Hansen et al., 2009).

2.2. Sustainable business models

The business model concept has been enjoying increasing popularity since the mid-1990s among academics and practitioners (Massa et al., 2017). The commonality between the various existing conceptualizations (e.g. Wirtz et al., 2016) is that a business model provides a "description of an organization and how that organization functions in achieving its goals (e.g., profitability, growth, social impact, ...)" (Massa et al., 2017: 73). Osterwalder and Pigneur (2010) describe a business model as the rationale behind an organization's value creation, delivery and capture. Additionally, the value proposition, i.e. benefits offered to customers, is widely accepted as the central component of business models (Osterwalder and Pigneur, 2010; Wirtz et al., 2016). As the concept integrates key aspects of the creation and consumption of a firm's offers (Boons and Lüdeke-Freund, 2013), it is useful to explore how firms address the sustainability issues discussed in Section 2.1 with their core business.

Research on sustainable business models, which are also described as business models for sustainability, has developed into its own research field in recent years according to Lüdeke-Freund and Dembek (2017). To operationalize the concept, Schaltegger et al. (2016a: 6) propose a definition connecting the three business model components of Richardson (2008) with a sustainability-driven rationale as follows:

"A business model for sustainability helps describing, analyzing, managing, and communicating (i) a company's sustainable value proposition to its customers, and all other stakeholders, (ii) how it creates and delivers this value, (iii) and how it captures economic value, while maintaining or regenerating natural, social, and economic capital beyond its organizational boundaries."

While many conceptualizations for analyzing business models exist (Wirtz et al., 2016), the analytical framework in Table 2 aligns with the definition above and is based on the widely accepted conceptualization of Bocken et al. (2014) and Richardson (2008).

One relatively recent research stream perceives (sustainable) business models as patterns of a repeatable value-creating solution to a specific (sustainability) problem (e.g. Lüdeke-Freund et al., 2018; Remane et al., 2017). Identifying SBM patterns with regard to business model components thus helps dispersing solutions to other actors in the smartphone industry by presenting design options for their business model innovation process (e.g. Rajala et al., 2016; Pieroni et al., 2019).

In general, SBMs supplement a firm-centric view with a multi-stakeholder perspective that integrates social, economic and environmental issues (Stubbs and Cocklin, 2008; Freudenreich

Table 2
SBM components based on Bocken et al. (2014), Osterwalder and Pigneur (2010), Richardson (2008).

Component	Description
Value proposition	Includes the products/services a firm offers to generate benefits for its customer segments, stakeholders and the natural environment.
Value creation & delivery	Describes the various aspects necessary to provide the value proposition sustainably, including key activities, resources, and partners.
Value capture	Covers both revenue model, i.e. how to appropriate value for the firm from the value proposition, and cost structure incurred through the value creation component.

et al., 2019). The focus of conventional business models on creating value for customers thus needs to be extended towards value for stakeholders and the natural environment (Bocken et al., 2014). Subsequently, companies are challenged to design value-creating activities (Zott and Amit, 2010) considering the dynamics and operating conditions of social and ecological systems they operate in (Stubbs and Cocklin, 2008). This also means that companies pursuing an SBM should consider the entire life cycle of their products (Hansen et al., 2009; Stubbs and Cocklin, 2008). As the interface between supply and demand (Massa et al., 2017), the business model concept considers value-creating activities of partners as well. Several authors argue that companies with an SBM ensure sustainable conduct of partners and customers, too (Boons and Lüdeke-Freund, 2013). The concept's comprehensive character underpins its utility for analyzing the contribution of a firm to a sustainable development of the smartphone industry. Additionally, taking an SBM perspective helps understanding how sustainability-oriented innovations are deployed and commercialized successfully in practice (Boons and Lüdeke-Freund, 2013). In this context, it has been suggested that innovative SBMs improve competitiveness (Schaltegger et al., 2012) and hence, potential market impact of companies (Schaltegger and Wagner, 2011). To date, an analysis of such SBMs is missing for the smartphone industry, despite the fact that smartphone production, consumption and disposal cause widespread sustainability issues.

In summary, an SBM describes a company's core business (Osterwalder and Pigneur, 2010) and its conjoint economic, societal, and ecological value creation (Schaltegger et al., 2012). The SBM concept represents an analytical tool to understand how sustainability pioneers improve value creation of smartphones with regard to aforementioned sustainability issues. The following analysis focuses on sustainability pioneers from the smartphone industry who deploy proactive sustainability strategies, i.e. "systematic patterns of voluntary practices that go beyond regulatory requirements" (Aragón-Correa and Rubio-López, 2007: 358), through their business models (Casadesus-Masanell and Ricart, 2010). They represent a relevant actor group for this research because sustainability pioneers address social and environmental issues by introducing more sustainable products and practices (Schaltegger and Wagner, 2011) that exceed market standards. Pioneering SBMs that are successful in superseding their conventional predecessors foster an industry's transformation towards sustainability (Schaltegger et al., 2016b). Acknowledging SBMs as promising units of analysis, the following section elaborates on the methodological choices of this study.

3. Methodology

3.1. Research design and case selection

The study follows an explorative approach to analyze the SBMs applied by European sustainability pioneers in the smartphone industry and how these SBMs create value by addressing socio-ecological issues. Case study research facilitates gaining new insights into the phenomenon in its real-life context (Yin, 2014) and is thus a suitable approach for studying the emerging and complex field of SBMs. A multiple case study design is chosen to cover the entire life cycle.

Following a theoretical sampling logic (Eisenhardt, 1989), sustainability pioneers were selected that address environmental and social issues in the smartphone life cycle through their products or services. Examples include products such as sustainable smartphones or conflict-free materials, and repair or recycling services. This is a useful screening approach as products and services reflect core aspects of business models (Osterwalder et al., 2005). Together, the cases cover the entire life cycle while each case has a different (initial) focus (Table 3).

One part of the sample was selected based on active participation in the Innovation Lab on Sustainable Smartphones in Germany (Hansen et al., 2018). The remaining companies were selected based on desk research and snowball sampling considering remarks of the interviewees (Babbie, 2013). As part of the screening, a preliminary SBM analysis was conducted based on publicly available information (e.g. websites, news reports). Only the business areas intersecting with smartphones were regarded for cases active in multiple industries or product categories. As pioneers can be small or large (Schaltegger et al., 2016b), both are covered in the sample.

3.2. Data collection

Data was collected from multiple sources (Babbie, 2013), including 16 semi-structured interviews with interviewees in key positions in the chosen companies conducted between January and August 2018. To ensure that the informants were knowledgeable about the business model, only managers in strategic positions in their company were interviewed. Face-to-face and video techniques were applied for the interviews which lasted between 30 and 45 min. The interviews were complemented with secondary data (news articles, press releases, company reports) and observation and documentation from the Innovation Lab on Sustainable Smartphones workshops (e.g. Hansen et al., 2018). This data triangulation aims at strengthening the validity of the study by using multiple measures to corroborate the same finding and hence, avoiding single source bias (Babbie, 2013). The data collection process was documented through a research file for each company to increase data reliability (Yin, 2014). The interview transcripts were sent to the interviewees to clarify whether everything was understood correctly and, in some cases, comments were added to the transcripts. Data collection concluded when a saturation point was reached and no new phenomena were observed (Eisenhardt, 1989).

3.3. Coding and data analysis

The collected data for each case was coded and qualitatively analyzed with the support of the software MAXQDA to ensure reliability of the analysis (Babbie, 2013). Data coding followed a hybrid process of combining deductive, a priori derived higher-order codes from literature and data-driven inductive coding (Fereday and Muir-Cochrane, 2006). The initial set of 3rd-order and 2nd-order codes derived from literature included the life cycle phases, sustainable business model components, and context- and industry-specific codes. These higher-order codes structured the data-driven codes that emerged inductively and referred to more detailed aspects across transcripts (Appendix). The process of

Table 3
Case overview.

LC phase	Case	Case Description	Country	Size (no. of employees)	Interviewees
Resource extraction and processing	Valcambi	Resource processing company	Switzerland	50–249	Executive manager, strategic manager
	Wolfram Bergbau und Hütten	Mining and processing company	Austria	250–1000	Senior manager
Design and manufacturing	Fairphone	Sustainable smartphone manufacturer	Netherlands	50–249	Co-founder and strategic manager
	SHIFT	Sustainable smartphone manufacturer	Germany	10–49	Co-founder and managing director
Distribution and network provision	Vireo	Sustainable smartphone reseller	Germany	10–49	Founder and managing director
	goood mobile	Network provider	Germany	10–49	Co-founder and executive manager
	Swisscom	Telecommunications company	Switzerland	>1000	Corporate sustainability manager
	Deutsche Telekom	Telecommunications company	Germany	>1000	Senior manager
Usage	reBuy	Smartphone refurbishing company	Germany	250–1000	Executive manager
	Back Market	Platform for refurbished smartphones	France	50–249	Co-founder and executive manager
	kaputt.de	Platform for smartphone repair	Germany	10–49	Co-founder and managing director
	akkutauschen.de	Smartphone repair company	Germany	10–49	Founder and managing director
Usage/End-of-life	AfB Group	IT and smartphone refurbishing company	Germany	250–1000	Strategic manager
End-of-life	binee	Smartphone collection company	Germany	< 10	Co-founder and managing director
	take-e-way	Smartphone take-back and recycling services	Germany	10–49	Co-founder and managing director
	Closing the Loop	Phone collection and circular services	Netherlands	< 10	Founder and managing director

descriptive coding (Miles et al., 2014) yielded a large number of 1st-order codes, leading to a total set of 468 codes across 2.440 coded segments. Each interview transcript was coded independently by two coders. The researchers analyzed the data set in an iterative process of coding and refined 1st order codes to reduce complexity and redundancies. All coding discrepancies were reconciled through discussions between two coders until agreement was reached (Campbell et al., 2013).

A thematic analysis (Braun and Clarke, 2006) was conducted within and across cases to search for similar or contrasting results (Eisenhardt, 1989). To reduce the complexity of the findings, SBM patterns were developed. These patterns were derived from the individual SBMs of the cases through abstraction (Spiggle, 1994). Following Eisenhardt (1989), this abstraction process was based on similarities in literature-based dimensions – SBM and LC – and supported by iteratively arranging findings in tables and figures (Miles et al., 2014). The patterns were formed from cases which exhibited the same LC coverage and similar features in the SBM components. Feedback on the patterns was given by the interviewees (participant checks; Shenton, 2004) for final clearance. A few minor disagreements on details expressed by some interviewees were corrected, enhancing the accuracy of the study (Yin, 2014).

4. Findings

This section presents the sustainable business model patterns observed across the cases (Fig. 1). The SBM patterns were termed according to their rationale. One important preliminary finding of this process was that the identified SBMs intend to improve the sustainability of their core value proposition through complementary products/services in other phases. Accordingly, most patterns span more than one life cycle phase.

In the following, each of these sustainable business models is explained with regard to its components (see Table 2).

4.1. Sustainable resource company

A sustainable resource company, represented by *Valcambi* and *Wolfram Bergbau und Hütten* (Table 4), makes large efforts to analyze and develop its supply chains with regard to conflict-free mining in high-risk areas. The SBM supports miners in improving their practices to meet industry standards and due diligence requirements and to access global markets. This is achieved by sharing knowledge and supporting local artisanal and small-scale mining operators towards responsible practices in collaboration and dialogue with industry associations and stakeholders such as non-governmental organizations, the civil society and the private sector. Conflict-free metals, which have been mined in a responsible way, are traceable back to mines operating under accepted standards. External audits confirm compliance with legal requirements (e.g. Dodd-Frank Act) and voluntary standards or guidelines (e.g. Organisation for Economic Co-operation and Development Due Diligence Guidance). Apart from conflict-free mining of raw materials, sustainable resource companies also process recycled raw materials. By re-using recycled materials, they extend their scope into the end-of-life phase and thus contribute to closing resource loops. This bridging between the end-of-life and resource extraction and processing phases prevents the ecological impacts of mining. Raw material availability can vary depending on the size of the mine or source of the metal. Whereas resource availability is low for responsibly mined materials from artisanal and small-scale mining, it is higher for responsibly sourced raw materials from large-scale mines and for recycled resources. Furthermore, responsible sourcing from artisanal and small-scale mines results in higher supply chain and operations costs, which are partly passed on to customers by charging premium prices, otherwise, market-based prices are charged.

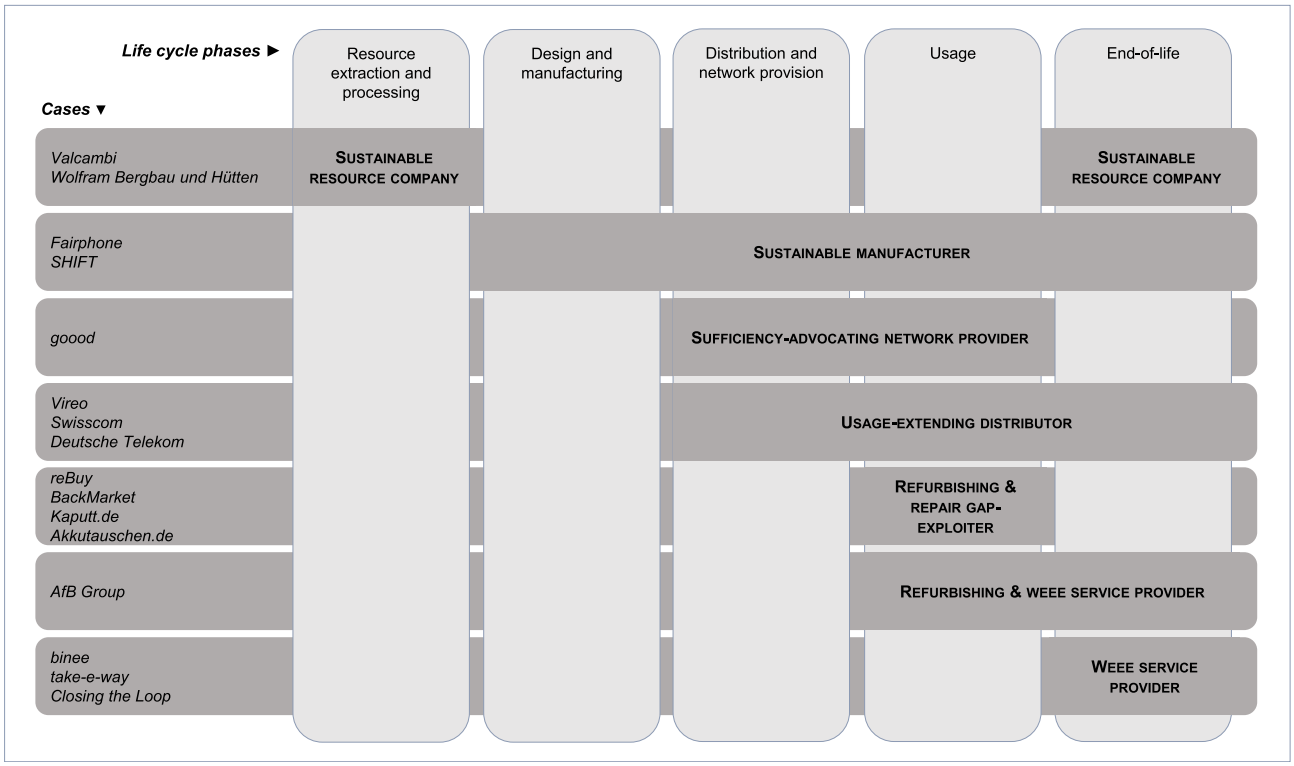

Fig. 1. Life cycle scope of SBM patterns.

Table 4
Sustainable resource company SBM.

Component	Description
Value proposition	- Traceable and more sustainable, conflict-free/recycled materials - Supporting compliance with legal requirements - Easier access to markets for artisanal and small-scale mining - Reducing health and ecological impacts from mining - Long lasting use of natural resources
Value creation & delivery	- Sourcing conflict-free and recovered materials - Formalizing and supporting process improvements of artisanal and small-scale mining - External audits for certified mines and traceability activities - Establishing multi-stakeholder partnerships for addressing artisanal and small-scale mining issues - Circular supply chain
Value capture	- (premium-priced) Resources sales - Increased supply chain/operations costs for artisanal and small-scale mining

4.2. Sustainable manufacturer

A sustainable manufacturer, represented here by *Fairphone* and *SHIFT*, covers most life cycle phases from design and manufacturing to end-of-life (Table 5). The SBM improves the sustainability of smartphones through new design solutions such as modularity. Additionally, it offers complementary services to increase product lifespans (e.g. repair), and collection/recirculation rates. Sustainable manufacturers engage and develop their suppliers to reduce worker and human rights violations as well as ecological damages in the supply chain in two ways. First, they adopt responsible sourcing practices for critical materials (e.g. gold) in collaboration, for instance with sustainable resource companies. Second, they exert more control over the production of their device, through either demanding higher standards from contract manufacturers or re-internalizing production. Furthermore, they acknowledge advanced product responsibility beyond the distribution phase (and additionally, beyond minimum legal requirements) through their long-time maintenance of smartphone generations with updates and services as well as take-back. Business model and design choices influence the options for product life extension or recycling in later life cycle phases. This gives them advantages over other repair SBMs (e.g. Section 4.5) through their in-house control of smartphone designs and access to spare parts. Sustainable manufacturers thus make use of reparable, durable and recyclable designs, while allowing and even encouraging consumers to repair their devices with original spare parts and repair instructions. Consumers are monetarily incentivized to return disused devices, which are then resold, reused for parts, or recycled depending on the residual value of the phone. Many of these sustainability improvements such as higher working standards come at increased costs, which are passed on to the consumer. To justify this, sustainable manufacturers communicate the societal relevance of their sustainability efforts, which creates intrinsic customer value. Nevertheless, they strike a careful balance between conventional aspects (such as design aesthetics) and sustainability-related ones

Table 5
Sustainable manufacturer SBM.

Component	Description
Value proposition	- Smartphones designed for longevity supported by spare parts availability, updates and repair services - Incentivized take-back of smartphones at end-of-life - Long-term customer relations - Improving livelihoods in production and supply chain - Reduced resource use and waste material through longer product life
Value creation & delivery	- Creating supply chain sustainability including supplier selection, development and coordination - Control of product assembly - Cross-sectoral network of partners and user community - Sustainable product strategy for longevity - Repair activities and spare parts stocks - Incentives for return through reward systems or buy-back schemes - Organizing consumer-to-business/business-to-business take-back and reverse logistics
Value capture	- Sales of new and refurbished devices and spare parts (cost-based pricing) - Service fees - Increased supply chain, operations and collection costs

to be able to compete with conventional manufacturers.

4.3. Sufficiency-advocating network provider

The sufficiency-advocating network provider, represented by *goood*, offers mobile phone contracts with integrated monthly donations for socio-ecological projects chosen by the customer (Table 6). This case covers the distribution phase *without* offering contract-smartphone bundles while at the same time advocating sufficiency, i.e. that consumers keep their own smartphones as long as possible. In other words, the SBM only covers the contract side in the distribution phase while actively promoting alternatives to the consumption of a new smartphone (offered by partners running a refurbishing and repair gap-exploiter SBM). Additionally, by integrating recurring donations for grassroots social projects into the monthly charge, consumers repeatedly contribute to charitable projects while being subscribed to the network contract, which creates additional emotional value for them. The pioneer cooperates with partners to handle donations, pre-select projects and monitor impact. The SBM's sustainability orientation favors the creation of a broad partner network whose partners mutually promote each other and thus achieve marketing savings, for instance with sustainable manufacturers or repair and refurbishing gap-exploiters. Interestingly, since this case acts as a branded reseller (a modification of the Mobile Virtual Network Operator model; Peppard and Rylander, 2006) of a network operator's unused network capacity, the consequent dependence on the network operator restricts the case's ability to influence the negative eco-effects (e.g. energy consumption) of its core service. However, it offers compensation of these CO_2 emissions occurring during the usage phase through partners.

4.4. Usage-extending distributor

The sustainability of the usage-extending distributors' business model, represented here by *Vireo*, *Deutsche Telekom*, and *Swisscom*, builds on two pillars (Table 7). First, these actors distribute smartphones that can be used over a long period of time, including models of sustainable manufacturers. Second, the business model enables longer use of a device by either the *same* or a *different* user through complementary offers. The smartphone portfolio of this pattern is sold either separately or with a mobile contract. The quality focus reduces the failure rates of devices experienced by customers and thus preempts the need for repairs or replacement caused by substandard manufacturing processes. Since sustainability and quality of offered smartphones depend on the original manufacturer, supplier cooperation and development is important for a usage-extending distributor. Two of the analyzed cases engage in a multi-firm sustainability audit alliance whose members share supplier audit results with each other. This co-opetition enables them to increase the overall auditing density whilst reducing audit costs per company, which would otherwise limit the auditing possibilities and scope for individual firms. Another focus of this SBM is the extension of the use phase by offering customer-friendly solutions for the different situations causing a device to fall out of use. The pattern offers smartphone accessories, which enable customers to prevent damages to their smartphones (e.g. protective cases). To restore the functionality of a damaged smartphone, pioneers sell repair kits, original spare parts, or provide repair services. Another option for customers is to return or trade-in disused smartphones, which are then either resold on second-hand markets or recycled for material recovery through a partner network.

Table 6
Sufficiency-advocating network provider SBM.

Component	Description
Value proposition	- Phone contracts with integrated donations for socio-ecological projects - Emotional value of "doing good" - Long-term customer relations - Support of grassroots social projects - Reduced carbon footprint - Reduced resource use and waste material through longer product life
Value creation & delivery	- Distributing unused network capacity of network operators - Communication for problem awareness and sufficiency - Partnering with donation platform to select and monitor projects
Value capture	- Network contract fees - High network capacity costs

Table 7
Usage-extending distributor SBM.

Component	Description
Value proposition	- Conventional and sustainable smartphones, either separate or combined with mobile contract - Long-term customer relations - Convenient and inexpensive repair options - Take-back/buy-back offers - Reduced carbon emissions - Reduced resource use and waste material through longer product life
Value creation & delivery	- Product portfolio management for long-life smartphones - Supplier cooperation, evaluation and development - Low-emission operations (e.g. mobile network, logistics) - Repair infrastructure - Refurbishment and recycling activities through partners - Incentivizing return through buy-back schemes - Organizing consumer-to-business/business-to-business take-back and reverse logistics
Value capture	- Network contract and service fees - Smartphone and accessory sales - Increased supply chain costs

4.5. Refurbishing and repair gap-exploiter

The rationale for this pattern (Table 8), represented by *reBuy*, *Back Market*, *kaputt.de*, and *akkutauschen.de*, is the retention of a disused smartphone's value for a *new user*, or the restoration of a smartphone's functionality and thus, its value, for its *current user*. The independent pioneers deploying this pattern increase the overall lifetime of *conventional* smartphones, as a difference to *sustainable manufacturers* who improve the lifespan of their own *sustainable* smartphones. The SBMs benefit from the unwillingness or inability of many consumers to pay increasing product prices for new devices. SBMs respond to customers' differentiated needs by either offering different refurbishment grades at different price levels, or by providing repair options such as spare parts alongside with repair instructions or full repair services. Refurbishment and repair can occur either in-house or by acting as multi-sided platform linking refurbishment/repair workshops with consumers. Multi-sided platforms allow consumers to compare refurbished smartphones suitable for their needs, or the ideal solution to the varying complexity of repair operations as well as the varying aptitude of consumers in repairing such complex devices. Both of these value creation structures (in-house/platform) have in common that they ensure the reliability of refurbished smartphones or repair services to overcome consumer doubt. As smartphone manufacturers are not necessarily willing to cooperate, it can be challenging for these independent companies to access original parts. Therefore, they also need to source parts from other parties or from disassembling old devices. For the same reason, technical capabilities and repair instructions are developed in-house as well.

4.6. Refurbishing and WEEE service provider

The refurbishing and WEEE service provider (Table 9), represented in our sample by the *AfB Group*, spans the usage and end-of-life phases by offering device take-back and recycling *or* remarketing services to business customers. This combination makes the SBM more flexible compared to single-phase patterns (in particular refurbishing and repair gap-exploiters and WEEE service providers) in providing the appropriate treatment for customers' disused devices. Depending on the residual value of the smartphones, i.e. their resale potential, devices are either refurbished and then resold to consumers for prolonged usage, or safely recycled via partners. In the former case, fees for collection and data deletion are offset against the residual value of the smartphone. Depending upon whether the costs outweigh the residual value or vice versa, business customers will either be charged a service fee or reimbursed for their devices. As additional value-adding service, business customers can receive feedback about impact reductions achieved with remarketing and recycling, and use this in support of their own sustainability targets. Additionally, the case constituting this SBM integrates positive social aspects (beyond the sustainability issues of the industry) by employing many people with disabilities.

Table 8
Refurbishing and repair gap-exploiter SBM.

Component	Description
Value proposition	- Convenient resale of disused/refurbished smartphones - Provide repair alternatives (spare parts, services, tutorials) - Lower costs compared to new device - Reliable and transparent repair/refurbishment offers (e.g. customer ratings, extended warranties) - Reduced resource use and waste material through longer product life

Value creation & delivery	- Building (technical) capabilities independently
	- Reverse/circular logistics (buy-back, disassembly)
	- Dynamic refurbishment:
	  - Acquiring and grading disused smartphones
	  - Restoring product functionality/reset to default
	- Repair activities:
	  - Sourcing spare parts
	  - Developing repair instructions

Value capture	- Sales of refurbished devices or spare parts - Repair service fees - Platform: commissions - Smartphone or spare parts acquisition costs

Table 9
Refurbishing and WEEE service provider SBM.

Component	Description

Value proposition	- Business-to-consumer:
	  - Convenient access to disused/refurbished smartphones
	  - Lower costs compared to new device
	- Business-to-business:
	  - Take-back services
	  - Secure certified data deletion
	  - Voluntary eco-impact reduction
	- Creation of employment opportunities for people with disabilities
	- Reduced resource use and waste material through longer product life
	- Long lasting use of natural resources

Value creation & delivery	- Business-to-consumer:
	  - Refurbishment activities to extend product life for new user
	  - Restoring product functionality
	- Business-to-business:
	  - Organizing take-back and reverse logistics
	  - Reusability inspection; resetting to default (certified)
	  - Impact reduction measurement and reporting

Value capture	- Business-to-consumer: - Sales of smartphones - Spare parts acquisition costs - Business-to-business: Take-back and data deletion or recycling fees contingent on residual value of smartphones

4.7. WEEE service provider

This pattern (Table 10), represented by *binee*, *take-e-way*, and *Closing the Loop*, exhibits a breadth of designs with the goal to close resource loops, thereby diverting harmful waste from landfills or human exposure. A range of collection systems is offered, providing convenient access and incentives for consumers to return devices. However, the cost of collection and processing cannot be reliably recovered through revenues from recyclable materials, due to fluctuations in supply, resource potential and market prices. Therefore, the SBM offers business-to-business services to fund these activities, which can take a variety of shapes: The SBM can support mandatory (e.g. as required under the European Union's WEEE Directive) and voluntary collection (exceeding legal requirements) by providing an electronic waste processing service for companies. Alternatively, it can integrate the eco-impact reduction or offsetting service into its business customer value proposition similar to the refurbishing and WEEE service provider. While one case developed a business-to-business service where for every phone purchased by the customer, one scrap phone is collected in Africa or Asia, another case harnesses its collection boxes as consumer-rewarding advertisement space. This cross-subsidization avoids charging the end users, which would create participation barriers. Materials are recovered by specialized large-scale facilities of recycling partners, since these SBMs can usually handle the collection, initial processing and logistics, only.

In summary, the analysis yielded seven SBM patterns across the different life cycle phases. These patterns reflect the variety and complexity of customer situations. The following section discusses the insights gained from the SBM patterns in the light of the sustainability issues of smartphones and the SBM concept.

5. Discussion

5.1. SBMs and sustainability issues along the smartphone life cycle

The SBMs of pioneers address sustainability issues along the smartphone life cycle and provide alternatives to current industry practices. Fig. 2 links the SBMs identified among the sustainability pioneers to specific sustainability issues, thereby answering the first research question.

Resource extraction and processing: The pioneers address issues such as illegal mining or environmental degradation through cleaner and safer production practices (e.g. Kambani, 2003). Whereas some conventional companies avoid conflict regions altogether, SBMs aim to develop conflict-free mines in the affected countries. Previous studies (Bleischwitz et al., 2012; Hofmann et al., 2018) show that increasing transparency (e.g. certifications, chain of custody) makes legal trade possible and prevents loss of income caused by illicit trade. *Sustainable resource companies* increase

Table 10
WEEE service provider SBM.

Component	Description
Value proposition	- Support compliance with electronic waste regulations - Convenient, safe, transparent collection, and recycling - Incentives for return - Voluntary eco-impact reduction/offsetting service (business-to-business) - Reduced health issues and pollution through proper WEEE recycling - Long lasting use of natural resources
Value creation & delivery	- Incentivizing return through reward systems or buy-back schemes - Coordinating resource flows to distributed recycling network - Logistics, reporting and recycling in compliance with applicable waste laws - Organizing consumer-to-business/business-to-business take-back systems and reverse logistics - Business-to-business impact reduction measurement and reporting
Value capture	- Take-back, recycling, service fees - Sales of resources/electronic waste - Collection/logistics and recycling costs

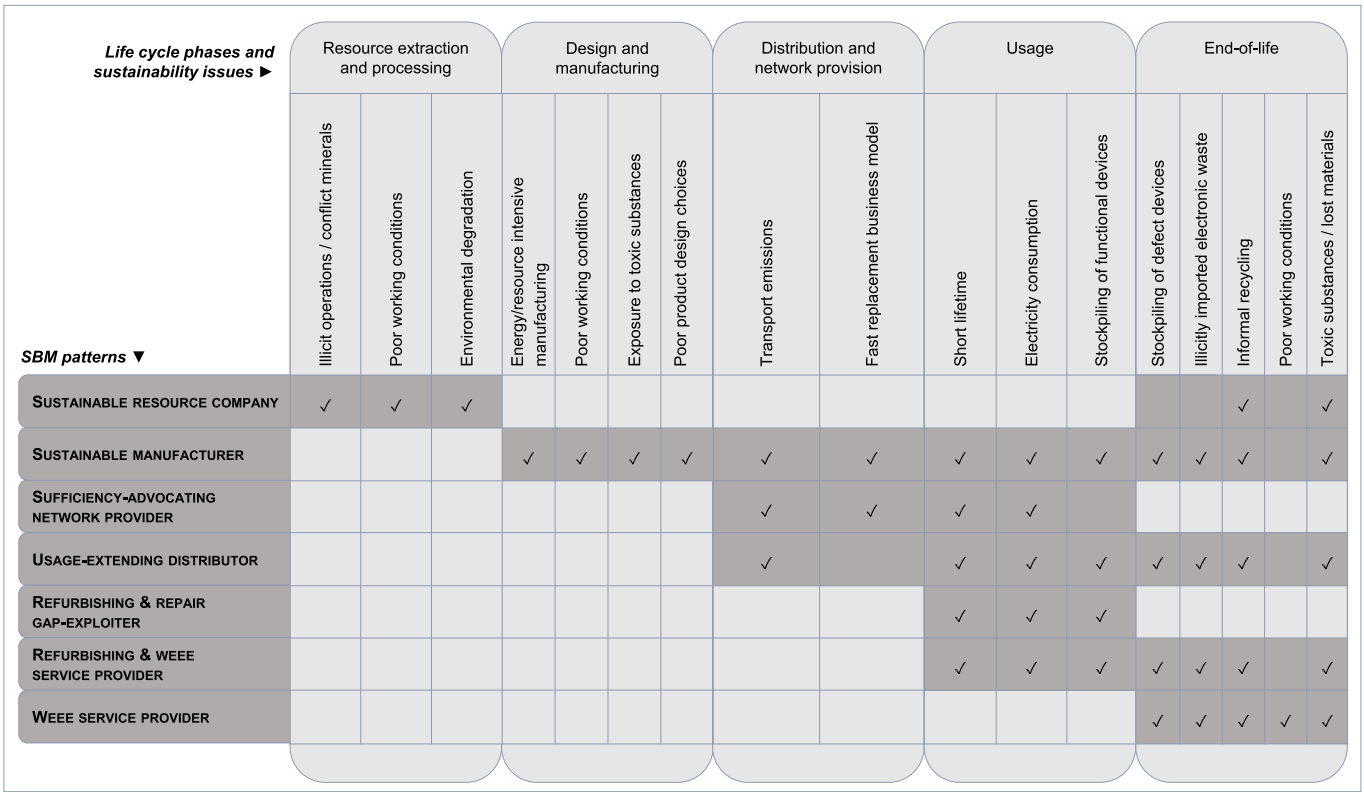

Fig. 2. SBM patterns addressing sustainability issues (dark grey background: LC phase coverage in line with Fig. 1, check marks "✓" indicate sustainability issues addressed).

transparency about suppliers, for instance through traceability of raw materials. This provides verification of responsible mining and prevents vulnerability to stakeholder concerns. In turn, the improved social conditions in this phase also play a key part in the value proposition of *sustainable manufacturers*.

Design and manufacturing: Pioneers in this phase focus on eco-design and cleaner production of smartphones while their choices affect sustainability issues across the entire life cycle. The business model choices of *sustainable manufacturers* in the design phase have profound influence on extending product lifetime (e.g. ease of repair) in later LC phases. The pioneers embed modularity in the design, which is a decisive factor for a longer product life (Wilhelm et al., 2015) and differentiates them from the proprietary and closed design of conventional smartphone manufacturers (Bridgens et al., 2017). Additionally, compared to modular smartphone concepts that failed or are still in development (Proske and Jaeger-Erben, 2019), the pioneers have successfully translated modular design into functional and sustainability value for customers. Their emphasis on modularity for reparability is a key driver of consumer value, though modularity does not go as far as to enable future upgrading of core components (e.g. processing unit). Moreover, user-driven eco-design can increase consumer awareness of environmental issues and acceptance of eco-designed smartphones (Liao et al., 2013). Whereas Liao et al. (2013) highlight the utility of quantitative tools to assess consumer preferences, *sustainable manufacturers* establish stronger ties through continuous exchange with their sustainability- or technology-oriented online communities. Previous studies observed that conventional smartphone manufacturers rarely assume responsibility for human rights violations in the production phase (Young, 2015). In contrast, *sustainable manufacturers* introduce working conditions with higher standards that are validated through audits. One pioneer built its own manufacturing site to have direct control over the social and ecological conditions under which smartphones are assembled. The resulting better working conditions and higher wages represent initial costs, however, pursuing social improvements can decrease health care costs and risks in supply chains (Wilhelm et al., 2015).

Distribution and network provision: In contrast to fast replacement business models accelerating device replacement (e.g. Boons and Lüdeke-Freund, 2013), *sufficiency-advocating network providers* offer network contracts without smartphones and *usage-extending distributors* sell (sustainable) smartphones detached from mobile contracts. This enables customers to split their purchases of contracts and smartphones, which supports more sustainable purchasing decisions (Hobson et al., 2018). Some usage-extending distributors struggle with curbing replacements of functioning smartphones caused by offering discounted new smartphones (Wieser and Tröger, 2018). To ensure that smartphones are returned after replacement, product-service systems – where manufacturers retain ownership throughout the life cycle – are suggested by some authors (Bridgens et al., 2017; Hobson et al., 2018). Whereas one *sustainable manufacturer* is currently piloting a business-to-business product-service system, its implementation would need to overcome consumer concerns regarding data traces from own usage or previous users (e.g. van Weelden et al., 2016). Additionally, to prevent premature replacements caused by defects and damages, the pioneers distribute high-quality smartphones and offer repair/refurbishing services in the usage phase.

Usage: By offering repair services and refurbished phones, the pioneers prolong the useful life span of smartphones, which is environmentally and economically preferable to recycling (Mugge et al., 2017). Through differentiated offers, they simultaneously respond to different market segments exhibiting differentiated preferences for refurbished smartphones (van Weelden et al., 2016) and repair activities (Riisgaard et al., 2016). The pioneers noticed

that offering repair or refurbished smartphones for a reasonable price is a feasible business with increasing customer numbers (Riisgaard et al., 2016). This opportunity only exists because conventional manufacturers regularly introduce new product generations (e.g. Bridgens et al., 2017) before the predecessor's value has significantly declined, while increasing prices of newer generations create demand for lower-cost alternatives. In other words, the pioneers exploit the overlapping product marketing life cycles (Anderson and Zeithaml, 1984) of conventional manufacturers. Complementing Mugge et al. (2017), who investigated how to increase consumer attractiveness of refurbished smartphones, the pioneers expressed that – due to lack of cooperation with large manufacturers – the most relevant challenge was to ensure supply of original spare parts. Additionally, the refurbishing companies found it more difficult to acquire disused devices rather than reselling them, which may be explained by the tendency of users to keep back-up devices or to pass devices on to friends or relatives (Wieser and Tröger, 2018). Finally, the fact that *sustainable manufacturers* encourage and support (self-)repair through complementary offers strengthens the argument that the business model plays a significant role in prolonging use phases (Proske and Jaeger-Erben, 2019).

End-of-life: SBMs of pioneers (e.g. *WEEE service provider)* offer compliance-based services and create the necessary infrastructure for collection and recycling, hence, increasing smartphone return and recycling rates (e.g. Welfens et al., 2016). Establishing a reverse logistics system bears high transaction and investment costs (Bleischwitz et al., 2012) leading to low collection rates (Kunz et al., 2018). Another aspect is the small amount of recoverable resource content of collected smartphones, making it difficult to cover collection and recycling costs through the sale of valuable resources alone (Kunz et al., 2018). The pioneers reduce transaction costs by setting up collection boxes with partners at accessible locations, making it more convenient for users to return their smartphones. Moreover, their collection is cross-subsidized, e.g. through compliance-based services or impact offsetting for companies. Each of the pioneers in this phase contributes to closing resource loops, which increases supply of recovered resources.

The explored SBMs introduce sustainable practices that substitute or complement the current 'take-make-waste' practices (Hofmann et al., 2018). The pioneers in the earlier life cycle phases develop sustainable alternatives to prevent negative impacts *(e.g. sustainable resource company*; *sustainable manufacturer)*. Contrarily, pioneers in later life cycle phases (e.g. *refurbishing and repair gap-exploiter*; *WEEE service provider*) mitigate the life cycle impacts of conventional smartphones (Hobson et al., 2018). As each SBM provides partial solutions to sustainability issues, only the interplay of different SBMs in the market leads to a more sustainable system of cleaner production, sufficient consumption and effective recycling of smartphones. Moreover, multiple SBMs can be linked by cooperating in networks or by vertical integration through a focal firm (Revellio and Hansen, 2017).

5.2. Characteristics of SBMs in the smartphone industry

The analyzed SBMs also need to be discussed with regard to the second research question, because understanding their ways of value creation is key to understanding their viability. Previous studies have emphasized that the 'ideal SBM' balances economic, social and ecological goals of business model stakeholders to achieve sustainability improvements along the life cycle (e.g. Bocken et al., 2014; Stubbs and Cocklin, 2008). Contrasting the cases with SBM characteristics proposed in the literature reveals that an 'ideal type' SBM could not be observed among the analyzed cases. The investigation of the pioneers' SBMs in the smartphone industry therefore allows for further differentiation of the concept.

Business models may remedy sustainability issues even when a sustainability orientation is implicit and when tensions are absent between sustainability dimensions and between competing customer value aspects. This was illustrated by the *refurbishing and repair gap-exploiters*, where sustainability was not deeply embedded into the customer value proposition compared to functional benefits (e.g. price advantages). While their SBMs integrated customer and socio-ecological value creation, i.e. realizing a synergy as suggested by Schaltegger et al. (2012), the link existed only tacitly without being emphasized to customers. Similarly, Riisgaard et al. (2016: 119) observed that Danish smartphone repair companies were frequently founded without a "green agenda". The explanation for this may be found in these SBMs' gap-exploiting nature (Bocken et al., 2016) where the product value created by original manufacturers can be retained for subsequent consumption cycles with comparably low economic effort. This finding can be contrasted with SBMs in other LC phases such as *sustainable manufacturers* who have to balance social, ecological and economic issues explicitly. Here, creating sustainability solutions can also cause tensions between sustainability-related and conventional customer value aspects, which have been rarely acknowledged in previous research (Davies and Chambers, 2018). For example, while reparability provides resource and cost savings, responsible sourcing and manufacturing practices create an intrinsic value, but incur additional costs for consumers (e.g. certification, living wages). This may explain why these SBMs explicitly integrate sustainability aspects into the value proposition through extensive sustainability communication to capture additional value. Alternatively, an SBM can cross-subsidize its socio-ecological value proposition with proceeds from complementary services, as illustrated by the *WEEE service providers*. While previous authors stress the internalization of external costs on the socio-ecological environment as an attribute of SBMs (e.g. Stubbs and Cocklin, 2008), this finding ascribes importance to internalizing, i.e. capturing, external benefits (along the LC) as well. Overall, these findings about the integration of sustainability and customer value respond to various consumer-based studies suggesting research on value-creating business models (e.g. Cox et al., 2013; Proske and Jaeger-Erben, 2019).

Furthermore, referring to the systems-based nature of the SBM concept (Stubbs and Cocklin, 2008), several authors suggest further empirical research on how different business models affect a product life cycle (Hansen et al., 2009; Joyce and Paquin, 2016). To fill this gap, this analysis examined different SBMs along a specific product's life cycle. Earlier research proposes that addressing the range of sustainability issues present in every LC phase (e.g. Welfens et al., 2013) comprehensively would require market solutions for the entire life cycle. In this context, the analysis conducted here found seven sustainable business model patterns, none of which spanning the entire life cycle. The number of identified SBMs and their differing LC coverage is an important finding because SBM-related research often studies firms that provide a finished product or service (e.g. Chun and Lee, 2013; Stubbs and Cocklin, 2008). The findings show that such a perspective omits the role of independent actors' complementary business models influencing the impact of existing products. These SBMs enable consumers to shape the course of the life cycle, for instance by extending usage phases or ensuring appropriate end-of-life treatment. Indeed, these cases are more numerous than the two companies designing and manufacturing consumer products (*sustainable manufacturers*), which supports this study's approach of considering SBMs across the whole life cycle (Joyce and Paquin, 2016). This corresponds with Riisgaard et al. (2016) analysis of

complementary service businesses who found the independent repair sector to be nontrivial in size. However, exclusively focusing on later LC phases carries the caveat of omitting the social and ecological impacts of production. The variety of SBMs and the fact that no pattern covered the entire LC thus illustrate the necessity of considering the complementarity of each SBM pattern's contributions. In this regard, the SBM patterns provide a more detailed explanation of how different phase-specific sustainability approaches (Chun and Lee, 2013) can be bundled in practice. Additionally, studies focusing on individual cases across different industries may not be comprehensive enough to understand how the sustainability of an entire life cycle – or even of one LC phase – can be improved.

The extent to which a life cycle may be effectively covered can be explained partially through the occurrence of economies of scope (Teece, 1980): Value-creating resources necessary for activities in one phase may improve a business model's ability to create value in other phases. The clearest example of this is the *sustainable manufacturer*, whose SBM exhibits the widest coverage of LC phases and thus comes closest to an 'ideal SBM'. Their resources in terms of, inter alia, design, customer relationships, and supply chain control, create advantages in providing complementary value propositions such as repair or refurbishing. Despite this study's prevalence of non-manufacturing SBMs, this strengthens the argument that a systemic conception of SBMs (Stubbs and Cocklin, 2008) remains desirable. Other patterns such as *repair and refurbishing gap-exploiters* have to build these capabilities in isolation and thus would need to ally with (conventional) manufacturers to build relational advantages (Dyer and Singh, 1998). However, this is obstructed by the persistent unwillingness of many manufacturers to cooperate with external usage-extending service providers (Joshi and Pargman, 2015).

Overall, the findings support that new business models are crucial to improve the sustainability across a product life cycle (Hansen et al., 2009). The sustainability needs emerging from different life cycle stages foster development of complementary offers to capture higher value from a product. Even further, complementary services can be expected to mitigate the significant impact of manufacturing (Suckling and Lee, 2015) with comparatively lower environmental impacts. Concluding, while the SBMs explored in this research exhibited heterogeneity in their modus operandi, all found ways of integrating social and ecological value with customer value, which is the foundation of an SBM's viability.

6. Conclusion

This analysis identified seven SBM patterns based on the empirical analysis of 16 sustainability pioneers in the smartphone industry. Compared to previous analyses highlighting a single perspective (e.g. specific actors, Riisgaard et al., 2016; or single LC phases, Wieser and Tröger, 2018), this research investigated SBMs across *all phases* of the life cycle for the same product group. Additionally, through its SBM perspective, this analysis contributes to the empirical understanding of how different approaches to improve the sustainability of a smartphone's life cycle can be viably deployed *in practice*. In the following, contributions to SBM research and implications for practice are described.

6.1. Implications for sustainable business model research

The analyzed pioneers have successfully commercialized sustainability solutions through their business models. Some of the identified SBM improvements such as fairer supply chains and proper end-of-life handling require increased value capture to achieve economic viability. The findings reveal several options for SBMs to achieve this value creation and capture, which also illustrate the links between SBMs and life cycles. First, SBMs can include complementary offers with functional and social/ecological benefits in the same or different LC phases. These offers can either be supplementary, leading to cross-subsidization, or enable capturing a larger share of the products' lifetime value. Regarding the latter, an SBM can simultaneously address multiple customer segments with varying price sensitivity by cascading the product through several reuse loops. This requires harmonizing aspects such as device design with use phase services and harnessing economies of scope (Teece, 1980). Second, SBMs can integrate intangible sustainability aspects of ecological and social production (e.g. fairness) into the customer value proposition. The challenge is to scale these aspects into the mass market with price-sensitive consumers (Schaltegger et al., 2016b), because the resulting costs are often financed through higher unit prices. In response, unit prices could be lowered if the SBM enables and captures value from longer and multiple use cycles.

This study has demonstrated how a life cycle perspective can support the structured analysis of SBMs within an industry. The seven SBM patterns differ in their coverage of life cycle phases and no example of an 'ideal SBM' covering all phases could be found in the sample of sustainability pioneers. This finding challenges the implicit assumption of SBM research that the focal manufacturing firm is necessarily the key actor addressing all life cycle impacts of a product (e.g. Chun and Lee, 2013; Stubbs and Cocklin, 2008). This analysis highlights the role of complementary SBMs that mitigate the impacts of conventional actors, for instance the *repair and refurbishing gap-exploiters*. SBM studies focusing on single cases or multiple cases across several industries may not yield sufficient insights if the goal is to study how the sustainability of the life cycle of a given product (group) can be improved. Consequently, different ways exist how sustainability issues can be addressed comprehensively, either through combining SBMs or through complementing conventional business models. The sustainable business model pattern of the *sustainable manufacturer* comes closest to an 'ideal SBM' conception, thus, this SBM can be combined with the *sustainable resource company* SBM to address sustainability issues along the entire life cycle. For combinations with conventional business models, several SBM patterns would have to be brought together to achieve full LC coverage, for instance with *usage-extending distributors*, *repair and refurbishing gap-exploiters* and *WEEE service providers*.

6.2. Implications for practice

With regard to managerial implications for pioneers and conventional smartphone companies, the SBMs identified in this analysis can be seen as first steps and drivers towards a sustainability transformation of the industry (Schaltegger et al., 2016b). As a difference to conceptual solutions emphasized in earlier studies (e.g. Proske and Jaeger-Erben, 2019), the identified SBMs have already entered the market successfully and gained visibility, indicating their viability. As such, they represent design elements (Zott and Amit, 2010) for conventional companies in the smartphone industry planning to implement their own SBMs. The literature suggests that ideation and development of a new business model design are important steps of the (S)BM innovation process (Frankenberger et al., 2013; Pieroni et al., 2019; Rajala et al., 2016). These steps, in turn, can be nurtured through the input of established SBM patterns, which can be understood as a repeatable solution to a sustainability issue (Lüdeke-Freund et al., 2018). This study therefore encourages industry-leading companies to follow exemplary pioneers in extending their perspective towards the

entire life cycle and in changing unsustainable modes of production, consumption and disposal.

Companies aiming to develop their business models to consider the entire life cycle can either vertically integrate complementary life cycle phases or find low transaction cost collaboration modes with sustainability pioneers in adjacent phases (Revellio and Hansen, 2017). Regarding the first path, systemic LC-spanning solutions need to be integrated that realize value capture opportunities and consider potential side effects of the functioning of the SBM in adjacent LC phases. Conventional manufacturers may capture a larger share of their products' total lifetime value throughout their marketing life cycle (Anderson and Zeithaml, 1984) by enabling multiple and longer use cycles similar to *sustainable manufacturers*. This would improve economic value creation to support investments in cleaner production and improved employment conditions. The potential for this approach is illustrated by the existence of *repair and refurbishing gap-exploiters* that exclusively focus on conventional smartphones. Relating to the second path of combining complementary business models, it is important to coordinate different SBMs on key issues such as device design or spare parts availability. Given the complexity of the industry and the limited organizational resources pioneers have, combining SBM extension and coordination may be a favorable path to drive sustainable development of the smartphone industry. The findings of Schaltegger et al. (2016b) suggest that the different SBMs of sustainability pioneers and following firms can only create a more sustainable system of production, consumption and disposal in the smartphone industry through co-evolution.

6.3. Future research

This analysis suggests avenues for future research. While this research focuses on Europe, future studies could extend the geographical scope to other regions such as Asia, where much of a smartphone's net value is created. Although desired by many of the examined pioneers, a sustainability transformation of the market has not happened, so far. This raises the question about other supporting factors necessary for a sustainability transformation beyond niche companies. Whereas this study focused on pioneers representing exemplary cases of the smartphone industry, conventional industry-leaders representing the smartphone mass market should be the subject of future studies. Longitudinal research may thus evaluate whether and how a co-evolution of conventional and sustainable business models towards a sustainable mass market (Schaltegger et al., 2016b) could be fostered.

Regarding conceptual limitations, the firm-centric perspective taken in this study could be complemented with additional research addressing the lack of consumer studies mentioned by van Weelden et al. (2016). Additionally, the cross-phase influences in a product life cycle emerged as a relevant topic for SBM research. Finally, the introduction of product-service systems by manufacturers to improve the circularity of devices (Hobson et al., 2018) remains a relevant research topic. Concluding, this research has provided insights into sustainable business models through which sustainability pioneers introduce solutions for a cleaner, more sustainable smartphone life cycle and thus, for a sustainability transformation of the market.

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Appendix

Structure of the coding scheme with deductive codes and inductive code examples.

	3rd order codes (deductive)	2nd order code (deductive)	1st order code examples (inductive)		
Sustainable business model	Value Proposition	Product/service	Smartphone	SpareParts	SecondHandSmartphones
			DeviceTakeBack	Repair	
		Customer Segments	DifferentiatedCustomerBase	EducatedCustomers	TensionSustainabilityCost
			PriceConsciousCustomers	SustainabilityConsciousCustomers	
		Value	PriceQualityRatio	Convenience	DeviceReparability
		Customers	EmotionalValue	Traceability	
		Customer Relationships	Transparency	Trust	StrongIdentification
			LongerProductUse	StrongCustomerOwnership	
		Value Stakeholders/Society	ImprovedWorkingConditions	EmployingDisadvantagedGroups	ConflictFree
			ASMMarketAccess	CharitableProfitSharing	
		Value Natural Environment	Recyclability	ReducedEcosystemDamage	EWastePrevention
			ResourceRecovery	IncreasingReusability	
	Value Creation Delivery	KeyActivities	CreatingSustainabilityAwareness	BuildingPartnerNetwork	SupplierDevelopment
			ResponsibleSourcing	DeviceDevelopment	
		Resources Capabilities	Sustainable/ TraceableSupplyChain Certification	MarketKnowledge RepairSkills	(Sustainable)Brand
		PartnersSuppliers	Recycler	AuditingPartner	B2BSupplier
			NGO	RepairPartners	
		Distribution Channels	OwnWebstore	Wholesale	ChannelTension
			MultiChannel	Platform	

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(*continued*)

	3rd order codes (deductive)	2nd order code (deductive)	1st order code examples (inductive)		
		Technology	ExchangeableBattery	PurityGrade	ModularDesign
		ProductFeatures	BatteryConsumableMaterials	AlternativeMaterials	
	Value Capture	RevenueModel	SmartphoneSales	SustainabilityPremium	CostBasedPricing
			SparePartsSales	ServiceFees	
		CostStructure	PurchasingCosts	Logistics	ProductionCosts
			CashFlowIssues	RecyclingCosts	
		GrowthStrategy	Scaling	Internationalisation	ImprovingSourcing
			SustainableGrowth	Diversification	
		StakeholderValueCaptured	KnowledgeInput		
			FreeMarketing		
	Industry Context	Pioneering	RethinkProcesses	SolveNeglectedE-wasteIssue	SocialBusiness
		Achievement	RethinkingSmartphoneProduction	PlatformRepairAlternatives	
		ExternalFactors	LegalResponsibility/regulations	IncreasingSustainabilityAwareness	AvailabilityIndustryStandards
			ExistingConsumptionPatterns	ProductReparability	
		TransformationalDynamics	ConstrainedByPartners	DifficultyVCTransparency	PioneerEcosystemSupport
			TransformingValueChain	MutualVision	
		Interactions	ComplementaryBusinessModel	MarketBasedTransformation	HighResidualValue
		PioneerIncumbent	ProofOfConcept	ReplicationIncumbent	
	Life Cycle Phases	RawMaterials			
		Manufacturing			
		DistributionSales			
		Usage			
		EndofLife			

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