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Circular value creation architectures

Make, ally, buy, or laissez-faire

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Abstract

Slowing and closing product and related material loops in a circular economy (CE) requires circular service operations such as take-back, repair, and recycling. However, it remains open whether these are coordinated by OEMs, retailers, or third-party loop operators (e.g., refurbishers). Literature rooted in the classic make-or-buy concept proposes four generic coordination mechanisms and related value creation architectures: vertical integration, network, outsourcing, or doing nothing (laissez-faire). For each of these existing architectures, we conducted an embedded case study in the domain of smartphones with the aim to better understand how central coordinators align with actors in the value chain to offer voluntary circular service operations. Based on the above coordination mechanisms, our central contribution is the development of a typology of circular value creation architectures (CVCAs) and its elaboration regarding circular coordination, loop configuration, and ambition levels. We find that firms following slowing strategies (i.e., repair, reuse, and remanufacturing) pursue higher degrees of vertical integration than those following closing strategies (i.e., recycling) because of the specificity of the assets involved and their greater strategic relevance. The typology also shows that higher degrees of vertical integration enable higher degrees of loop closure (i.e., from open to closed loops) and better feedbacks into product design. Furthermore, we differentiate the understanding on third-party actors by distinguishing between independent and autonomous loop operators. Overall, we strengthen the actor perspective in product circularity literature by clarifying the actor set, their interrelationships, and how they form value creation architectures.

KEYWORDS
business model innovation, circular economy, consumer electronics, corporate sustainability, partnerships, product design

1 | INTRODUCTION

The circular economy (CE) has emerged as an umbrella concept for integrating various life cycle-based approaches from research and practice with the aim to decouple economic growth from absolute resource use (Blomsma & Brennan, 2017). Acting as a long-term vision for closed product, parts, and material loops, the CE concept aims to displace primary production, while evading potential rebound effects (Zink & Geyer, 2017). It covers both technical (i.e., products of use) and biological (i.e., products of consumption) cycles (EMF, 2012; McDonough & Braungart, 2002). We focus on product circularity, which goes beyond traditional waste management approaches by covering slowing strategies for product life extension (repair, reuse, remanufacture) and closing strategies for material recovery (i.e., recycling) (Bocken, de Pauw, Bakker, & van der Grinten, 2016; Bocken, Olivetti, Cullen, Potting, & Lifset, 2017; Lüdeke-Freund, Gold, & Bocken, 2018; Stahel, 2010). Taking a systems perspective, it spans diverse actors, organizations, and life cycle stages (EMF 2012; Geissdoerfer, Savaget, Bocken, & Hultink, 2017; Stahel, 1984), transcending the narrow product focus toward a product-service orientation and new business models (Hansen, Große-Dunker, & Reichwald, 2009; Lüdeke-Freund etal., 2018; Stahel, 2010; Tukker, 2015; Zufall, Norris, Schaltegger, Revellio, & Hansen, 2020).

For businesses pursuing product circularity, three interrelated strategies are discussed in the literature: adapting product design, adjusting business models, and establishing reverse cycles for product and material flows (Bocken et al., 2016; EMF, 2014). While we touch upon all three strategies, this article's focus is on coordination mechanisms for slowing and closing of technical cycles (Stindt et al., 2017). Both original equipment manufacturers (OEMs) and retailers increasingly engage in circular service operations to slow and close product cycles beyond mandatory extended producer responsibility (EPR) mechanisms (Fleischmann, 2003; Lifset, Atasu, & Tojo, 2013). Their motivations are to reduce costs, develop brand value, match new demands, and protect aftermarkets (Toffel, 2004) in order to generate competitive advantage beyond product sales. This also leads to new loop operators emerging in the market (Canning, 2006; Stindt et al., 2017). Consequently, the CE requires additional coordination efforts in the up- and downstream value chains (Boons, 2002; Esty & Porter, 1998; Sharfman, Ellington, & Meo, 1997). While industrial symbiosis provides insights into inter-firm coordination for (waste) material circularity during production (Chertow & Ehrenfeld, 2012; Magnusson, Andersson, & Ottosson, 2019; Prosman, Waehrens, & Liotta, 2017) and closed-loop supply chain literature provides insights into remanufacturing (Guide & van Wassenhove, 2009; Savaskan, Bhattacharya, & van Wassenhove, 2004), there is little research on coordination for holistic product circularity (Hopkinson, Zils, Hawkins, & Roper, 2018; Revellio & Hansen, 2017; Toffel, 2003).

We address this gap with three interrelated research questions: *How can voluntary reverse cycles (both slowing and closing) be centrally coordinated? What are the relationships between the central coordinator (OEM or retailer) and loop operators (e.g., repair providers)? And what are the loop configurations and potentials of different circular coordination patterns?* We address these questions by utilizing the classic "make-or-buy" concept rooted in transaction cost economics (TCE; Williamson, 1991) and the resource-based view (RBV; Wernerfelt, 1984) to compare the degrees of vertical integration of different value creation architectures (Dietl, Royer, & Stratmann, 2009). More specifically, we apply the operationalization used in product take-back literature with four generic coordination patterns of make, ally, buy, and do nothing (Toffel, 2003). For each existing coordination pattern, we conduct an embedded case study (Yin, 2014) on the central coordinator for circular smartphone services, with the aim of better understanding circular coordination, loop configuration, and ambition levels. Together this results in our typology of circular value creation architectures (CVCA).

The remainder of this article is structured as follows: In the literature review, we situate our study in the CE context, introduce the make-or-buy perspective, and discuss our preliminary framework. Then we present our multiple case study method. In the results section, we characterize each of the four CVCAs. Finally, we discuss the results and conclude the paper.

2 | LITERATURE REVIEW

2.1 | Product circularity in technical loops

From a product perspective, the CE represents an extension of life cycle-oriented innovation in which products are designed, managed, and evaluated along the entire value chain from resource provisioning to recovery (Hansen, et al., 2009; Ny, MacDonald, Broman, Yamamoto, & Robért, 2006). Product circularity covers slowing and closing strategies (Table 1) and is rooted in 4R frameworks with the main technical loops of repair/maintain, reuse, remanufacture, and recycle (Kirchherr, Reike, & Hekkert, 2017; Reike, Vermeulen, & Witjes, 2018). It aims at lifetime extension on product, component, and material level, and is facilitated through new product designs (Hopkinson et al., 2018). A specific arrangement of loops (and their interaction) is what we later call an organization's overall loop configuration.

In line with the established waste hierarchy and Stahel's inertia principle, these loops are ordered with environmental and economic benefits principally decreasing from repair to recycling (EMF, 2012; Kirchherr et al., 2017; Stahel, 2010). For the recycling loop, literature distinguishes between open- and closed-loop recycling (Geyer, Kuczenski, Zink, & Henderson, 2016; Haupt, Vadenbo, & Hellweg, 2017). Closed-loop recycling displaces primary production of that same material, whereas in open-loop recycling the material is not returned to the original application because inherent material properties are negatively affected (Dubreuil, Young, Atherton, & Gloria, 2010). While closing loops, whether as open- or closed-loop recycling, is considered the weakest option, slowing strategies are not perfect either. They may also lead to rebound effects (Makov & Vivanco, 2018; Skerlos et al., 2003). Against this background, circumstances may exist where both closing and slowing strategies contribute to absolute output expansion due to market-wide effects, but this is mostly outside of an individual firm's control (Zink & Geyer, 2017) and therefore not focused in this article.

As known from environmental management more broadly (Aragón-Correa & Rubio-López, 2007), technical loops can either be driven by government regulation or strategic rationales (Fleischmann, 2003; Stindt etal., 2017; Toffel, 2003). This represents reactive to proactive postures to circularity—or ambition levels—as known from existing stage models (Maon, Lindgreen, & Swaen, 2010). Previously, loop operations were dominated by recycling-focused legal obligations arising from EPR legislation, which were regularly outsourced to third parties (Johnson, McMahon, & Fitzpatrick, 2018; Krikke, 2010; Lifset etal., 2013). The strategic perspective on voluntary reverse operations is less prominent (Esty & Porter, 1998; Toffel, 2004). But it has become evident that OEMs and retailers increasingly follow strategic motives (Ferguson & Toktay, 2006; Krikke, Hofenk, & Wang, 2013). It is these strategic loop operations that push beyond mere recycling and create new competitive advantages (Gaustad, Krystofik,

TABLE 1 Product and material loop definitions

Loop type	Technical loop	Recovery strategy	Level of analysis	Recovery activities	Value creation
Slowing (product integrity)	Maintain/repair	Maintaining	Product	Detecting and replacing worn parts	Maintaining product functionality and value
		Repairing	Product	Detecting defects and replacing defect parts utilizing spare parts	Restoring defective product to original function
	Reuse	Reusing/ redistributing	Product	Inspect, clean, and redistribute a functioning product (cosmetic repairs only)	Reselling for second/consecutive use phases, also to users with lower performance requirements
		Harvesting	Module/ component	Extracting functioning modules or parts for later reuse	Reusing modules/spare parts in new or used products
	Remanufacture	Refurbishing	Product/ module	Inspecting critical modules and restoring product to specific quality level	Repairing/replacing critical modules to restore product functionality
		Remanufacturing	Product/ component	Inspecting all modules and parts. Restoring to "like new" quality level	Combining harvested and/or new parts into (new) product with potential upgrades
Closing (material recovery)	Recycle	Closed-loop recycling	Materials	Consecutive large scale processes to recover inherent material properties (functional recycling)	Reusing materials as "virgin materials" in similar products to displace primary production
		Open-loop recycling	Materials	Shredding and sorting (downcycling)	Recovering material value partially; reusing materials in low-grade products in different industries

Source: Based on Bocken et al. (2016), Cooper (2005), den Hollander et al. (2017), EMF (2012), Stahel (1984, 2010), Thierry et al. (1995), and Kirchherr et al. (2017).

Bustamante, & Badami, 2018; Webster & Mitra, 2007). Unlike regulated EPR activities, voluntary loop operations require significantly different processes concerning quality, volume, and timing (Fleischmann, 2003; Jayaraman, Baker, & Lee, 2010; Stindt etal., 2017) as well as related inter-firm coordination along the value chain (Sharfman etal., 1997). In the remainder of this article, we therefore refer to circular service operations (CSO) when technical reverse cycles are implemented voluntarily as the basis for a service differentiation in the market.

2.2 | Coordinating circular service operations

2.2.1 | A make-or-buy perspective

For our analysis of circular coordination mechanisms we draw on a make-or-buy approach grounded in TCE and RBV as complementary approaches to explain organizational boundary decisions (Espino-Rodríguez & Padrón-Robaina, 2006; Madhok, 2002). In this perspective, the organizational boundaries of a firm are determined by market costs (Coase, 1937), related asset specificity of a transaction (Williamson, 1979), and a firm's underlying core competencies (Arnold, 2000; Williamson, 1998).

For CSO and environmental management in general, a TCE perspective has been commonly utilized in various studies on coordination mechanisms (Morana & Seuring, 2007; Rosen, Bercovitz, & Beckman, 2000; Toffel, 2003, 2004). A life cycle orientation further increases coordination requirements due to the extensive interactions with up- and downstream actors in the value chain (Boons, 2002; Sharfman et al., 1997). Generally, transaction costs increase significantly for idiosyncratic activities outsourced in arms-length contracting or "buy" solutions (Williamson, 1991). In contrast, hierarchical coordination within organizational boundaries follows administrative command and mitigates opportunistic hazards or information asymmetries and thus decreases costs for idiosyncratic activities (Williamson, 1991). TCE is thus concerned with a comparative evaluation of whether an activity is more efficiently performed within firm boundaries (i.e., vertical integration) or via the open market (i.e., disintegration) (Williamson, 1979). Between these two poles, other hybrid forms of coordination emerge, most importantly, "ally" as long-term partnerships or joint ventures (Borys & Jemison, 1989; Powell, 1990; Williamson, 1991).

Rather than focusing on single transactions, we consider a particular product's entire circular setting and its contribution to competitive advantage (Arnold, 2000). This follows Dietl et al. (2009) concept of (integrated, quasi-integrated, and disintegrated) "value creation architectures", which are defined as "the structure[s] and relationships of all the value-adding activities that are carried out by various actors and companies to bring a particular product or service to market" (2009, p. 26). This approach does not imply that all (circular) activities follow the same coordination mechanism, but rather depicts the prevalent strategy. We are interested in the architecture's central coordinator who is "the linking pin between production and distribution side" (Dietl et al., 2009, p. 44). While not considered in the present article, the same product may also be operationalized in plural forms (Bradach & Ecles, 1989) and, for different products, organizations can develop individual architectures (Abbey & Guide, 2018).

TABLE 2 Major influencing factors for comparative make-or-buy decisions

	Degree of integration:	
Influencing factors	**High (vertical integration)**	**Low (disintegration)**
Asset specificity (of production processes, design, quality, know-how, logistics)	High asset specificity (i.e., custom activity only transferable with high costs)	Low asset specificity (i.e., generic activity, easily transferable to market actors)
Strategic relevance (knowledge and capabilities relevant for competitive advantage)	High strategic relevance (i.e., activity contributes to competitive advantage)	Low strategic relevance (i.e., activity does not contribute to competitive advantage)

Note: We follow Picot et al. (2008, p. 44; see also Picot, 1991) suggestion that asset specificity together with strategic relevance determines core competencies and are therefore considered the two major influencing factors. Further supporting drivers such as uncertainty and transaction frequency can also be relevant (Williamson, 1979), but are not further pursued in the present article due to our focus on entire circular settings rather than individual transactions.
Source: Factors based on Williamson (1991, 1998) and Wigand et al. (1997).

2.2.2 | Strategic relevance and asset specificity influencing make-or-buy

For the related make-or-buy comparison we apply a "reduced form analysis" (Williamson, 1991, 282). As frequently suggested, asset specificity has to be complemented with a strategic perspective from the RBV (Arnold, 2000; Wigand, Picot, & Reichwald, 1997; Williamson, 1998). These two factors are essential, because if the circular activities are both "specifically and strategically important, the fundamental capabilities can be interpreted as core competencies […] and should […] always be organized within and not external to the firm" (Picot, Reichwald, & Wigand, 2008, p. 44). Generally, higher asset specificity and strategic relevance of an activity favor higher degrees of vertical integration (Table 2).

Asset specificity is the main determinant of transaction costs and depicts the degree to which an asset can assist in performing a certain (circular) activity. Assets which are idiosyncratic, knowledge intensive, and immobile, lead to a so-called "small-numbers supply condition" with bilateral dependencies (Williamson, 1998, p. 36). Activities that require specific operational assets are more efficiently coordinated internally as external transaction costs (e.g., research, negotiation, or quality control costs) would increase disproportionally (Wigand et al., 1997). For industrial ecology, Andrews (2000) highlights that asset specificity of reverse operations hinders closed material loops via markets due to initial set-up costs and uneven material flows. Similarly, Rock, Lim, and Angel (2006) demonstrate how new environmental requirements lead to relational contracting with suppliers. Regarding product remanufacturing, Martin, Guide, and Craighead (2010) analyze drivers for make-or-buy decisions, concluding that asset specificity and intellectual property concerns are primary drivers for make solutions.

By extending the TCE perspective with the RBV in line with Madhok (2002), we consider an activity's strategic relevance characterized by their contribution to a firm's competitive advantage and core competency (Williamson, 1998). Core competencies are based on resources that allow access to a variety of markets, provide customer benefits, and are difficult to imitate (Prahalad & Hamel, 1990). Strategic activities require highly specific knowledge and act as a differentiator in the market. However, not every specific activity is also strategically relevant. Strategically relevant activities are maintained internally by the central coordinator for proprietary reasons and to cope with complex knowledge and skills. Early indication of the strategic relevance of reverse operations is documented in the closed-loop supply chain literature (Krikke, van Harten, & Schuur, 1998; Stindt et al., 2017; Thierry, Salomon, van Nunen, & van Wassenhove, 1995). With regard to CSO, Jayaraman et al. (2010) point out that reverse capabilities are difficult to imitate and thus contribute to competitive advantage. Toffel (2004) identified strategic motives for a central actor's decision to coordinate reverse operations. Addressing circularity strategically requires a redefinition of "how companies create and capture value" (Lüdeke-Freund et al., 2018, p. 3), often leading to new business models and the design of new "value creation systems" (p. 6).

2.2.3 | Make, ally, buy, and do nothing regarding CSO

We now review the role of coordination mechanisms in the CE context. Product circularity, in particular for consumer goods, involves the coordination of multiple actors in all stages along the product value chain to minimize disperse product and material flows. So far, make-or-buy studies of CSO mainly focus on single circular strategies, in particular remanufacturing and recycling, and polar coordination, in particular integration versus outsourcing (Magnusson et al., 2019; Pagell, Wu, & Murthy, 2007). Comprehensive studies considering all 4R strategies with a more nuanced approach are missing. An exception is Kirchgeorg (1999) who utilized TCE to distinguish coordination strategies for subdivided reverse functions (e.g., logistics, reconditioning, disposal). Literature on closed-loop supply chains, reverse logistics, and remanufacturing (Guide & van Wassenhove, 2009; Kalverkamp & Raabe, 2017; Lind, Olsson, & Sundin, 2014; Lund, 1985) provide initial insights into actors involved in reverse operations. Lund (1985) studied remanufacturing actors in the automobile industry and identified, alongside OEMs, contract and independent remanufacturers—the latter often without formal relationships to the central coordinator. Although the CE adds another level of complexity with multiple hierarchical loops going beyond remanufacturing, there seem to be similar actor structures. For example, Stahel (1984) mentions in his early work that, in addition to OEMs, "independent work units" are locally organized to perform loop activities. Similarly,

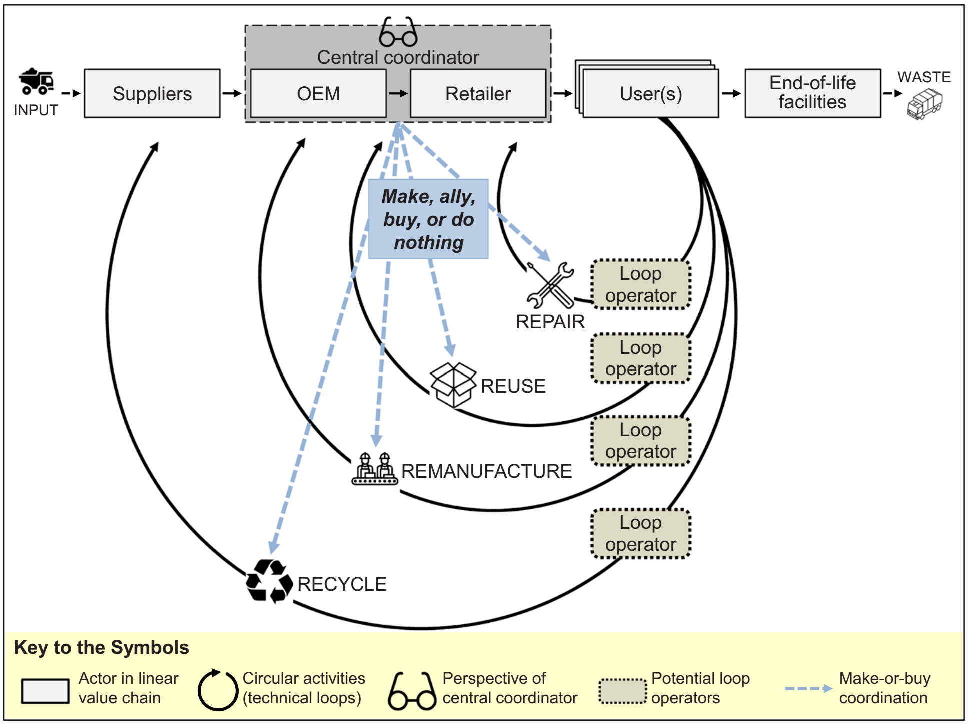

FIGURE 1 Preliminary conceptual framework of circular value creation architectures

Canning (2006) and Geyer and Blass (2010) point to third parties regularly commissioned by OEMs for take-back and recycling in the electronics industry.

Rooted in transaction cost and RBV-related theories, Toffel (2003, 2004) outlines a conceptual decision tree for strategic product recovery by the central coordinator: while the first three strategies—hierarchy, hybrid, and market—resemble the traditional set from make-or-buy, the fourth strategy ignores strategic circularity and "does nothing to support product recovery" (Toffel, 2003, p. 118). The latter strategy requires a closer look into the literature. For example, closed-loop supply chain literature similarly points to emerging third-party remanufacturing firms and related opportunity costs if OEMs "ignore the (locally) profitable remanufacturing opportunity" (Ferguson, 2010, p. 16). Furthermore, third-party loop operators are identified as a threat to after-markets and brand image (Esty & Porter, 1998; Toffel, 2004) and as one of the five forces that drive recovery markets (Stindt et al., 2017). For OEMs without circular strategy, Jayaraman and Luo (2007) show that neglecting attractive reverse operations can lead to a potential backfire on revenues. In recent CE literature, third-party business models based on CSO that are untapped by OEMs are referred to as gap exploiter models (Bakker, den Hollander, & van Hinte, 2014; Bocken et al., 2016; Whalen, Milios, & Nussholz, 2018). As explored in detail in the discussion of this article, we refer to third-party actors without a formal relationship to the central coordinator as "autonomous" actors operating in a "laissez-faire" architecture.

2.3 | Preliminary conceptual framework

The integration of circular strategies, coordination mechanisms, and value creation architectures leads us to propose the following preliminary framework (Figure 1):

1. A life cycle orientation represented by a simplified linear value chain spanning from resource extraction to end of life.
2. Voluntary technical loops for recovering products and related materials preventing their end of life.
3. An extended systems perspective with loop operators as third-party actors offering various CSO.
4. A central coordinator linking production and distribution. This can be either an OEM, with direct sales channels, or a retailer—both acting as service providers (EMF, 2012, p. 22). In the CE, their role is strengthened as they become product-service providers with recurring points of contact (Bocken et al., 2016; Reim, Parida, & Örtqvist, 2015; Tukker, 2015). From a policy perspective, both are typically held responsible for the fulfilment of legal warranties (EC, 2011) and take-back (EC, 2012) in their role as distributors.
5. The central coordinator's strategic choice to make, ally, buy, or do nothing concerning each CSO.

3 | METHOD

In this article, we analyze organizational coordination mechanisms for voluntary CSO building on an extended make-or-buy approach. To understand this emerging research field, we use a case study research strategy. We combine two popular case traditions (Ridder, 2017): Yin's (2014) comparative multiple case studies and Burawoy's (1998) extended case method emphasizing in-depth cases. In contrast to exploratory case studies aiming at inductive theory development (Eisenhardt & Graebner, 2007), we follow the lead of Yin and Burawoy who both stress the need of preexisting theory, which we specified in our preliminary framework. Our ultimate aim is therefore abductive theory *elaboration*, not inductive *development* (Fisher & Aguinis, 2017; Vaughan, 1992). While the remainder of this section introduces the research design in a sequential form, our research was developed in an iterative process of systematic combination of the theoretical framework, data sources, and analysis (Dubois & Gadde, 2002).

3.1 | Industry context

For our empirical analysis, we selected the smartphone segment in the consumer electronics industry due to the sustainability challenges it faces and its emerging circular solutions. Environmental and social issues include conflict minerals (Moran, McBain, Kanemoto, Lenzen, & Geschke, 2015), limited repairability, premature obsolescence (OECD, 2011; Wieser & Tröger, 2017), and rapidly accumulating e-waste with limited recyclability (Baldé, Wang, Kuehr, & Huisman, 2015; Navazo, Méndez, & Peiró, 2014). Major environmental impacts during production and the high monetary reuse value of embedded modules prioritize slowing over closing smartphone cycles (Cooper & Gutowski, 2017; EMF, 2012). Due to these challenges, EPR legislation already requires distributors to undertake basic circular activities (EC, 2012). However, existing legal regulations have not only been unable to prevent unsustainable practices by industry and users, they sometimes even promote them. For example, EU waste electrical and electronic equipment (WEEE) legislation has a strong recycling focus that impedes reuse strategies (Johnson et al., 2018). Furthermore, despite existing mandatory warranties, today, most smartphone repairs are non-warranty issues resulting from excessive wear and tear or environmental exposure (e.g., cracked screens and faulty connectors) (Wieser & Tröger, 2017). With the rise of sim-only contracts, smartphones are commonly distributed by both telco operators and OEMs (Watson et al., 2017; White, 2018), with both actors potentially serving as a central coordinator.

Legislative shortcomings have made pioneers develop alternative approaches. Social initiatives have used a crowd-sourcing approach to develop online repair manuals like iFixit (Charter & Keiller, 2016). Local professional maintenance service firms have emerged to supplement insufficient OEM-based repair services (Riisgaard, Mosgaard, & Zacho, 2016). A large proportion of out-of-use phones, especially those with low intangible brand values (Makov, Fishman, Chertow, & Blass, 2018), are considered "lost" in personal storage after short duration of use (Wilson etal., 2017). Still, different reuse models for formal exchange have been identified (Kissling etal., 2012). In fact, growth rates of secondary markets have recently exceeded those for new devices (Counterpoint Research, 2018). Finally, pioneering smartphone OEMs have emerged who apply circular design strategies such as device modularity and upgradability (Hankammer, Jiang, Kleer, & Schymanietz, 2018; Schischke, Proske, Sommer, & Trinks, 2016; Zufall et al., 2020).

Overall, the smartphone production and consumption system represents a suitable empirical context to study newly emerging coordination mechanisms in the CE.

3.2 | Case selection

To become familiar with the industry and grounded in the problem domain, we followed an engaged scholarship approach (van de Ven, 2007, p. 268). As part of a larger research project, we established the Innovation Network aiming at Sustainable Smartphones (INaS)—a kind of design or living lab (Clausen & Gunn, 2015). The participants, predominantly from German-speaking areas and organizations, represent industries across all stages of the smartphone value chain, civil society organizations, and academia. We frequently held workshops over a 3-year period to discuss challenges and co-develop solutions (e.g., Hansen, Weber, & Schaltegger, 2016; Revellio, Hansen, & Schaltegger, in press). Not all organizations participating in our lab were included in our sample—rather, we considered them as potential candidates and as a springboard to gain access to other actors using a snowballing technique.

We selected cases for their potential contrasting results rather than to increase statistical significance (Dubois & Gadde, 2002; Yin, 2014). Thus, our primary selection criterion follows *theoretical* replication that "predicts contrasting results but for predictable reasons" (Yin, 2014, p. 57). We were only interested in central coordinators whose predominant coordination strategy matched our preliminary framework (Yin, 2014). As a variant of "polar type" sampling (Eisenhardt & Graebner, 2007, 27), we chose four cases, together, covering Toffel's (2003) product recovery strategies make, ally, buy, and do nothing (see Table 3). In our embedded setting, we applied two units of analysis: the central coordinator and related loop operators. We decided to investigate these four embedded cases in greater depth instead of increasing our sample size (Dubois & Gadde, 2002). We thus aim to provide in-depth empirical evidence to elaborate established coordination patterns in the emerging literature on product-level circularity (Eisenhardt, 1989; Fisher & Aguinis, 2017).

TABLE 3 Case sampling, unit of analyses, and actor characteristics

Case coordination strategy	Unit of analyses: Central coordinator	Unit of analyses: Loop operators	Loops covered	Actor description (coordinators/loop operators)	Coordination mechanism with loop operators
1: Make	SmartMan	–	Repair, reuse, remanufacture	German niche OEM for smartphones. Founded on a sustainability mission. SmartMan considers CSO as a core competency. Ultimately, they commercialized a modular and repairable product design	*Overall*: Strong vertical integration by covering most activities internally
		ReverseOp1	Recycle (collection)	Non-profit reverse logistics specialist for WEEE. Focus on take-back traceability, and data privacy. Hires long-term unemployed workers	Partnership contracts
2: Ally	TelcoPro	–	None	Large German telco operator buying devices from OEMs and cooperating with loop operators to co-develop CSO	*Overall*: Hybrid coordination focused on equity investments and strategic partnerships
		ReverseOp2	Recycle/reuse	Reverse logistics specialist for electronic equipment. Focus on take-back collection, data privacy systems, and buy-back programs	Equity investment
		RepairOp2	Repair	Repair specialist for popular smartphone models in Germany	Equity investment
		RefurbOp2	Remanufacture	Refurbishing facility for smartphones specialized on common spare parts components (e.g., screens)	Strategic contracts
		RecycleOp2	Recycle (materials)	Large recycling facility for WEEE with shredding and pre-sorting process stages, but without metallurgic processing stage	Equity investment
		NGO2	Recycle (collection)	Environmental NGO, active in WEEE take-back systems and policy design	Long-term contracts
3: Buy	TelcoBasic	–	None	Large German telco operator focusing on compliance-based take-back schemes to reduce WEEE costs and increase image	*Overall*: Market-based coordination with short-term partnerships
		ReverseOp3	Recycle (collection)	Non-profit reverse logistics specialist for WEEE. Focus on take-back traceability, and data privacy. Hires long-term unemployed workers	Contractual with short-term revisions
		NGO3	Recycle (collection)	Large German environmental NGO promoting take-back and undertaking public relations for WEEE in Germany	Contractual with short-term revisions
4: Do nothing	n.a. (all relevant coordinators)	–	n.a.	No contact to coordinators as loop operators work autonomously. Services limited to basic repairs due to missing access to original spare parts and information asymmetries	*Overall*: Uncoordinated activities by third-party actors
		MaintainOp4	Maintain/repair	Battery exchange specialist for electrical and electronic devices with one local facility and international online sales	None
		RepairOp4	Repair/reuse	Regional repair service (two shops) for smartphones and related mobile devices. Some used phone sales	None

Note: CE = circular economy; NGO = non-governmental organization.

TABLE 4 Overview of qualitative data sources

Data type	# Count	Length [hh:mm]	# Organizations covered	Documentation type
Semi-structured interviews	18	17:10	13	Transcripts
- Central coordinators and their suppliers	(8)	(07:45)	(3)	
- Loop operators	(8)	(07:55)	(8)	
- Industry experts	(2)	(01:30)	(2)	
Ethnographic interviews	27	24:10	13	Field notes
- Central coordinators and their suppliers	(18)	(16:45)	(4)	
- Loop operators	(6)	(05:15)	(6)	
- Industry experts	(3)	(02:10)	(3)	
Focus group sessions (e.g., meetings with multiple managers)	2	05:45	2	Field notes
Site visits with observations	9	36:35	8	Field notes, photographs
Participatory observation of organized industry workshops	4	32:00	n.a.	Workshop documentation
Observation of industry events (e.g., specialized congresses)	5	43:30	n.a.	Field notes, presentations
Archival data (e.g., company websites, press releases, product flyers, and media reports)	60	n.a.	n.a.	Electronic documents and scanned documents

3.3 | Data collection

Following the extended case design, we iteratively collected data over a 30-month period of time—from April 2016 to July 2019—and from different places (Burawoy, 1998). Data from various sources (Table 4) was triangulated both for reasons of discovery and verification (Dubois & Gadde, 2002). A key source was semi-structured interviews with company representatives from central coordinators and loop operators at management level, often coupled with site visits. For primary data collection, we developed semi-structured interview questionnaires building on the preliminary conceptual framework as well as organization-centric desk research. As recommended in the extended case method, we actively seized opportunities for additional informal ethnographic interviews with participants and their partners to learn in a natural context (Munz, 2017). This allowed us to move from observing to understanding an individual case in its context (Hammersley & Atkinson, 2007; Yin, 2014). We stopped data collection when we reached theoretical saturation regarding the newly elaborated categories (i.e., circular coordination, loop configuration, ambition level) in our existing four patterns (Saunders et al., 2018).

3.4 | Data analysis

For the analysis, we built on Yin's (2014) pattern matching technique for matching predicted patterns from existing theory on coordination mechanisms (i.e., make, ally, buy, do nothing) with empirical ones in the context of product circularity, representing a contrasting approach (Fisher & Aguinis, 2017). We reconstructed and elaborated this theory (Burawoy, 1998) and refined existing concepts to "improve [their] logical and empirical adequacy" (Fisher & Aguinis, 2017, p. 445), with the ultimate objective of "matching theory and reality" (Dubois & Gadde, 2002, 554). Then we compared cases in an abductive approach utilizing both deductive categories from existing theory and inductive (sub)categories emerging from the empirical context to improve validity and scope (Fisher & Aguinis, 2017). One researcher was involved in coding the raw data before discussing, synthesizing, or aggregating them together with the second researcher. To increase credibility, we followed trustworthiness criteria by Guba (1981), in particular, "member checks" with case representatives and "peer debriefing" among researchers.

4 | RESULTS

Based on the theoretical patterns from the literature review, we then used case studies to elaborate each architecture regarding its loop configuration, circular coordination, and ambition level (Table 5). We present the architectures in a continuum from high to low degrees of both vertical integration and strategic orientation of circularity.

TABLE 5 Case results: characterization of circular value creation architectures

	Architecture 1 **Vertically integrated**	Architecture 2 **Network**	Architecture 3 **Outsourcing**	Architecture 4 **Laissez-faire (do nothing)**
Overview	**SmartMan** covers all technical loops themselves. Developed internal capabilities for CE and adapted product design to reduce complexity. As a result, value focus shifted from product sales toward sustainable product-service system	**TelcoPro** offers advanced CSO coordinated through strategic partnerships and equity investments with multiple specialized LOs. Focus on customer-oriented and cost-efficient circular solutions to offer life cycle services	**TelcoBasic** performs compliance-plus activities limited to standardized recycling processes. Coordination through arm's-length contracts strongly linked with evolving legal framework. Focus on take-back as effective CSR program	**MaintainOp4 and RepairOp4** offer repair/maintenance and some reuse activities. No formal contact to central coordinators, who leave voluntary circular services unaddressed. Ambivalent relationship through perceived mutual benefits
Loop configuration	**Holistic**	**Broad**	**Narrow**	**Diverse**
- Technical loop coverage and synergies	All loops covered in integrated strategy concept	Multiple loops initiated in decentral departments. Limited synergies	Single loop focus (mostly recycling) in compliance with legal regulations	CSO ignored by central coordinator. Single loops undertaken by local third-party operators: mostly repair, some remarketing
- Loop evolution and slowing relevance	Slowing loops first: follows product life cycle phases	Closing loops first: from WEEE compliance toward profitable slowing loops	Follows developments in legal regulation	Depends on exploitation strategy of autonomous actor. Strong market orientation and learning by doing
- Degree of loop closure	High: products and parts remain in original value chain for consecutive loop iterations	Medium: most products exit original value chain to semi-controlled secondary markets	Low: products exit original value chain. Central coordinator aims to control over destination to prevent misuse	Medium to low: no control by central coordinator. Reintroduction to other markets depends solely on autonomous LOs
- Feedback to product/portfolio design	First-hand CE involvement shapes future development to modular product design and deposit system to reduce life cycle costs	Second-hand experience leads to indirect feedback: adapt procurement decisions. Some feedback to adapt service design and initiate new services	Limited second-hand experience leads to indirect co-development or feedback to product or service design as each actor follows own agenda	No formal second-hand feedback due to lack of feedback channels. But potential feedback through publicly available information

(Continues)

TABLE 5 (Continued)

	Architecture 1 Vertically integrated	Architecture 2 Network	Architecture 3 Outsourcing	Architecture 4 Laissez-faire (do nothing)
Circular coordination	**Make**	**Ally**	**Buy**	**Do Nothing (left to autonomous LOs)**
- Coordination mechanism	Vertical integration through internal capacity building for CE activities	Alliances and strategic partnerships with LO specialists, particularly for slowing loops	Market-based coordination with several potential partners to choose from (large-number supply condition)	Central coordinators ignore autonomous LOs. Uncoordinated relationship
- Relationship to loop operators	Little need for LO involvement. LOs must fit to central coordinator's values and norms	Strategic partnerships and minority equity investments to co-develop technical loops proactively	Contractual relationships with yearly reviews. Partners are charitable organizations	No formal contact exists. Ambivalent relationships with perceived negative connotation
- Strategic relevance				
– *Degree*	High: CE as intrinsic motivation with CEO promotion. Development as core competency and key to brand positioning	Medium: CE loop activities initiated by individual internal promotors. Limited internal visibility and slow cultural change	Low: voluntary recycling activities complement compliance obligation from CSR perspective	Low: central coordinators offer very limited CSO beyond legal minimum
– *Value focus*	Shift from product sales toward a product-oriented sustainable product-service system	Offer add-on life cycle services alongside core product to protect existing markets and develop new ones	Address minimum of circularity as cost of doing business and attempt to benefit through improved image	Ignore value of extended use and residual values. Product sales paramount
– *Business case for circularity*	CE as driver for innovation and product (life cycle) quality. CE as part of brand value	CE activities as reaction to market developments. Safeguard market share, profit margins and tap into new markets	Focus on reputation and cost reduction. Prepare for potential future legal developments	None. Protect traditional business model
- Asset specificity	Investment in specific skills, processes, designs. Close customer contact with highly skilled technicians	Specific assets required but not available at central coordinator. Close exchange with partners on processes and customer contact	Low asset specificity due to standardized recycling activities. No specific investment required	Limited loop activities by central coordinator. Autonomous LOs deal with highly specific investments in tools and skilled staff
Ambition level	**Lead the industry**	**Strategic**	**Compliance plus**	**Reactive**
- Environmental/circular potential	Development of closed-loop system with potentially little leakage. Proprietary solution might limit scale Focus on slowing loops creates largest resource and energy efficiency potential Differentiation through new modular design and market communication increases pressure on other industry members to follow	Mix of integration and market-based approach potentially allows for both improving and scaling circular system	Minor "end-of-pipe" (e.g., recycling) improvements within existing system Contribution to public debate and awareness through collaboration with NGOs	Autonomous LOs develop localized, low-cost and therefore accessible solutions. Market niche products due to informal character Innovative solutions with high loop-specific expertise developed by autonomous LOs become potential target for partnerships and acquisition by coordinators

Note: CE = circular economy; LO = loop operator; NGO = non-governmental organization.

4.1 Vertically integrated architecture

4.1.1 Loop configuration

Unlike other smartphone OEMs, SmartMan was founded to promote sustainability. SmartMan's strategic product life cycle approach is based on their owner-managers' intrinsic motivation:

> *These [technical] loops, we just did them all intuitively. [...] Because we realized to do it [the phone] well, we have to deal with them [technical loops]. (SmartMan, Owner-manager 1)*

Loop activities reach beyond those covered by legal warranty. Their initial starting point was to make their phones repairable, offer reasonably priced original spare parts, and in-house repairs. Phone lifetimes are prolonged through a strong user–product relationship, for instance, by supporting do-it-yourself repairs through publishing repair manuals on YouTube. SmartMan implemented a deposit system to increase return rates and minimize the number of "lost" phones in the public collection scheme. As owner-manager 1 clarifies: *"We need them back. We can reuse and recycle them best because we know our phone best."* The deposit system is a precondition for a high degree of loop closure. SmartMan remarkets returned and remanufactured phones to customers with lower performance requirements:

> *We have enough customers who ask for an old phone. They're not asking for the latest Android version; they mainly want to send a few messages on WhatsApp. (SmartMan, Owner-manager 1)*

Their closed-loop collection system facilitates harvesting strategies to collect spare parts for later reuse. A modular product design enables refurbishing, including limited hardware upgrades. Material recycling activities are closely managed with an external loop operator (ReverseOp1) because the limited amount of material does not technically allow for internal recycling operations.

4.1.2 Circular coordination

SmartMan first considered outsourcing some activities, but quickly realized that it would not fit their strategy. In order to extend their value chain control to all four technical loops, they now perform most loop operations in-house. SmartMan's engagement focuses on slowing loop strategies, which require customer proximity as well as device-specific knowledge assets (e.g., defect statistics) and spare parts. Particularly their circuit board repair processes call for specific process knowledge and tools, which they receive from their closely managed suppliers. To build internal capacities, SmartMan's owner-managers participate in CE trainings and hire circular specialists for customer support. Close customer contact through a direct sales concept and lean processes are key to their CSO:

> *Customers call us and receive individual advice about whether to send in their phone or we recommend a [do-it-yourself] repair. In contrast, this [i.e. outsourcing] would mean having lengthy additional processes and thus increasing costs. (SmartMan, Owner-manager 1)*

Vertical integration of CSO facilitates information flows within the firm and is a driver for innovation on technical (e.g., device modularity), product (e.g., new services), and organizational (e.g., deposit system) levels. First-hand experiences with loop activities link back into product development processes. New device generations were designed to simplify repairs and ultimately led to a modular product design (ranked 9 out of 10 in iFixit, 2019):

> *I think it's nice and important to have as many [CSO] as possible in-house. Because we have learned so many things already. [...] If outsourced, sure we could conduct surveys, [...] but having it in-house means communication channels are shorter. (SmartMan, Owner-manager 2)*

To reduce support complexity, they aimed at a two-level device modularity. It facilitates both basic DIY user repairs (e.g., battery, screen, and connectors) and professional in-house repairs down to the level of the main circuit board (e.g., exchange of integrated circuits or eliminating short circuits).

From a strategic perspective, their devices' circular and broader sustainability characteristics have become SmartMan's core competency and unique selling proposition. They have positioned themselves in a niche that rewards an integrated life cycle approach. Furthermore, they are able to generate additional revenues through spare parts sales, in-house repair services, and remarketing activities, thus moving toward a product-service system.

4.1.3 Ambition level

By coordinating the entire circular value chain, SmartMan has developed a closed-loop system for their products, parts, and, to some extent, materials. Although the system is at an early stage and scaling is time consuming, their strategic focus on slowing loop strategies provides high potential for prolonged product lifetime and related resource efficiency. Thus, with their vertical integration approach, SmartMan leads the industry with regard to closed-loop circularity and increase pressures on established industry actors to adopt similar circular systems.

4.2 | Network architecture

4.2.1 | Loop configuration

TelcoPro's CSO originate from a donation-based collection system complementing European WEEE legislation. Initiated by the CSR department and operated in partnership with loop operators, it focuses on outdated mobile phones. However, as this recycling-focused system is not a self-sustaining business model, TelcoPro developed three further services. First, jointly with ReverseOp2, they developed a remarketing business aiming at smartphones with higher reuse values, "*typically kept in personal drawers*" (Key-account manager). Still, similar to the initial collection system, returned smartphones do not re-enter TelcoPro's original value chain as they are not sold alongside new products. Instead, ReverseOp2 conducts cosmetic repairs and remarkets them in batches to verified resellers.

Furthermore, TelcoPro's after-sales department has entered a strategic partnership with RepairOp2 to offer a competitive on-site same unit repair service. This is a reaction to increased out-of-warranty repair requests, expensive fixed-rate repair options from OEMs (which in some cases are mandatory to retain warranty), and emerging third-party repair services:

> *With more smartphones with sleek designs, bigger screens, more glass, and increased usage intensity, damages due to drops have increased. […] A B2C customer does not want to pay €300 to fix a cracked screen. This is where third-party repair shops have appeared in the city centers. (TelcoPro, After-sales manager)*

One obstacle encountered in all of TelcoPro's CSO is limited access to original spare parts. Although TelcoPro is one of the largest telco operators in Germany, their relationship with global OEMs is limited. TelcoPro thus developed a third partnership with RefurbOp2, targeting refurbishing practices with harvested parts (so far, focusing on screens). Except for RepairOp2's same unit repair service, most smartphones exit TelcoPro's original value chain with unknown destinations, representing a medium degree of loop closure.

4.2.2 | Circular coordination

This architecture is characterized by strategic and long-term partnerships with specialized loop operators, allowing TelcoPro considerable control. While TelcoPro uses CSO as a customer retention strategy, loop operators gain access to the coordinator's existing customer base through distribution agreements. TelcoPro maintains these alliances mostly through minority equity investments. Modes of collaboration include joint service development, distribution partnerships, and exclusivity agreements. We observed that loop integration increases from closing to slowing loop strategies. Standardized recycling activities can still be easily outsourced, as processes in the dominant recycling system are identical regardless of smartphone brand, condition, and usage patterns. In contrast, refurbishment or repair activities call for specific quality requirements, close customer relationships, and constantly changing (post-consumer) market knowledge:

> *Recycling is far away from our core business, which is sales [of smartphones and network contracts]. […] For the recycler it doesn't matter what we told the customer in the beginning. In the end, they receive pallets with goods and process them. In contrast, the buy-back firm [ReverseOp2] asked us to specify this and that in advance, so they can pay us more. There is a constant feedback process. Also [RepairOp2] performs test purchases and then tell us what to improve in the sales process; a recycler would never do that. (TelcoPro, After-sales manager)*

Slowing-based CSO can be considered distant and, sometimes, contrary to the core business. TelcoPro's key promotors have struggled with organizational inertia and resistance from other departments due to provision-based sales and revenue-oriented target agreements leading to risks of cannibalization. To increase flexibility, TelcoPro adopted a corporate venturing strategy:

> *A big firm [such as TelcoPro] is like a huge tanker. They have their business and the tanker sails straight ahead and is probably very successful. But you can't tell this tanker: tomorrow you have to do the opposite and sail in a different direction. […] To do this they need small dinghies like us. (ReverseOp2, Key-account manager)*

With the strategic focus moving from CSR-driven activities toward consumer-centered circular services, the business case shifted from a reputation and cost focus to a profit and sales focus. Similarly, the partner selection shifted from non-profit waste collectors toward profit-driven loop specialists. However, with their buy-back program, they also aim to increase their market share (i.e., buy-back vouchers serve as an incentive for customers to return to the shop), leading to potential environmental rebounds.

4.2.3 | Ambition level

With their strategic approach of strong alliances, TelcoPro has set up a system with the potential to scale rapidly. Currently the demand for circular services is limited and profit margins cannot compete with product sales, but especially in the B2B setting their importance for total ownership costs and attractive service agreements is increasing. The next step toward a higher degree of loop closure could be offering used smartphones in their own sales channels:

> *We have already established the partnerships, infrastructure, and processes. Nevertheless, so far, we don't have the customer base and necessary volumes. […] We are considering offering used smartphones to target other customer groups […] but this would seriously conflict with our business model of selling new smartphones. (TelcoPro, After-sales manager)*

4.3 | Outsourcing architecture

4.3.1 | Loop configuration

Firms may buy out of collective WEEE systems by setting up their own voluntary collection schemes. TelcoBasic commissioned two non-profit organizations, ReverseOp3 and NGO3, to develop a voluntary scheme to collect outdated mobile phones from users on a donation basis. Profits from material recycling and partial remarketing (5–10%) benefit one of NGO3's environmental projects and TelcoBasic's publicity activities. Similarly, ReverseOp3 employs long-term unemployed people to handle logistics, data deletion, and material recycling operations.

4.3.2 | Circular coordination

In this architecture, inter-firm coordination activities are strongly influenced by legal regulations. Take-back and related recycling activities represent a regulated, standardized, and large-volume activity, neither specific to brands nor devices, so that TelcoBasic can choose from a breath of loop operators. Although TelcoBasic's contractual relationships are often characterized by medium-term runtimes, they are subject to short-term (yearly) adjustments:

> *Generally the contract is open-ended, however it is subject to a yearly review process. […] The contract is changing constantly and fills an entire file with its appendices. This is also because the law is constantly changing. (ReverseOp3, CSR manager)*

From a strategic perspective, TelcoBasic's main motivation is to exceed legal regulations to increase reputation and brand value. Loop activities are based in the CSR department and follow a responsibility rationale with end-of-pipe environmental benefits. Some additional compensation is generated through non-related environmental projects enabled through donations by TelcoBasic to NGO3. Overall, the scheme is a cost factor for TelcoBasic, as returns from material recycling and remarketing do not cover costs of operations. Also, the CSO are not integrated into their core business model but remain add-ons.

Feedback processes to increase circularity do not target TelcoBasic's smartphone procurement decisions, but their collection processes regarding smartphones with higher reuse values. However, each actor in this architecture follows their own agenda. While NGO3 supports the collection of outdated mobile phones only for ecological reasons (i.e., to reduce waste and increase recycling), ReverseOp3 wants to increase the proportion of high-value smartphones for resale through a buy-back program to cross-finance the donation-based system.

4.3.3 | Ambition level

Although this architecture still focuses on recycling (with some limited reuse activities), it represents an incremental improvement to existing EPR schemes. Particularly, TelcoBasic aims at increased collection rates and traceability. Still, as all smartphones exit the central coordinator's value chain, this architecture represents relatively open cycling.

> *None of our phones leaves the European Union. We have internal processes that forbid wholesale. […] We have no intermediary for the recycling; everything goes directly to the recycling plant. (Reverse-Op3, CSR manager)*

4.4 | Laissez-faire architecture

4.4.1 | Loop configuration

In cases where central coordinators do nothing to offer adequate CSO in the market, they leave a vacuum for uncoordinated third-party actors to fill the gap—basically they take a laissez-faire posture. MaintainOp4 and RepairOp4 are such third-party repair service providers for smartphones and other consumer electronics, serving niche markets as international online retailers and local shops. Both are specialized in repair and maintenance, with RepairOp4 also engaging in some remarketing activities. Their service targets those damages not covered by the distributor's warranty, repairs not offered by OEM repair services, or price-sensitive customers preferring low cost, fast, or local services.

As both operators lack formal relationships with central coordinators, they have difficulty gaining access to original spare parts. Furthermore, strong information asymmetries exist with respect to the smartphone's design and supply chains. As a result, they have developed their skills and supply chain through *"learning-by-doing"* (Owner-manager, MaintainOp4). As they would be otherwise dependent on a few intermediaries for spare parts with varying quality levels—sometimes rather *"dubious"* ones (Owner-manager, RepairOp4)—loop operators develop in-house techniques to harvest disused smartphones to create their own supply of (used) original spare parts:

> *Here we are of course fully self-sufficient, this means away from OEMs. […] We do not have access to [original] spare parts. This means we are dependent on solving these things in the "small" loop. (MaintainOp4, Owner-manager)*

4.4.2 | Circular coordination

Central coordinators in this architecture either completely ignore CSO or offer them in a very limited and unattractive manner (e.g., expensive flat-rate repair tariffs). Dominant business models often aim at a fast replacement of smartphones and may not allow to profit from CSO. Potential business cases for circularity are neglected by coordinators as of perceived low strategic relevance. Instead, "autonomous" operators such as MaintainOp4 and RepairOp4 emerge to which coordinators do not maintain any contractual or otherwise formal relationships.

Insights from our study show that attempts by autonomous loop operators to collaborate with coordinators were usually rejected, with reference to product safety or customer convenience. According to the owner-manager of MaintainOp4, the lack of support from established actors makes them "*lone warriors*," While coordinators do not actively support autonomous loop operators, we also observed ambiguity in their behavior: they are sometimes indirectly supported or at least tolerated. For example, against their company policy, some OEMs do not completely impede original spare parts access:

> *OEMs are absolutely aware of our existence. They could be strict and say […] that these spare parts only go through their own channels and […] that they do not appear on the open market. But they obviously let it happen. (MaintainOp4, Owner-manager)*

Overall, the relationship between central coordinators and autonomous loop operators in the value chain seems to be not straightforward, as they usually receive no official support but are at the same time tolerated or even desired actors. Surprisingly, despite this situation MaintainOp4 and RepairOp4 attain double-digit growth rates. They offer their services with the legal minimum warranty of 1 year. Autonomous loop operators thus contribute to the satisfaction of central coordinators' customers by providing them with a less restricted service. Without such unofficial repair options, customers may turn away from certain brands or models:

> *Officially we are unwanted; unofficially we are the basis of their [OEMs] success. (RepairOp4, Owner-manager)*

Due to the lack of a formal relationship among actors in this architecture, central coordinators do not receive feedback from autonomous loop operators. This represents a lost opportunity, as autonomous repair shops collect valuable information regarding weak points in product or service design and often develop innovative solutions.

> *We are better in many things. I can solve problems that an Apple employee, the entire Apple store, would not even begin to understand. We can solve these because we are much more closely involved in the matter. (RepairOp4, Owner-manager)*

4.4.3 | Ambition level

When coordinators follow a laissez-faire approach for out-of-warranty repairs and used phone sales, they leave the market uncontested to autonomous loop operators. Autonomous offerings are characterized by local, low-cost, or instant service and therefore provide accessible CSO with considerable growth rates. However, their informal character is an obstacle for mass-market adoption, as they lack industry-wide standards and certification as well as established professions. Still, autonomous loop operators have developed valuable skills and knowledge regarding specific repair processes and customer contact, making them potentially valuable collaboration partners for coordinators with broader ambition levels.

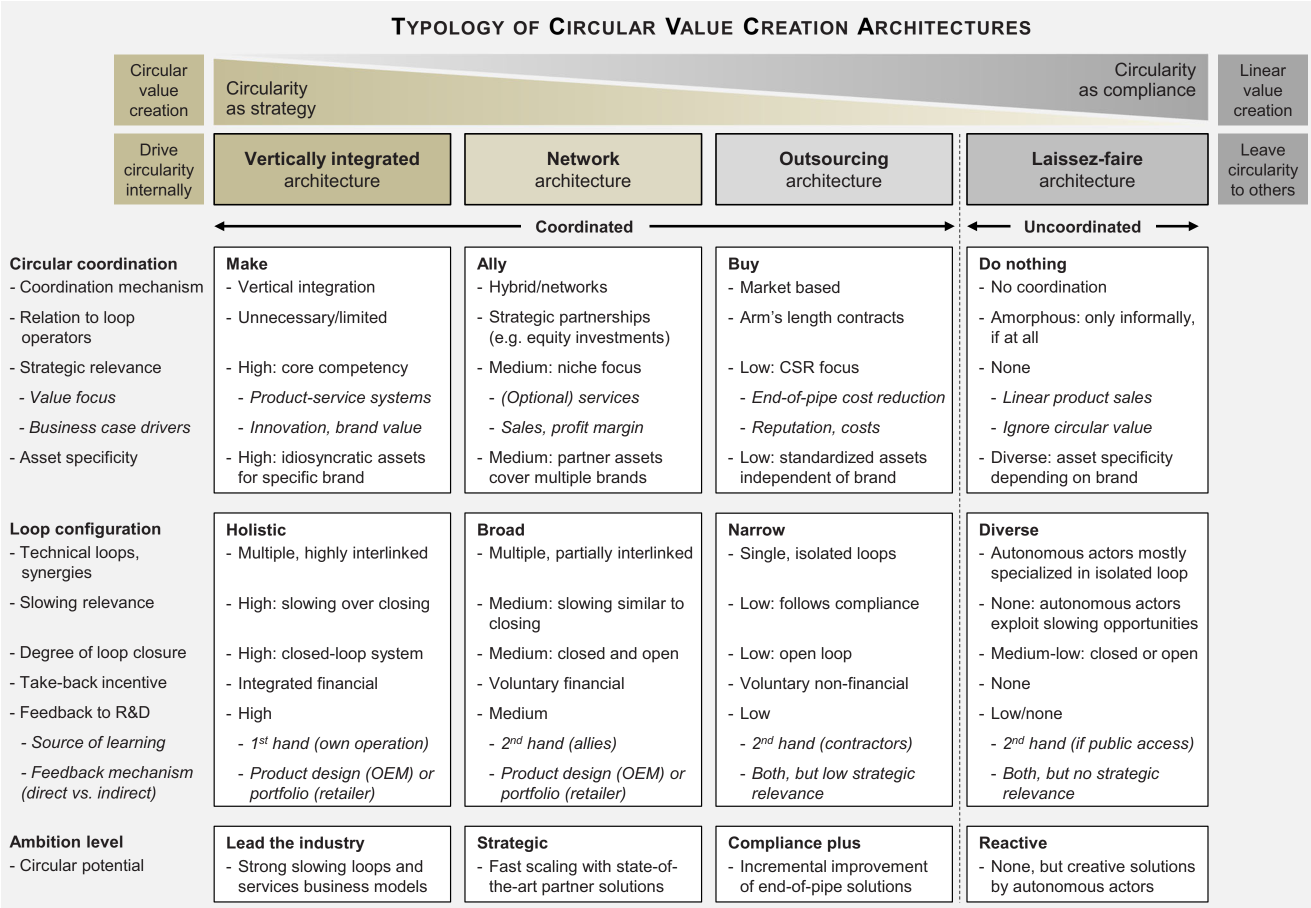

FIGURE 2 Typology of circular value creation architectures (CVCAs) from a central coordinator's perspective
Note: The four architectures are based on Toffel's (2003) strategic decision tree for product recovery and Dietl et al. (2009) value creation architectures. The graphical layout of the typology has been inspired be Tukker (2004)'s seminal paper on "Eight types of product-service systems." The business case for sustainability (Schaltegger, Lüdeke-Freund, & Hansen, 2012) was adapted to the circular setting. R&D = research and development.

5 | DISCUSSION

5.1 | A typology of circular value creation architectures

Building on Toffel (2003), we elaborated four generic CVCAs in terms of their circular coordination, loop configuration, and ambition levels (Figures 2 and 3). We define CVCAs as the structure and relationships of all value-adding CSO carried out by central coordinators and loop operators to keep products, parts, and incorporated materials in the market (based on Dietl et al., 2009, p. 26).

The *vertically integrated architecture* is characterized by maximizing internal loop coordination as a core competency and related market differentiation. Central coordinators follow a holistic approach to circularity and pursue a closed-loop system in which products and, to some extent, materials remain in the original value chain. Vertical integration allows for the management of complex circular systems (Krikke et al., 2013). Central coordinators in this architecture focus on slowing loop strategies with high asset specificity regarding process knowledge, infrastructure, and individualized customer relationship channels, which are generally higher than in alternate closing strategies (still each closing strategy differs in their individual degree). Through an integrated circular business case, coordinators become powerful enough to shift part of their value creation to CSO, resulting in a product-service system approach (Tukker, 2004). CE activities are seen as a source of innovation, particularly in the improvement of product design (Esty & Porter, 1998). Overall, with a lead-the-industry approach regarding circularity, these actors pressure the industry to rethink their linear systems.

In the *network architecture*, central coordinators manage their CSO through a network of affiliated loop operators, thus gaining access to state-of-the-art processes with fast external scaling options. They pursue strategic partnerships and co-develop CSO, moving successively from compliance-oriented recycling toward voluntary and profitable slowing loop strategies, thereby making circularity a profit center rather than a cost center. This leads to increasing asset specificity, which is then managed by coordinators together with their partners. A key challenge for the central coordinator

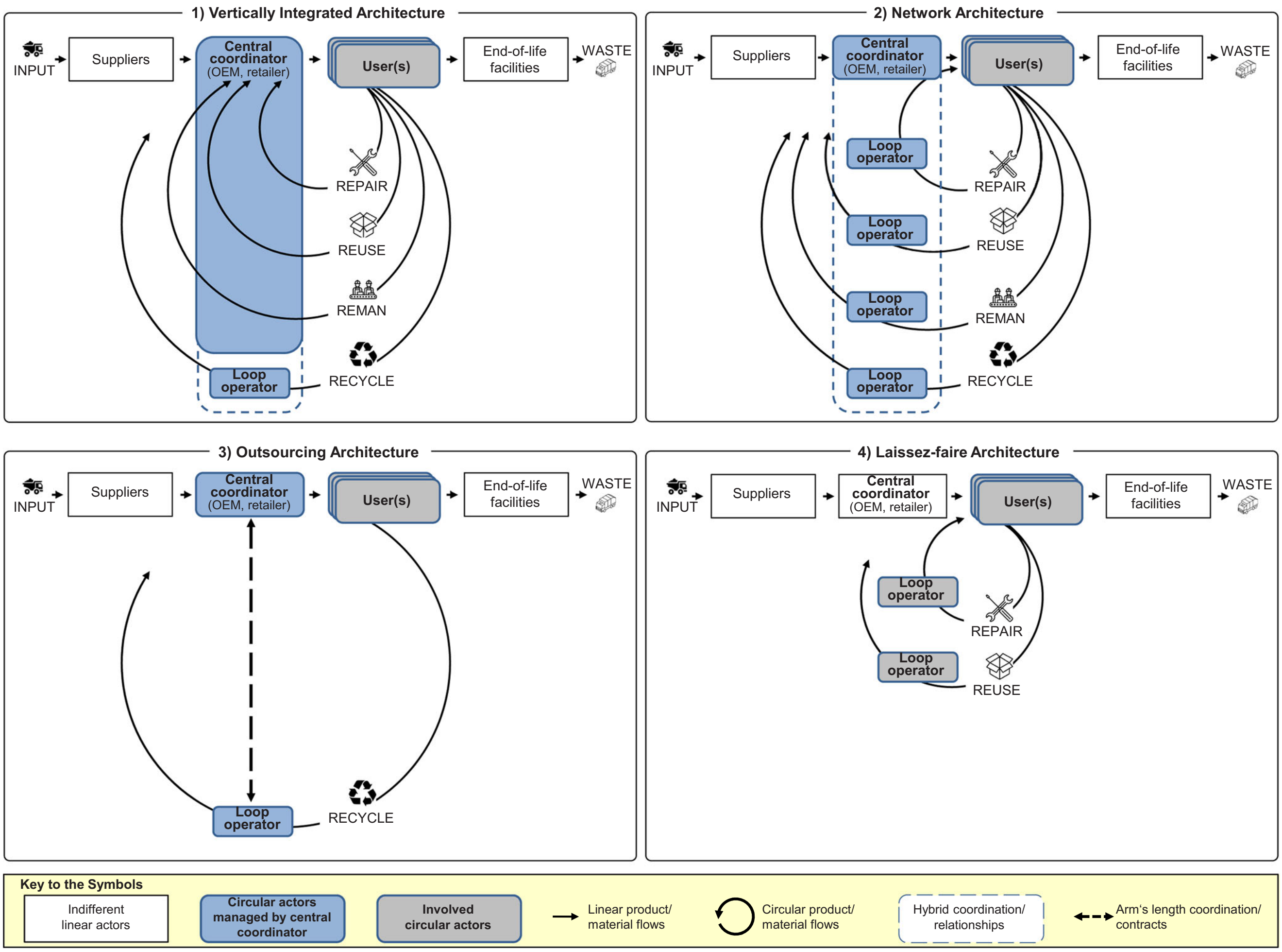

FIGURE 3 Schematic representation of different circular value creation architectures (CVCAs)
Note: Reman = remanufacture.

is to increase synergies among different loop operators working on different loops with different degrees of loop closure. The strategic focus of this architecture is on extending conventional services with add-on CSO to protect after markets (Toffel, 2004) and, if possible, generate additional profits.

The *outsourcing architecture* is characterized by the central coordinator's perception of circularity as relatively non-strategic and as a cost factor. Cost-efficient outsourcing is usually only possible for standardized CSO with low asset specificity. This limits CSO to loops with well-established and often more regulated infrastructures and markets, as is the case with open-loop recycling (Toffel, 2003). Still, coordinators in this architecture incrementally expand the solution space of compliance-oriented practices by seeking loop operators able to provide superior circular value, for example, through voluntary collection schemes by non-profit organizations. Driven mainly by CSR and PR departments, the business case is limited to enhancing image and reputation.

The *laissez-faire architecture* is characterized by an indifferent approach of central coordinators toward CSO coupled with a reactionary protection of conventional sales-driven business models (Stindt et al., 2017). The resulting vacuum in the market creates growth opportunities for existing or emerging autonomous loop operators. They may develop profitable business models based on the untapped value at the end of a product's use or life cycle, and thus focus on high-value slowing loop strategies such as repair or reuse (Whalen et al., 2018). From a coordinator's perspective, these are uncoordinated loop operations because a formal relationship to loop operators is lacking. A laissez-faire architecture may well allow for open loops with singular recirculation, provide opportunities for decentralized entrepreneurial innovation (e.g., harvesting techniques), and local solutions with corresponding job potentials. But it still poses substantial barriers because coordinators in this architecture frequently disincentivize more comprehensive circularity due to potential cannibalization effects.

While we analyzed these four basic architectures, distinguishing further nuanced ones could be a promising research avenue, for instance, considering joint ventures as a special network architecture (Toffel, 2003) or differentiating the central coordinator's behavior toward autonomous actors (e.g., from ignoring to inhibiting) as variants of the laissez-faire architecture.

5.2 | The role of increasing degrees of vertical integration for the CE

5.2.1 | Slowing versus closing

The literature suggests that CSO, as a life cycle orientation in general, require increased intra- and inter-firm coordination (Boons, 2002; Esty & Porter, 1998; Sharfman et al., 1997). Likewise, closed-loop supply chains call for higher coordination efforts in the production of quality products and parts (Guide & van Wassenhove, 2009; Jayaraman, Guide, & Srivastava, 1999). For product circularity, we find that architectures with higher degrees of vertical integration are more beneficial, which also supports Bocken et al. (2016) insight that manufacturers should ideally develop slowing loop business models themselves. Slowing strategies in particular benefit from internal coordination due to their idiosyncratic and knowledge intensive nature. Stahel (2019, 67) calls these knowledge assets "operation and maintenance skills." For example, our case results show that individual repair requests can differ regarding necessary skills and that reuse processes require specified procedures, both suggesting a higher asset specificity. Correspondingly, we observe stronger vertical integration for slowing loops on product level, confirming previous research (Kirchgeorg, 1999, p. 425). Whereas other architectures depend on allies or other third-party actors, with vertical integration, organizations keep the internal control. Given that slowing is in greater need of business model changes (e.g., lost revenue streams from repeat sales need to be compensated by service revenues), coordinators with higher level of vertical integration are in advantage, because they have higher control over slowing loop operations, can build services on them, and are in the best position to capture the related value.

By contrast, for closing, the predominant shredding and sorting processes for WEEE recycling are not device specific and non-strategic (Toffel, 2004). Industry-wide collection processes further reduce transaction costs because of a large-numbers supply condition enabling market-based solutions. However, given that these processes become available to all competitors and are therefore perfectly imitable, they do not contribute to competitive advantage. At the same time, novel product-specific recycling processes based on pre-disassembly of modular devices (see SmartMan case or the Fairphone 2; Reuter, van Schaik, & Ballester, 2018) or disassembly robots (Apple, 2016) not only represent new recycling potential by reducing systemic contamination (Baxter, Aurisicchio, & Childs, 2017), but also increase asset specificity, provide incentives for vertical integration, and bear the potential for generating competitive advantage.

5.2.2 | Vertical integration and the degree of loop closure of recycling, remanufacturing, reuse, and repair

Moving from *open*- to *closed*-loop recycling can improve environmental benefits (Dubreuil et al., 2010; Haupt et al., 2017). We propose to extend the open- versus closed-loop understanding from the material recycling context to product cycling, with closed loops defined as products being returned with their same inherent properties to the original value chain (controlled by the central coordinator) and open loops for cascade markets with possibly lower substitution effects (Krikke, 2011). Vertical integration of product circularity can mitigate some of the challenges of open-loop systems, prevalent particularly in the consumer electronics industry, such as non-transparent product and material flows after multiple ownership changes and complex material separation (Graedel et al., 2011).

In our study, we find that vertical integration of CSO enables higher degrees of loop closure with respect to returns to the original value chain, not only in recycling, but also across all loops (i.e., including remanufacturing/refurbishing, reuse, and repair). In the case of SmartMan, high degrees of loop closure are achieved through proprietary circular systems, for example, by a device deposit scheme. SmartMan avoids cannibalization effects that could arise from the sale of used devices through market segmentation (Debo, Toktay, & van Wassenhove, 2005; Hopkinson etal., 2018). Similarly, TelcoPro, together with their affiliated loop operators, apply a same-unit repair system with refurbished original spare parts, creating the potential for a closed-loop system in the repair loop.

The extension of the relationship between the degree of loop closure and the degree of vertical integration to all loops, as proposed above, is also supported by extant literature. This includes reverse logistics (Carter & Ellram, 1998), specifically the model of Savaskan et al. (2004) on product return rates for different integration degrees of closed-loop supply chains. Furthermore, Krikke et al. (2013) find that repeated product cycles require careful vertical integration. Similarly, Kirchgeorg (1999) observes that outsourcing leads to rather open product and material loops. Increasing the degrees of loop closure, such as in brand-specific, proprietary circular systems, is not without limitations: they exclude third-party innovators (e.g., autonomous loop operators) and when applied by several OEMs may result in parallel systems that impede macro-level efficiencies, resilience, and scaling (Raworth, 2017, p. 195). Hence, while in the early phase of disruption of linear systems new business models driven by proprietary cycles are important, if not necessary, elements to accelerate the transition towards a CE, once the CE becomes the new norm, more openly designed systems — or at least standard setting to enable interoperability — may be better to drive macro-level system regeneration.

5.2.3 | Vertical integration as enabler for feedback into product design

Without circular product design, the full value creation potential cannot be achieved, particularly for repair and refurbishing activities (Hopkinson et al., 2018). Refurbishing costs for mobile devices may be halved through circular design (EMF, 2012) and central coordinators with high vertical integration are most prone to introduce such designs because they directly benefit from it. Esty and Porter (1998) point to innovation incentives and increased competitiveness when a life cycle orientation is coupled with higher degrees of vertical integration. We found that sources of learning from loop operations can be *first* or *second* hand, depending on the degree of vertical integration and the accessibility of information. The feedback

TABLE 6 Independent vs. autonomous loop operators and their links to central coordinators

Link to central coordinators	*Independent* third-party loop operator	*Autonomous* third-party loop operator
Coordination type	Buy (contractee)*	Do nothing (uncoordinated)
Relationship type	Contractual agreements	No formalized contact; "amorphous" relationship
Business model	Linked to coordinator's business model with joint exploitation	Gap exploiter model (exploit residual value of products or materials to prolong their lifetimes)
Feedback to product design	Direct exchange, depending on collaboration level	Limited to informal learning and utilization of public information
Legal aspects	Operating within existing legal framework (aligned with coordinator)	Push the boundary of existing legal frameworks (no alignment to coordinator)

**Note*: Ally coordination of third-party actors decreases their independence making them affiliated entities.

mechanism to product design can be *direct* or *indirect*, depending on the position of the central coordinator in the value chain (OEM or retailer). In our vertically integrated loop architecture, SmartMan—as an OEM—has directly fed back first-hand experience from loop operations into product design, leading to modular devices. TelcoLtd, as a retailer, uses second-hand feedback from allied loop operators to modify procurement guidelines for their device portfolio, which represents indirect feedback to the product design at their supplying OEMs. Future research could look closer at how listing and delisting products in retailer portfolios affects OEM product development priorities.

5.3 | The role of laissez-faire architectures

We find that the emergence of CSO is not limited to central coordinator initiatives. When coordinators fail to coordinate CSO or when those offered are locally unavailable, unattractive, or even disincentivized for end-customers (e.g., overpriced and temporarily limited repair services), autonomous loop operators with gap exploiter business models (Bakker et al., 2014; Bocken et al., 2016) step in to exploit untapped value at the end of a product life cycle (Whalen et al., 2018). To reduce potential threats from autonomous actors, the coordinator must proactively develop CSO (Ferguson & Toktay, 2006) and manage potential cannibalization effects (Hopkinson et al., 2018). This finding extends existing CE literature (including on closed-loop supply chain management and remanufacturing). First, there is a lack of clarity about the role and coordination of autonomous actors. While some researchers explicitly suggest central coordination of third-party loop operations (den Hollander, Bakker, & Hultink, 2017; Guide & van Wassenhove, 2009), others are not explicit about coordination mechanisms (Lund, 1985; Stahel, 2010). To further clarify the CE actor set with regard to third parties (Abbey & Guide, 2018), we suggest making an explicit distinction between *independent* loop operators (who may have a contractual relationship to coordinators) and *autonomous* loop operators (who have no formal relationship to coordinators), see Table 6. Making the laissez-faire architecture and their contributing actors more explicit, increases visibility of and acknowledgment for decentralized solutions by local repair businesses, new service ventures, citizen initiatives (e.g., repair cafés), and social movements (e.g., iFixit). This distinction also emphasizes that coordinators may lose control over their downstream value chain, if CSO are not at least coordinated with independent loop operators (Ferguson, 2010; Jayaraman & Luo, 2007; Stindt et al., 2017).

Second, the inclusion of both coordinated and uncoordinated CSO in our typology also highlights the need to better understand the relationship between coordinators and autonomous loop operators (Whalen etal., 2018) and the respective contribution to circularity. We found indications in our data suggesting that their relationship is not straightforward but somewhat "amorphous" (Abbey & Guide, 2018, p. 379): a laissez-faire attitude makes coordinators relatively ignorant of autonomous actors. Simultaneously, service offerings from autonomous actors may shield coordinators from customers frustrated by non-existent or unattractive proprietary repair services. From the perspective of autonomous loop operators, strong information asymmetries with central coordinators (Krystofik, Wagner, & Gaustad, 2015) lead to major barriers to their activities, including limited access to original spare parts (Sabbaghi, Cade, Behdad, & Bisantz, 2017; Watson etal., 2017). In our data, owner-managers from autonomous loop operators report that they spend up to one-third of their time sourcing quality spare parts. However, despite (or even because of) these constraints, they develop creative circular solutions, such as sophisticated harvesting techniques to retain used original spare parts from discarded devices. As these harvesting techniques require detailed knowledge about product design, defect frequency, and logistics (Thierry etal., 1995), autonomous loop operators collect valuable information and develop sophisticated capabilities for decentralized circular systems. This is also called "autonomous innovation" by Pisano and Teece (2007). As observed in the case of TelcoPro, this can lead to collaboration with coordinators, minority investments, or even make autonomous actors an acquisition target (on the David vs. Goliath analogy in sustainable entrepreneurship, see Hockerts & Wüstenhagen, 2010). In the latter case, higher degrees of vertical integration could then also facilitate a mutual exchange of reverse production skills and spare parts. Furthermore, research is needed to investigate how formal and informal relationships between central coordinators and autonomous loop operators develop over time (e.g., from a laissez-faire to an ally architecture) and how this collaboration can be facilitated to improve circularity (Canning, 2006).

These findings also contribute to the general make-or-buy perspective. Our coverage of the laissez-faire architecture is inspired by Toffel's (2003) strategy of "doing nothing." But it was Williamson (1998) who already pointed out that the traditional make-or-buy perspective does not account for all possible market transactions. Williamson explored how the government as "public bureaus" (1998, p. 45) could take over transactions in case the private sector would not (e.g., public waste management systems). In place of the government, our laissez-faire architecture introduces autonomous loop operators as an alternative actor type taking over CSO when central coordinators fail to do so. By including both coordinated and uncoordinated architectures, our framework better accounts for all CE transactions as well as for their diverse actors and relationships—together providing a more accurate circular systems perspective.

5.4 | Implications for policymakers

Our findings suggest various policy implications. First, they show that it is a bigger challenge for companies to implement slowing than closing strategies and that this comes along with more coordination efforts as represented by higher degrees of vertical integration. Policies such as EPR should thus balance incentives for slowing and closing. This is not always the case. For example the European Circular Economy Package focuses more strongly on closing than slowing (Johnson et al., 2018). Second, our typology indicates that both coordinated and uncoordinated circularity should receive attention, as both have the potential to improve circularity (EMF, 2018). It remains subject to further research to what extent each architecture exactly contributes to sustainable development and, relatedly, how architectures are prioritized and incentivized by policy makers. In particular, the service and innovation potential of autonomous loop operators calls for new policies to remove barriers (Sabbaghi et al., 2017) and facilitate product circularity through compulsory access to original spare parts and necessary documentation (at least for retailers and professional repair operators). This is also discussed in the "right to repair" initiative (The Repair Association, 2019) and the European Parliament (EP, 2017) as well as in future revisions of the EU Ecodesign Directive (EC, 2016).

Overall, while we observed pioneers developing new CVCAs, most struggled with considerable costs and limited market demand. For mainstreaming the CE, CSO have to become more competitive than linear solutions and, following the waste hierarchy, slowing loops have to be prioritized over closing loops. An exemplary measure in this regard is shifting taxation from labor (e.g., reducing value added taxes on repair) to natural resources (e.g., increase carbon taxes) (Ex'tax Project, 2016; Stahel, 2016).

5.5 | Limitations

Our study is also subject to limitations. First, including OEMs and retailers in the umbrella category of central coordinators makes our results more generic and relevant to a broader type of actors in the value chain. Most importantly, while we find feedback channels for both actor types into the upstream supply chain, we do not further explore the effect of different feedback levels. Future studies could look more closely at their differences. Second, we did not use literal replication (Yin, 2014) but focused only on one case study per architecture, reducing the level of generality of the CVCAs. Third, to reduce complexity, we focused on a single product system and assumed that it is operated under a single CVCA. However, following a plural forms approach, coordinators may be active in different CVCAs simultaneously, for instance, by partly integrating and outsourcing repairs (Bradach & Eccles, 1989). Fourth, our empirical study analyzed CSO for smartphones as exemplary for durable electronics—it remains subject to further research to clarify whether and how our findings could be transferred to other goods and sectors. Finally, our understanding of circular strategies (see Table 1) is based on established resource management frameworks and prioritizes long life products (slowing) over closed material loops (closing). While our aim was not to investigate environmental impacts of specific CE activities but their principal coordination mechanisms, we should mention that every resource management framework needs careful empirical and industry-specific evaluation regarding environmental benefits (Blomsma, 2018). In particular, rebound effects have to be considered (Makov & Vivanco, 2018; Zink & Geyer, 2017).

6 | CONCLUSION

Developing circular service offerings for smartphones requires central coordinators to invest in reverse cycle operations. As a variant of the classic make-or-buy decision problem, coordinators can develop four distinct CVCAs representing a continuum from proactive to reactive postures: vertically integrated, network, outsourcing, and laissez-faire. Higher degrees of vertical integration enable coordinators to move from closing to slowing strategies, open to closed loops, and conventional to circular product designs and portfolios. In contrast, with an uncoordinated laissez-faire approach, coordinators may lose control over viable aftermarkets and allow for the emergence or growth of autonomous loop operators. With this comprehensive set of CVCAs, we clarify the actor constellation in the CE and make the situation of autonomous solutions more visible. Against this background, the CVCA typology serves industry actors, in particular central coordinators, as a strategic decision tool to develop their circular value architectures for a specific product. Furthermore, it could also inform decisions on individual transactions for specific loop strategies, as not all technical loops of a given product will always use the same coordination mechanism.

While we have focused on a coordinator perspective on CSO for smartphones, current developments in other industries show that similar strategic decisions must be taken at other positions in the value chain. For example, virgin polymer suppliers of the packaging industry are increasingly investing in recycling facilities to become a one-stop shop for both virgin and recycled polymers (e.g., Borealis Group, 2019). We therefore assume our findings are transferable to other actor types and sectors.

While pioneering companies demonstrate the possibility to engage in more proactive CVCAs, a broader transformation of industries and markets will require policy interventions. It is particularly important to facilitate slowing strategies through both central coordinators and decentral autonomous actors and raise the competitiveness of circular versus linear offerings via a shift of costs from labor to resources.

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AUTHOR CONTRIBUTIONS

The two authors were listed in alphabetic order because they contributed equally.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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