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Article

How Do Companies Collaborate for Circular Oriented Innovation?

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Abstract: Collaborative innovation is necessary to explore and implement circular economy strategies. Yet, empirical investigations into such collaborations are scarce. It is unclear whether the circular context creates differences or represents adaptions within how collaborative innovation is conducted. We draw upon strategic management and open innovation literature to highlight what is known about collaborative innovation and the types of innovation conducted. We use these insights to investigate explorative qualitative case research into how practitioners in the Netherlands have conducted collaborative circular oriented innovation. Our findings show that open innovation criteria can aid our understanding and analysis. Key managerial considerations relate to the incremental or systemic nature of the innovation pursued, which induce different collaborative projects and knowledge management structures. For incremental innovation, we observe phases of collaboration, whereas for more systemic innovation, we observe a more collaborative portfolio and layered approach. Furthermore, the more radical innovation pursuits that explore slowing or recovery strategies, especially beyond business-to-business arrangements, challenge companies. A crucial challenge remains related to how to develop and assess collaborative and system-oriented business models in the transition towards a circular economy. Finally, future research is needed to assess whether the current modes of collaborative innovation are sufficient to deliver a circular economy transition.

Keywords: circular economy; circular oriented innovation; collaboration; strategic management; open innovation; circular business models

1. Introduction

The circular economy (CE) concept promotes innovation strategies to adapt or create new systems to reduce material throughput, waste, and environmental impacts [1,2]. Circular oriented innovation (COI) is increasingly researched to understand how to operationalise and support the transition towards a CE and a more sustainable society [3,4]. COI is distinguished by its combination of product design, business model, and value-network strategies intent on narrowing, slowing, and closing (material and energy) resource loops [5–7]. The strategic aim is to manage obsolescence, maintain product and material integrity, and keep value capture opportunities at their highest possible levels, throughout multiple life-cycles [8,9]. To do this, recovery strategies are essential (reuse, refurbishment, remanufacturing, and recycling), but the resources, knowledge, capabilities, and infrastructure needed to integrate these are dispersed across actors [8,10]. So, new value-network configurations and relationships (created through collaboration) appear needed to connect actors' innovation activities to explore how to adapt or create new systems [11–13]. Such innovations require a higher degree of complementary innovation activities, across different levels of interaction within a system, to

generate or facilitate value creation, delivery, and capture opportunities by connecting actors business models [14,15]. It is also not always clear what complementary innovations are required, how to create or test potential combinations, or even whether positive systemic changes are produced; this necessitates a more collaborative, iterative, and experimental approach towards innovation [16].

Since COI aims to change how systems operate (by innovating for more circular material and energy flows), increasingly, collaborative, radical, and systemic innovation activities should be pursued. Yet, collaborative innovation for sustainability requires specific internal and external competencies [17]; and in COI, also, a range of 'hard' and 'soft' factors, such as linear system operations or cultural barriers, can inhibit efforts [18–21]. This means actors from across the system and product life-cycle stages (who may not have traditionally worked together) need to align company motivations, expectations, and cultural differences to explore the tactical and operational requirements to implement COI [10,18]. The challenge is to understand how collaborative COI can be organised, while successfully integrating CE goals, principles, and recovery strategies into technical and market-based innovations.

Research clearly indicates collaborative innovation is necessary within CE (e.g., [3,20,22–24]). Yet, Korhonen et al. [25] highlight that difficult practical and strategic questions for 'how' to manage collaborative networks (e.g., organisational structures, knowledge sharing, sharing of returns, or risk management, etc.) is one of the key CE challenges. Answering such practical questions are needed since real-world examples of COI implementation are rare [23,26]. This represents a knowledge-implementation gap, which requires focus upon the processes and challenges involved in 'how' companies can implement COI [22,27]. CE research predominantly focuses on product or business model innovation, which is important for understanding what to do. However, the investigation into how strategic decisions and knowledge management approaches are selected and conducted for collaborative innovation (needed to integrate and implement CE product and business model innovations within a system) is nascent. Moreover, there is a lack of empirical investigation, especially into the collaborative aspects of COI. Bogers et al. [16] have recently initiated exploration into how open innovation can be used to engage with circular economy and sustainable grand challenges, to understand the collaborative structures and knowledge management between multiple organisations. The focus of the present study is to bring this strategic management and open innovation lens into the COI context, by developing explorative cases to investigate whether this aids our understanding of how companies collaborate for COI. Understanding 'how' collaborations can be coordinated is crucial to advance the CE knowledge-implementation puzzle. We seek to address this gap by exploring the following research question: How do companies collaborate for circular oriented innovation?

We firstly present the literature background and key concepts used in this paper. The research design and empirical findings follow. Findings focus on how contextual elements can impact the structure and collaborative approach for COI. We then discuss these findings and present limitations, further research, and our conclusions.

2. Literature Background

Since COI is a nascent research field and largely lacks a collaborative innovation focus, we review adjacent research into collaborative innovation to gain insights into how it can be coordinated. We firstly present factors derived from strategic management and open innovation literature. We then highlight the different types of innovation that can be conducted within collaborative innovation. Throughout, connections are made to COI.

2.1. Strategic Management of Collaboration

Strategic management concerns the development of strategic visions, the setting of objectives and formulating, selecting, and implementing specific strategies to secure competitive advantages. One strategy can be to pursue collaborative advantage, which requires selecting specific approaches, performing deliberate actions, [28] and represents a key strategic tool and source of competitive

advantage [29]. Within strategic management, key factors to consider for collaboration are broadly connected to the need for; (1) deliberate and emergent phases of planning, and (2) flexibility.

Firstly, many collaboration studies focus on the phases of collaboration that broadly incorporate assessing the context, partner selection, collaborative strategic planning, and implementation. Such phases require deliberate planning to assess the problem and context in relation to; the available resources, characteristics of potential collaborators, their number or level of heterogeneity, credibility, and possible power differentials [30–32]. Imposed and emergent factors derived from the context can impact collaborative implementation [28,33]. Thus, collaborative strategy should incorporate both a deliberate planning phase and adapt to emergent factors throughout; which can arise from the collaboration itself or the individual collaborators involved [34]. Clarke and Fuller [34] further state phases need to be specific to the issue(s) pursued within the collaboration and tailored throughout towards the needs of partners (both the group as a whole and the individual partners involved). Secondly, the requirement to tailor collaborations throughout connects to the aspect that increased collaborative success is linked to increased flexibility. From a systematic analysis of 22 longitudinal cases, Majcherzak et al. [35] conclude the most successful collaborations are those that overtime proactively adapt in response to emergent factors. Such adaptions can incorporate evolving collaborative goals, contracts, decision-making, or actor composition [35]. Thus, collaborators need to be responsive to emergent factors and actively initiate changes, rather than following prescribed innovation or collaborative management trajectories.

2.2. Open Innovation: Degrees of Openness, Challenges, and Tensions

Within the strategic management, open innovation research investigates the strategic decisions and knowledge management strategies required to acquire, assimilate, transform or exploit knowledge from across organisational boundaries through collaborative innovation [36]. The intersection of circular economy and open innovation research is underexplored, but notable additions from Bogers, Chesbrough, and Strand [16], and Curley and Salmelin [37], have started to explore whether open innovation practices can provide a foundation for understanding 'how' collaborative innovation can be conducted to support sustainable pursuits.

Open innovation research broadly examines how companies accelerate internal innovation, competitiveness, and performance through increased inflows and outflows of knowledge across organisational boundaries [38,39]. Of importance to collaborative COI are investigations into 'coupled' innovation, whereby companies jointly develop and commercialise innovations [40,41]. West and Bogers [39] show these can represent either singular or multiple projects, and, can be structured around different collaborative relationships from buyer/supplier or bilateral co-creation to larger-scale innovation networks or ecosystems. Within these types of collaborative projects, knowledge sharing is crucial for success [41–43]. West and Bogers [39] also show how collaborative innovation is increasingly networked, iterative, and moves away from the linear innovation funnel presented by Chesbrough [44]. Chesbrough [45] has also later supported this view; stating future open innovation strategies will require increased collaborative systems, especially to implement new product-service combinations. However, West and Bogers [39,46] show research into how these new business models are implemented represents a gap. More specifically, research that investigates how companies commercialise innovations collaboratively and measure value capture rather than just value creation is lacking. Bogers et al. [36] identify two aspects that are crucial: (1) the business model around how technology is developed (i.e., the proportion of in-house vs. contract or external research, and (2) how intellectual protection is structured (open or closed). The challenge is that increasingly, value creation, delivery, and capture activities operate at the system-level [36,46,47]. Thus, the need to understand dependencies and complementarity between the multiple business models and collaborations required to function across product life cycles are of specific importance for both open innovation and circular economy research.

Two elements stand out from open innovation research that companies should be clear upon when thinking of collaborating; (1) the structure of the project and the level of openness, and (2) the potential challenges and tensions.

Collaborative innovation can have different project structures with different levels of openness, which result from strategic decisions [36,41]. Pisano and Verganti [48] explore the openness of collaborative innovation and identify that the company's strategy, capabilities, and organisational processes can dictate the 'right' conditions to select different collaborative structures. They propose external participation can be open or closed and governance hierarchical or flat. Lazzarotti and Manzini [49] advocate open innovation represents 'degrees of openness' directed by partner variety (the number and type of partners) and the innovation openness (the number and type of phases open or closed to external collaboration). Yet, coupled innovation projects rely on multiple knowledge flows from complementary partners, but both the diversity of partners and the potential presence of competitors can affect knowledge sharing [41]. Additionally, Bogers [42] shows how pre-competitive and competitive collaboration can also impact the levels of knowledge sharing. A further strategic factor is whether the type of knowledge is explorative (new & radical) or exploitative (capitalising on existing knowledge & incremental) [50–52].

Starting collaborative innovation is challenging since all partners need to develop trust [53], recognise collaborative advantages, and the innovation potential [54,55]. This indicates collaborators require competencies to orchestrate knowledge, leverage existing, or generate new resources to create value for the collaboration. Yet, knowledge sharing represents a key tension within collaborative innovation. Bogers [42] defines this as the 'open innovation paradox', whereby firms share, but simultaneously want to protect and secure knowledge or advantages when collaborating. Bogers [42] identifies two coping strategies employed to overcome this paradox. When the potential value of collaboration is extremely high, collaborators can use 'open exchange strategy' to share knowledge under secrecy agreements and agree to co-own resulting outputs, such as patents. Alternatively, a 'layered collaboration scheme', is used when vertical and horizontal (potential competitors) actors are present. Collaborators are layered into sub-collaborations (inner and outer members), whereby joint licensing agreements can share outputs. The defining selection criteria between these coping strategies are the number of partners involved, whether competitors are present, and whether the knowledge is specific (exploitative) or new (explorative). Rouyre and Fernandez [41] similarly explore the effect of competitors on knowledge sharing within coupled innovation projects; finding different project structures that use different formal and informal mechanisms are important and shaped by the type of innovations pursued and the types of partners present within the project. Faems et al. [56] also explore the distinction between the type of knowledge and types of partners, and advance another collaborative approach, to arrange multiple different but complementary collaborations within a portfolio; they find this is more likely to create new or improved commercially successful innovations. Thus, the availability and distribution of knowledge, and whether it requires competitors to be present for innovation activities contribute towards selecting different collaborative approaches [57,58]. It is, however, unclear whether such criteria derived from open innovation literature are also valid within the COI context.

2.3. Types of Circular Oriented Innovation

COI is a comprehensive term that promotes a holistic view of innovation that goes beyond the boundaries of a single organisation to adapt or create new systems [59]. When companies explore how to adapt or create new systems, this needs increased focus, and integration of innovation activates across the levels of product, process, organisational, and market innovations. Pouwels and Koster [55] find a positive and significant effect of collaborative innovation across these same types. Since our focus is on collaborative innovation between companies, we focus on these types of innovation. Yet, we note that there are perspectives that take a wider focus on innovation that brings in, for example,

policy or cultural aspects; such as the multi-level perspective in transitions research [60,61] or the research on technology innovation systems [62].

Product innovation, when focused on circularity, represents improvements to the use-phase or recoverability of products through new product developments (NPD), or re-design, and the addition of associated services, such as product-service combinations [8]. This entails integrating CE product design principles and strategies, such as: the reduction, substitution or the removal of harmful and non-recoverable materials (narrowing loops); designing long-life products or life-time extension through modular product structures to increase repair, refurbishment, or remanufacturing opportunities (slowing loops); and component recoverability, material recyclability, or integration of recovered materials (closing loops) [5].

Process innovation is closely linked to product innovation, for it is the introduction of new technologies or methods of production [63], which in COI means improving use of renewable inputs (such as energy or materials) or recoverability of outputs. COI recoverability entails redesigning operations across the value-network to minimise or eliminate, through design choices, non-product outputs, such as waste or hazardous by-products; or to recover, reuse, and reintroduce materials, components, or products [3].

Organisational innovation represents strategic decisions that change routines or structures to introduce new ways of arranging or thinking about things, such as resource scarcity, supply chain, or environmental management [55,63]. Within collaborative COI this can reflect how new collaborative processes are structured between companies. Klewitz and Hansen [63] also establish that an organisational innovation can be redesigning the company's innovation process via integrating new innovation principles, increased reflexivity, and interaction with external actors; which is especially relevant for COI. Pouwels and Koster [55] emphasise that collaboration in the design and development phase is commonly around product and service innovations, while process and organisational innovations aim at how to produce such products or accompanying services. They also highlight that process and organisational innovations are necessary preconditions for developing new products and services.

Market innovation is closely linked to the concept presented by Schumpeter of opening up new markets, but expands upon this through the experimentation of variations [55]. Kjellberg et al. [64] proposes that market innovation requires successfully changing existing market structures or how business is done through innovating new business models, modes of exchange, and assessment methods. This encompasses integrating CE business model strategies, such as providing services over ownership to extend product value or to exploit residual value through recovery activities. Pouwels and Koster [55] raise the point that to change market structures commonly requires a collaborative approach.

When COI is more focused on adapting how systems operate or creating new systems, it is anticipated that there will be an increased investigation across these different types of innovation to explore the degree of complementarity needed to implement the innovation and assess the environmental or societal impacts. However, this increases the complexity of innovation activities. Zucchella and Previtali [65] propose an orchestrator who acts as a transformational leader is crucial to secure the tangible and intangible resources to promote radical innovations and navigate such complexity. Curley and Salmelin [37] propose such leaders act as catalysts, educators, and visionaries by developing real-world experimentation. Yet, it remains unclear how collaborative experimentations are conducted or coordinated across these types of innovation.

Finally, innovation activities can be incremental or radical. The key distinction is whether the innovation activity modifies accepted processes, products, services, technologies, and ways of doing business, or aims to create entirely new ones that are disconnected from the current context [59,66,67]. Both are important when pursuing sustainability. Yet, research by Brown et al. [18] into collaborative COI, which builds on research into sustainable oriented innovation by Klewitz et al. [63], Adams et al. [67], and Ceschin et al. [68], show how increasing sustainable impact requires more radical socio-technical and system-oriented approaches towards innovation. Szekely and Strebel [69] advance

that 'game-changing systemic innovations' require transformation of the relationships and interactions within and across a system. Takey and Carvalho [14], state systemic innovations only generate value if accompanied by complementary innovations, and highlight how this is linked to open innovation concepts, whereby producing innovations requires increased collaboration across company boundaries [70].

2.4. Research Gap

Circular economy focused research has grown quickly and is seen to hold promise to stimulate a sustainable transition. However, many contributions are conceptual and focus upon 'what' changes are required to product design [5,71], business models [12,72], and the required value-network [73,74]. Studies that explore 'how' to operationalise and implement such changes, especially collaboratively, are needed but are lacking [4,75]. Understanding how COI coevolves and is conducted to adapt or create new systems is needed [25,76]. We argue that understanding how collaboration is conducted is crucial to advance the knowledge-implementation gap [15,22,27]. Additionally, COI has much to gain from integrating strategic management and open innovation literature to understand; (1) the potential structure of the collaborative projects [41], (2) how open to be when collaborating within the COI context [48–50], (3) the challenges of the open innovation paradox [41,42]. These aspects require investigation if COI is to innovate to adapt or create systems and advance collaborative business models focused upon circular recovery strategies. Thus, the main objective of this exploratory research is to understand how a strategic management and open innovation focus could aid our understanding of how collaborative COI may be conducted.

3. Research Design

The research field of COI is underexplored. Hence, we conducted exploratory qualitative research, through semi-structured interviews with business practitioners to gain empirical insights. This study focused on the Netherlands. The Dutch government is actively supporting COI activities intending to become fully circular by 2050 [76], and many companies have started activities in this field. This means the Netherlands offers the opportunity to gain insights from the state-of-the-art into how companies collaborate for COI.

We chose semi-structured interviews to ask 'how' questions to practitioners [77,78]. This generated insights into the specific events, actions, rationale, and the context. Interview topics and questions were derived from literature and focused on how COI projects were structured, managed, and evolved to identify different approaches used (Appendix A shows interview questions). Our unit of analysis was the collaborative actions undertaken. We chose a diverse sample of companies across multiple contexts to provide a rich and broad-view of the COI phenomenon to conduct our explorative qualitative research. Cases were selected based on a stated CE vision and external communication of a collaborative COI project. We focused upon commercially oriented COI projects, although a few cases were precompetitive, or partially developed through or followed public funding. Accessibility of key managers who directly led the COI projects was another criterion for selection. This resulted in 25 semi-structured interviews (one to two hours) with a range of company roles of interviewees from 19 companies, which produced insights into 23 collaborative cases, presented in Table 1. This range indicates that there are currently no specific positions who manage these types of projects, because of the relatively new nature of the COI phenomenon.

Table 1. Companies, interviewees, and scope of the circular oriented innovation cases.

Company	No. of Interviews	Total Length	Interviewee(s)	Industry	Product Category/Type	No. of Employees	Case	Aim and Scope of Collaborative Circular Oriented Innovation
1	1	85 Mins	Corporate Social Responsibility, CO_2 and Circularity Consultant	Energy	Infrastructure	>5500	A	B2B infrastructure CE tender (rules require minimum of two suppliers): single product re-design, material fairness & selection, upgradability and recoverability
2	2	130 Mins	Director of Sustainability + Senior Manager Sustainability	Electronics	Consumer products	>70,000	B	Testing closed-loop recoverability & re-use of post-consumer material with challenging product specifications
			2 X CE Design and Business Model Researchers				C	Pre-competitive exploration of CE business models, use phase & consumer acceptance focused on retail
3	1	75 Mins	Circular Economy Manager	FMCG	Food, Drink and Health Products	>100,000	D	Testing recoverability of material for single consumer product
							E	Alliance to explore options for CE material selection: focus on Bio-PET plastic for single FMCG product stream
4	1	60 Mins	Circular Economy Specialist and Strategic Consultant	Real Estate	Sustainable construction	>25	F	COI living lab space to conduct collaborative COI projects
5	1	60 Mins	Lead Global Centre Circular Economy	ICT	Hardware and services	>350,000	G	Buildings as material banks: material reuse and data passports (some partners previously engaged in separate H2020 Project)
							H	Buildings as material banks: focus materials, product, business models & data integration (built off previous H2020 project)
6	2	125 Mins	Program Manager Sustainable Entrepreneurship	Tourism Hospitality	Holiday accommo-dation	>3000	I	New product-service innovation: Role of buyer - Ran multiple collaborations with suppliers to explore product categories
7	2	136 Mins	Supply Chain Manager	Furniture	Beds and Mattresses	>200		Role of supplier–Understand new business model (B2B) from traditionally business to consumer, product redesign, logistics and circular recovery operations
			Research Engineer					
8	1	70 Mins	Director EMEA regulations, environmental affairs and producer responsibility	ICT	Hardware and services	>100,000	J	Pre-competitive exploration: potential for cross-sector recovery & reuse of plastics
9	2	175 Mins	Head of Sustainable Development (EMEA)	Flooring	Carpet	>3000	K	Consortium producing a range of B2B and B2C products exploring material recovery & reuse of Ocean plastics: expansion of previous successful project by company 9 with additional partners
			Concept Designer					
10	1	80 Mins	Co-founder, resource efficiency manager	Electronics	Smartphone	>75	L	Circular operations testing for spare parts to assess upscale and expansion of a B2C CE business model to maintain products
							M	Explore global material supply chain: focus on fairness of supply, reuse potential and operations (H2020 collaboration)

Table 1. *Cont.*

Company	No. of Interviews	Total Length	Interviewee(s)	Industry	Product Category/Type	No. of Employees	Case	Aim and Scope of Collaborative Circular Oriented Innovation
11	1	90 Mins	Circular Economy Manager	Furniture	Office Furniture	>150	N	Circular tender B2B product-service (role of supplier) expanded on CE design knowledge from public funding: testing circular recovery operations & data for refurbishment & reuse
12	1	90 Mins	Director of sustainability	Flooring	Carpet	>350	O	Material selection for CE product (re)design to improve material heath and recovery for B2B product
							P	Consortium to explore material selection: PVC materials for a mix of B2B and B2C products
13	1	90 Mins	Sustainability marketer	Chemicals	Health, Nutrition and Materials	>21,000	Q	Development & marketing of new product and adhesive process to improve end-of-use recoverability for circular products (Companies 7, 11 & 17 in contact as potential users & initial discussions towards collaborations)
14	1	80 Mins	Project Manager Business Development	Waste Manage-ment	Material collection and recovery	>8000	R	Material recovery and reuse potential: primarily exploiting core knowledge
15	1	75 Mins	Co-Founder	Sports Equipment	Refurbished race bicycles	<5	S	Operations testing (sourcing, diagnostics, refurbishment) for B2C circular business model: including users to sell old products or parts.
16	1	75 Mins	Material Resource Manager	Waste Manage-ment	Material collection and recovery	>80,000	T	Material recovery and reuse potential: primarily exploiting core knowledge
17	2	140 Mins	Circular Economy Business Developer	Material Producer	Waste to biological composites	>60	U	Pilot new CE process to test & upscale operations: repeated collaborative projects focused on new customer development to exploit material recovery & reuse knowledge (company 4,7 & 13 discussing potential collaboration)
18	2	125 Mins	Project Manager Sustainability EMEA + Sourcing Manager Packaging and Waste	FMCG	Coffee Retailer	>250,000	V	Material selection, product & process for CE recovery potential: pilots across countries built upon a previous failed collaboration with new & expanded collaborators
19	1	90 Mins	Sourcing Manager + Corporate Sustainability + Commercial Market Manager	Energy	Energy infrastructure management	>150,000	W	Pilot for circular building: Separate build, use-phase, and reuse & recovery. Case focus: Use-phase operations testing for B2B product as service models for buildings and potential recovery

Note: If interviewees discussed multiple cases, these are linked to the same company (e.g., Cases B & C). If multiple companies interviewed discussed collaborating on the same case these are linked to the companies (e.g., case G). B2B is business-to-business; B2C is business-to-consumer.

We coded the interview transcripts within NVivo software. The coding started by using broad explorative initial codes with subsequent refinement (Appendix B). This was used to deepen our understanding of the case material and their approaches towards collaboration. This supported our later use of process research methods; such as developing narratives of the events within the COI, based upon the experiences presented by our interviewees. We also used desk-based research from supporting communications about the collaboration (press releases, company communications, and websites) to cross-reference [79]. We then combined visual mapping strategy to support data synthesis by ordering frequently occurring events across our cases. This identified initial patterns across the different contexts to sequence 'how' collaborations were conducted [79]. Further, building upon the reviewed open innovation literature (Section 2.2), we assessed the composition of the collaborators; their number, diversity, relationships, and especially whether competitors were involved. Then, we assessed the type of innovation (Section 2.3) conducted within cases, their scope, and anticipated implementation timeline. Since our objective of our case analysis is exploratory, we used this to support pattern-matching (comparison of patterns from theory Sections 2.2 and 2.3 with those empirically observed) across our multiple cases to highlight similarities and differences between our cases and theory to offer explanations for how collaborations were conducted [76].

4. Findings

This section presents the landscape of collaborations (Figure 1) and case examples to highlight the different approaches used (Cases presented in Table 1). The focus is on how the context can affect the collaborative approaches used and specifically, how the project and knowledge management are structured. Case analysis shows a distinction between incremental and more radical oriented COI that pursue system changes. This is assessed by analysis of two COI characteristics: (1) the types of innovation conducted to advance and implement the COI and (2), the composition of collaborators, their number, relationships, and whether competitors are present (when below four collaborators competitors were not present). These characteristics result in different collaborative project structures, phases of collaboration, or portfolios of collaborative projects (shown in Figure 1), and explained below with case examples.
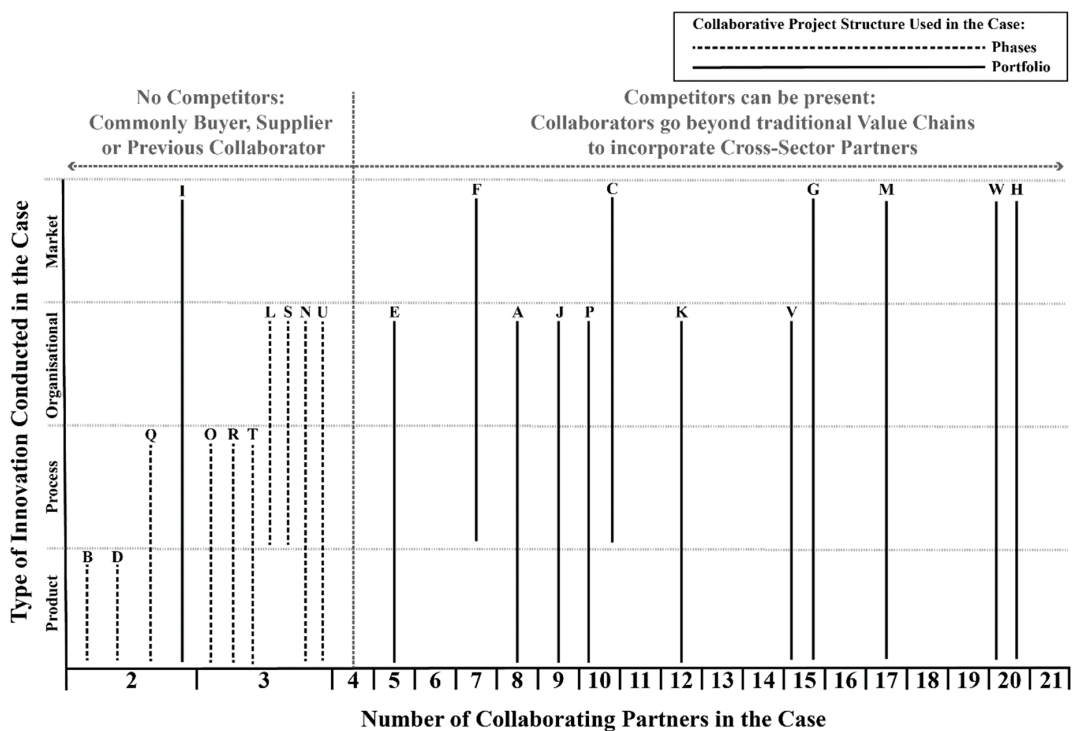

Figure 1. Landscape of collaboration within circular oriented innovation from our cases.

4.1. Incremental Circular Oriented Innovation: Phases of collaboration

Incremental COI is distinguished by the following:

Firstly, more incremental COI conducts fewer types of innovation, due to a lower degree of complementary innovations required to implement. The focus is commonly on the product or process with limited organisational innovation. For example, Case Q stated: *"they had the idea around [Product name], but their struggle was around the development of the [Process]. That is of course our strength"*.

Secondly, the CE strategy is predominantly focused on closed-loop material recovery and reuse. Knowledge is largely exploitative. Implementation can be more immediate, requiring reduced deliberate planning, and the reduced potential for emergent factors. Implementation is commonly achievable with the selected partners. This was demonstrated in Case B, who innovated with a known partner: *"The alternative material we were using had failed three times (. . .) So then we ended up with [name of collaborator]. Why, because we knew them, we had already done similar testing before with them."*

Thirdly, partner selection maintains traditional value-network arrangements engaging buyers, suppliers, previous collaborators, or known research institutes and competitors are not included. Case N for example worked with buyers to understand operational requirements needed for new CE business models:

"We have to prove we can make steps towards the development of a circular business model. [Buyer Name] helps as the first step is to organise how they buy the furniture, so we are collaborating with their reuse people to develop a kind of webshop, so we can arrange refurbishment."

Due to the partner selection process, trust can be higher. This allows reduced agreements to initiate the project; represented by Case B:

"One and half months later they had a material that we could test and it met the requirements. (. . .) Not having it completely tide up in MOUs [sic. memorandum of understanding] and contracts. But just go for a first try small-scale at first and then scale-up and just do it."

This also shows a common rationale, at least initially, is to construct the 'minimum viable collaboration' needed to develop proof of concepts.

The project structure observed for incremental COI are more traditional phases of collaboration. Between phases, the collaborative dynamics (roles, partners, responsibilities), the resources for further experimentation cycles, and implementation or the agreements and contracts can be assessed or (re)negotiated. Case R for example, showed that different partners might emerge to support experimentation:

"We started a diaper project with a technology partner and somebody we knew who can pre-process the diaper. In the first concept, in the first collaboration, we explored the diaper processing. Although, the technology partner is now out, since we worked out we only needed one process step, and we could do that (. . .) But, the whole project now is turned around, since we found somebody who is making diapers and needs the cycling as a marketing tool. But it's still ongoing, we will experiment further and pilot at the end of the year."

4.2. Systematic Circular Oriented Innovation: Collaborative Portfolios

Systemic COI is distinguished by the following:

Firstly, when the COI aims to adapt or create new systems, knowledge is more explorative and spans more innovation types and exploration of complementary innovations. This creates a longer implementation timeline, greater need for deliberate planning and increased potential for emergent factors. Case H stated:

"We are the business model advisors looking into the industry model, business model and technology proof of concepts needed (. . .) we started by building the first passports for 10 product categories within buildings. Then when I sit with a mechanical engineer, we can ask what is the relevant information you need to have as a professional buyer".

Yet, here Case W describes how aligning exploration can be challenging by the statement:

"the collaboration between the partners is really based on how can we strengthen each other. But, also that's the main challenge, finding the right synergy between the right partners within the whole partner community we have to explore the steps towards circular maintenance and services."

Secondly, the innovation focus is also more organisational (Cases A, E, J, K, P, V), how to produce new products or services, although material recovery through exploring closed-loop activities can still be a predominant aim (Cases E, J, K, P, V). When the focus is on business model innovation (Cases C, F, G, H, W) exploration can be more on how slowing strategies might function. Here, understanding how to structure agreements between partners and share innovation outputs is a key feature. Case H stated:

"as any company we are used to contracts with party 'X'. So how do we build a contract to 4 to 5 to 'N' parties together, while we are all providing services to each other. So how do you do that? Now we are in the middle of this. We will find a solution to these problems. But these are all new problems."

The business model focus is also predominantly business-to-business (B2B) as Company 7 [Supplier] Supply chain manager discussed the benefits of Case I:

"It helps us now because [Company 6 - Buyer] brings volume and shape that makes it feasible for us to build a product that can become circular for a future consumer point of view. This is because consumers are still pretty linear."

Thirdly, in the case of more systemic COI, partner selection can go beyond traditional value-chains to include cross-sector partners and competitors. Company 9's head of sustainable development stated:

"We have so far been working within our supply-chains. But to drive the circular economy to a larger scale we have cross-sector collaborations slowly starting now, but it is not the easiest thing to do. Because everyone is working with different materials, mind-sets and KPI's, which makes it more complicated."

When scale is needed, cases displayed a pursuit for new partners, and to lead by example to prove the concept and attract others. For example, Case V stated: *"We know unless everyone is in, it's not going to work. (. . .) But we said let's not wait for everyone. Let's do it, set an example and lead, and hope we can inspire others to join"*.

Similarly, Case H stated: *"So the thing is around this platform new business models start to emerge. We have the municipality who are interested*, [and other organisations discussed interested in collaborating] *as you also see new roles for these people. Once we have a winning ecosystem, others will start to look at it and then it will expand. I am hoping that the projects that we are starting now will truly be proof of a concept at the ecosystem level."*

The project structure observed for systemic COI is more complex, whereby we observe a portfolio approach for collaborations is used to separate and manage the complexity of conducting the collaborative innovation and knowledge management. Once separated, the resulting projects are then commonly conducted using the more traditional phases of collaboration (observed in incremental COI). This also offers the potential to subsequently layer collaborators, creating inner and outer members, to reduce challenges around knowledge sharing. Our case analysis highlights four separation drivers.

Firstly, separation is used to purposefully manage participation, displayed in Case I by Company 7's Supply chain manager statement:

"[Company 11] are very interested to join, although at this stage it is too early for us to bring on board additional people. But when [Company 6] see some proofs of concept working [Company 11] would be a very nice partner to include into the project and deal with."

Here, Company 6 stated the involvement of other suppliers when discussing Case I:

"No, it's different suppliers [within other collaborations] and that's also I think really nice, as it keeps it simple. So it's two other suppliers, which we work with already for like a decade, for different product categories. I think when the time is right to move there will be more integrating of these, but not now."

Secondly, separating competitors within a project to conduct innovation activities is illustrated by Case A:

"We tried to get the two suppliers to collaborate with each other to exchange knowledge. But this is a highly vulnerable thing as they are both innovating and want to be the first. So, we now actually have two different pilots with the two different suppliers. One focuses on data collection of the system to map and visualise, so we

know what the best options are (. . .) Then the other pilot with [Collaborator Name] was much more on the prototypes, so really redesigning the [product]."

Thirdly, separating to move from open sessions of knowledge sharing and ideation to more closed sessions of knowledge development is used in Cases C, G, J, M, V, W.

Case C for example mentioned on knowledge sharing *"But now we have gathered all the data. It is the retailers by themselves that are going to use that data to create different pilots. So, it is kinda open, closed, diverging to converging regards information sharing".*

Here, Case J described how collaborators separated to perform investigations by stating:

"So it is much more about generic issues or solutions that we have come across when open. The real results are not derived from a fully open network. Rather out of the network 2 or 3 partners need to then go off and do something".

Fourthly, separating complementary innovation exploration within a systemic idea is found in Cases F, G, H, K, M, W. Here, Case F firstly shows purposeful separation of competitors, but also layered innovation activities to explore the systemic idea:

"We make sure we do not have 2 or 3 companies that work in the same niche all at the same table. (. . .) But you should do it in 3 to 4 different places to find out if there is a business case underlying something that superficially does not represent something that would or could stand as a business case, but still needs to be done in order for the other 3 things to be effective. Then bringing it back together, that is the really hard part."

5. Discussion

We set out to understand how companies collaborate for COI by assessing whether open innovation aids our understanding of collaborative COI or whether specific characteristics are displayed. Our contributions are fourfold: firstly, we found that open innovation criteria can aid our understanding and analysis of collaborative COI. Secondly, we show how the incremental or radical scope of COI can result in different collaborative project and knowledge management structures. Thirdly, we empirically show how much of the collaborative activity is currently incrementally exploring COI and is primarily focused on B2B relationships. Fourthly, we show that a crucial challenge remains for how to develop and assess collaborative and system-oriented business models. We discuss these contributions below and present the limitations, future research, and our conclusions.

5.1. How the Context and Scope Structure Directs the Collaborative Circular Oriented Innovation Approach

Criteria derived from open innovation, such as the number of collaborators, phases of collaboration to be open or closed [36,49], and the type of innovation and associated challenges for knowledge sharing [41,42,50] support investigations into how collaboration can be conducted within COI. A critical consideration within COI is the associated degree of complementary innovations needed for adapting or creating new systems. This can signify the COI implementation timeline, and whether competitors are required to complement innovation activities or participate to reach scale, and therefore increase potential risks and costs. The focus on systems, recovery across multiple life cycles, and the increased importance of non-financial assessment impacts how collaborations and knowledge management can be structured. These characteristics create a distinction between more incremental or more systemic focused COI.

The more incremental the COI is, the lower the degree of complementarity and the less engagement there is with competitors. This means the collaborative structure is similar to hierarchical and closed participation of 'elite circles' [48] and 'integrated collaborators' [49]. Partner selection, at least initially, constructs a 'minimum viable collaboration' needed to reach the innovation goal and commonly selects previous relationships. Collaborators are engaged to bring specific and exploitable knowledge; project teams remain separate with clear task divisions, and knowledge sharing is limited to the minimum levels needed to achieve the innovation aim. The finding that contracting and agreements at least initially can be reduced to speed up collaborative activities indicates managers are able to use informal mechanisms, while more formal agreements become more important when the

innovation advances towards marketisation. These elements link to insights from Rouyre and Fernandez [41] that the incremental nature indicates both a reduced cost in terms of project structure and risks within knowledge management. In addition, since the innovation pursuit is more defined, planning is easier and expected implementation more immediate, whereby more traditional phases of collaboration are conducted. Phases allow collaborators to iterate the innovation pursuit (resources required, implementation, upscale potential, or decisions to halt or persevere the innovation focus) and renegotiate the collaborative dynamics (changing roles or responsibilities, actors involved, agreements, and contracts). This increases flexibility to adapt to emerging factors from the collaborative process and increases the potential for successful collaborations [34,35,80]. The implication is that exploring incremental innovation offers a way to start small, learn, and build competencies for COI. Yet, managers and companies who really want to engage with grand sustainability challenges, will, at some stage, need to be prepared to undertake more radical COI; and thereby engage more complex and costly collaborations to adapt or create new systems.

The more the COI activities focus on adapting or creating new systems the higher the degree of complementary innovations and the need to engage competitors. This creates complexity, risks, and costs in terms of project structure and knowledge sharing. In response, managers separate collaborators or complementary innovation activities into smaller, more manageable projects to reduce complexity, confirming the work by Rouyre and Fernandez [41], but the alignment of partners (still) needs to be addressed. Yet, we found multiple motivations for separation into smaller projects; these resulted in a more collaborative portfolio approach, whereby companies arrange different but complementary collaborations to increase potential success [56]. However, the separation at the project-level draws similarities to the 'layered collaboration scheme' of inner and outer members to control knowledge flows [42]. We did not find central project structures that used an external and independent third party, identified by Rouyre and Fernandez [41], yet it could be that currently there are no suitable third parties to run such COI projects. We only found the use of third parties as 'knowledge brokers' to facilitate pre-competitive or initial knowledge exploration activities. Here, the use of third parties offered the ability to withhold specific technical or sensitive details such as costs to avoid competitive constraints on knowledge management by adopting a hybrid strategy of open and closed knowledge sharing. This suggests an additional strategy to the 'open exchange strategy' presented by Bogers' [42] by separating actors.

At the project management level, we rather found companies who instigated the COI project needed to decide upon the structure and how connected or separate projects are to be. This could also be presented to the collaborative group as a means to gain legitimacy, accountability, and to build trust within how the project and knowledge management is structured. When directed by the instigating company hierarchical control is maintained, but this might challenge alignment, trust, and knowledge management. When made by the collaborative group, this signifies a flatter governance structure, which focuses upon consortium, network and co-development [48,49], but can be harder to maintain. In either case, the structure, governance, and knowledge management might be required to become externally more open in time, due to the need or desire to scale participation (to secure competencies, knowledge, or creativity) or explore systemic value opportunities and share risks to reduce the implementation timeline. Thus, the structure, roles, and agreements can (and might have to) evolve more requiring closer participation and advanced managerial competencies (compared to more incremental COI) to maintain flexibility, adaptability, and crucially accountability [34,35,79]. An implication for managers and companies who want to engage with more radical COI is that they need to be clear on these costs, timelines, and the required ability to balance both formal and informal knowledge sharing mechanisms; since the complexity and number of competitors means one cannot rely on trust or individual capabilities or relationships [41]. This could ultimately mean this is prohibitive for some types of companies (especially start-ups or low resource companies) due to the lack of resources, capabilities needed, or the associated risks and costs.

5.2. Collaborative Circular Oriented Innovation Challenges

Our study highlights challenges remain within collaborative COI. Innovation activities show that at present, many collaborative COI projects are incremental in scope. The primary focus is on exploitative knowledge for material recovery (closed-loop, material reuse, or removal from the environment) to integrate into products. Additionally, the more radical COI projects can also represent incremental innovation steps that exploit existing knowledge from specialised collaborators. Explorative knowledge into circular design and business model combinations to slow loops is limited to B2B arrangements, yet these are still mostly in research or pilot phases. Consumer products maintain a transaction of ownership, without specifying slowing or recovery mechanisms. Exceptions are start-up cases founded to pursue circularity (Case L, Case S) that engaged collaborations to explore how slowing models for consumers could work, though product ownership is still transferred. This indicates that the pressures to maintain existing business models and predictable revenue seems to limit extant firms' ability to explore radical COI, especially when engaging consumers. This empirical finding supports desk-based research by Stewart and Niero [81] into fast-moving consumer goods. The literature argues that pursuing more explorative knowledge is a matter of timing linked to perceived levels of risk versus disruption to current operations and experience of successful explorations [51,52,56]. Within COI currently, B2B arrangements offer less risk or disruption to current operations for incumbents compared to consumer arrangements. Though, incremental COI is shown to aid increased buy-in through proof of concepts and early wins that can incentivise more radical and systemic-focused COI, which Bogers et al. [16] suggest is key to advancing companies engagement with grand sustainable challenges.

Finally, even when the COI scope was more radical, requiring increased complementary innovations to explore market-based collaborative activities, understanding how to create and test agreements or contracts for collaborative innovation and business models was a key innovation goal. This indicates companies are still figuring out the business model for collaborative COI and associated intellectual property (IP) strategies, which represents a key open innovation challenge [36]. This adds to recent guidance provided by Bocken et al. [47] that practice should critically assess system boundaries, value created versus captured, and fairness between partners over-time, while business models still evolve. The fact that collaborative agreements also evolve throughout innovation processes advances this guidance. Furthermore, our case analysis shows practice is still trying to answer how to measure and understand system-level dependencies between multiple business models for COI to perform economically and sustainably. This wider empirical analysis substantiates findings from Bogers et al. [36] that the longer-term perspective and purpose driven nature of COI requires companies to increasingly incorporate non-pecuniary mechanisms to understand systemic impacts needed to move beyond a solid 'business-case', but that also scaling COI activities requires aligning business models across partners. However, a common theme discussed that limits collaborative agreements and business models is the traditional mindset to maximise individual advantages, over exploring the potential value from a whole-system perspective. Thus more radical, collaborative, and systemic COI activities centred on how to solve grand sustainability challenges will be frustrated, and are still underexplored in practice [15,47]. We argue this challenges the effectiveness of the current modes of collaboration and represents a bottleneck that confronts companies' ability to implement COI that can adapt or create new systems. If this is not overcome, it could potentially halt a transition towards a circular economy.

5.3. Limitations and Future Research

Our findings present a first empirical investigation across multiple collaborative COI projects. Firstly, we acknowledge that other literature streams within and beyond strategic management and open innovation that have not been considered for this study, could contain useful additional information on collaborative COI. Future research should expand on and integrate these into COI, since our analysis has shown CE research can learn valuable insights from integrating strategic management perspectives. Secondly, limitations stem from our explorative research approach and data collection,

which represent three elements: (1) the country context, (2) the retrospective nature, and 3) the availability of data. Firstly, case selection focuses on the Netherlands, which reduces our ability to generalise findings to other country contexts. Secondly, collecting retrospective data meant details provided may suffer memory bias that could impact accuracy, interviewees also rarely mentioned failures or whether collaborative actions were part of wider strategic plans. Thirdly, even though the Netherlands represents a 'hotspot' for circular activity and we engaged leading circular companies, we found few cases had to date fully advanced or implemented radical and systemic collaborative innovations. This highlights the CE knowledge-implementation challenge [22,26] and the longer implementation timelines and timespan of circular business models [23].

To address these limitations, future research should expand our analysis by firstly collecting data from different country contexts and larger data sets (where available). Secondly, we propose in-depth longitudinal action-research that investigates from initiation to implementation to specify how companies collaborate throughout the entire process. This can offer insights into the effectiveness of current collaborative processes and agreements with the aim to propose normative changes to stimulate increased radical COI activities. This could develop practical guidance on how open information sharing needs to be or what are minimum requirements; especially around costs to adequately assess collaborative business models and value across multiple life cycles ,within a proposed COI. Furthermore, this could also inform partner engagement and collaborative negotiations by linking these to the required levels of openness (internal and external) to facilitate radical collaborative COI.

6. Conclusions

Our explorative study set out to understand how companies collaborate to advance COI. Our empirical insights from practice lead to four main contributions. Firstly, criteria established in strategic management and open innovation literature supports empirical investigation and analysis of collaborative COI. Secondly, within COI, a key managerial implication is the need to understand the degree of complementarity. More precisely, the increased complementary innovations required to implement circular recovery systems and associated business models can dictate whether competitors or increased participation are needed. This results in different collaborative projects and knowledge management structures. We observe a phased collaboration approach when innovation activities are more incremental, immediately implementable, and commonly engage a 'minimum viable collaboration' without competitors. We observe a more collaborative portfolio approach when innovations are more radical, have uncertain implementation timelines, require competitors, or scale is needed. This portfolio approach can separate complementary innovation activities or competitors to facilitate collaborative management and reduce complexity. Thirdly, we show how more radical exploration of circular recovery expands collaborative innovation beyond market delivery, which means collaborators need to assess how systems of business models can operate to narrow, slow, and close resource flows across multiple lifecycles. This remains a challenge for companies, especially to move beyond business-to-business arrangements. Fourthly, we show how a wider, longer-term, and more collaborative view on value creation and capture is needed to understand potential system impacts and move beyond the need for a solid business case when pursuing more radical COI. Yet, it still needs to be established to what extent the current collaborative arrangements described here will result in systemic innovations and the collaborative business models needed to stimulate a circular transition.

Appendix A

Table A1. Interview Questions.

Questions
1. Who or which organisation(s) were involved within the initial collaboration? Did this evolve overtime? If so, why and how did this happen?
2. How long were collaborative activities undertaken and how did they develop?
3. Who or which organisation did you collaborate most closely with to deliver the circular innovation strategy? Please describe how and why you engaged with them
4. Please describe or sketch the process or phases and associated activities you undertook/are undertaking for COI?
5. Is the structure of the project different? And is this the ideal set-up?
a. If yes, what are the challenges you experienced to get to this point?
b. If no, what would be?
6. How did you identify the right partners for the project?
a. Do you choose different partners for COI projects? If so how?
7. How do you choose/identify what experiments or pilots to run?
8. Do you recognise specific differences with regards to how you or your project partners make decisions?
a. How do you agree actions and decisions to be taken within COI projects?
9. How is IP, contracting and financing decided for these projects? How is it different?
10. How would you describe the benefits/challenges you [and/or your organisation] experienced within the collaborative COI process?
11. What were the results you [and/or your organisation] experienced through the collaborative COI processes?
12. Can you discuss any specific differences experienced between collaborative processes when pursing circular strategies in comparison with linear/traditional?
13. If in the future (15-20yrs) CE is more standard operation, do you think that collaboration between companies will be different at this point?

Appendix B

Table A2. Codes Developed and their Explanation.

Initial Code	1st Level	Explanation	2nd Level	Explanation
Collaboration	Project	Explicit discussion of collaborative project	Partners	External partner(s) are discussed
			Decisions	Interviewee discusses key decisions
			Ways to Improve	Interviewee mentions ways to improve or experience of how to improve collaborations
			Selection of Partners	Interviewee mentions how partners were selected
			Roles/Capabilities	Interview discusses what actors did within the collaboration process
			Formal vs. Informal Structures for Project management	Interviewee discusses different ways of project or relationship management
	Scalability	Scalability is discussed	Project ambition	Scale of the innovation is discussed
			Number of Partners	Scale of partner engagement discussed
	Collaboration vs. Competition	Competition is discussed within the collaborative process/project	Pre-Competitive	Instances of pre-competitive (non-commercial) collaboration discussed
			Coopetition	When collaboration between competitors is discussed
			Competition	Collaborative partners are discussed in reference to elements of competition
	Trust	Trust between partners is explicitly discussed	Levels of trust	Interviewee discuss trust required for collaborative innovation
			How to Develop/ Maintain Trust	Ways used to develop trust
	Commitment	Interviewees discuss commitment	Project	Commitment to the innovation and project
			Partners	Commitment between partners
	Challenges	Interviewee discuss collaborative challenges	Mindset	The mindset of the person, company or collaborating partners is discussed
			Alignment	How to align partners thinking
			Planning	How partners plan innovation
			Resources (In)	How resource decisions are made
			Innovation Outcomes	How decisions on outputs are made
Circular Oriented Innovation	Method for Innovation	Interviewee discusses specific methods or practices used	Collaborative Foresight	Collaborative foresight practices are discussed
			Technical	Technical-based experimentation practices are discussed
			Market	Market-based experimentation practices are discussed
	Type of Innovation pursued	Interviewee discuss the type of innovation pursued	Product	Product Innovation pursued
			Process	Process Innovation pursued
			Organisational	Organisational Innovation pursued
			Market	Market Innovation pursued
	COI Context	Interviewee discusses COI project idea	Focus	Interviewee discusses the intended CE strategy of the project
			Scope of COI	Interviewee discusses the intended scope of the project (Incremental or Radical)
	Challenges	Interviewee discusses COI challenges	KPI's & Assessment	Interviewee discusses assessment or measurement processes for circular innovation strategies or outputs
			Linear Vs. CE	Interviewee discusses the differences between CE and Linear

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