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Circular economy implementation in operations & supply chain management: Building a pathway to business transformation

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ABSTRACT

Our aim is to understand the circular economy (CE) transformation challenge and the synergies with operations & supply chain management (OSCM). CE represents a major industry transformation from linear production to circular value creation where products, components and resources are maintained at the highest value for the longest period. Yet despite OSCM's long association with reverse logistics, the practical means of CE implementation is lacking where business transformation means systemic innovation not incremental change. Our method is to adopt a longitudinal approach where rich data from over 1000 senior practitioners on interactive events identifies 3 stages comprising of identification, initiation, and implementation, and reveals why some companies move between the stages and others become stuck. We illustrate these stages and the successful pathways used in 5 industry cases: Philips, Schweizer Bundesbahn, Renault, Ricoh, and Steelcase. Rather than develop new tools, we present a framework for implementing CE using business elements which are grounded in everyday practice and part of a taxonomic process that is continuously tested over time. We find successful CE implementation requires attention to product design, underlying business models, reverse flow management and enabling conditions (e.g. policy, finance), unlocking new sources of circular value creation and capture. There is no one-size-fits-all model for successful initiation and implementation of CE, but rather a continuous process of identifying value leakage and creation opportunities, progressive initiation of pilots, evaluation of business outcomes, and ability to manage risks associated with complexity and scaling. Our contribution views the challenge as a complex pathway consisting of configuring CE building blocks whose business transformation hallmarks are reflected in architectural change and systemic innovation.

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1. Introduction

There are now multiple arguments for industry to adopt circular economy (CE) as a basis for new forms of value creation and capture, and to drive exponential resource productivity and environmental benefits including reduced externalities and rebuilding natural capital (EMF. 2013; Geissdoerfer et al. 2017; Geng, Sarkis, and Bleischwitz 2019; Stahel 2016). The growth of interest in CE has resulted in a significant increase in definitions and characterizations (Kalmykova, Sadagopan, and Rosado 2018). At the centre of most definitions, however, is a set of guiding principles and concepts for the design of future industrial economic systems (Chen, Hung, and Ma 2020; Marrucci, Daddi, and Iraldo 2019; Masi et al. 2018; Mishra, Hopkinson, and Tidridge 2018). The definition which we use as our reference point is 'a framework for designing out waste and pollution, keeping products and materials in use, and regenerating natural systems' (EMF 2020, 1).

Operations & supply chain management (OSCM) has experienced many important developments in reverse supply chains, recycling and product-service design, yet the links with CE remain relatively unexplored (Batista et al. 2018a; Blackburn et al. 2004; de Sousa Jabbour et al. 2018; Guide, Harrison, and Van Wassenhove 2003). We see the challenge where companies wishing to reap the benefits of CE and circular operations typically face the following complications: identifying and selecting initiation tools and strategies, and scaling up of CE programmes for adoption, as the core operating foundation. While successful cases of circular business practice are emerging typically by sector (e.g. Hopkinson et al. 2018; Sehnem et al. 2020; Susanty, Tjahjono, and Sulistyani 2020), much of the literature is focussed on the conceptualization and re-classification of business models from the 'outside in' (Blomsma and Brennan 2017; Bocken et al. 2016; Osterwalder and Pigneur 2010), and lacking empirical foundation or evaluation of what actually happens in practice from the 'inside out'. Not only can this be confusing for practitioners, but important questions remain over the application of operational approaches for CE initiation, implementation and scaling across the supply chain (EMF 2015b; Kalmykova, Sadagopan, and Rosado 2018; Lieder and Rashid 2016).

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We examine CE implementation in relation to OSCM based on our research with senior practitioners from 2014 to 2021 across 5 multinational organizations engaged in circular transformation initiatives of high value, materially intensive supply chain and operations sectors. Our research identifies 3 phases which, independent of size or industry, a circular transformation needs to pass through: identification of opportunities, initiation of pilot projects, and implementation at scale. We build up a model of implementation architecture drawn from CE innovation in OSCM literature (e.g. Bag, Gupta, and Foropon 2019; Henderson 2021; Hopkinson et al. 2018) and feedback from over 1000 business practitioners across multiple sectors, showing how a range of approaches are being deployed by leading companies to initiate, implement and scale-up CE practices to deliver new sources of value. Our research question therefore is around understanding the CE transformation challenge, and what is needed to support its delivery. Hence: *how does taking an operations & supply chain management approach enable transformation of circular economy implementation?*

Our paper is structured as follows: first we set out the guiding principles and concepts for CE, and the context for their application. Then, we identify the elements of CE in OSCM literature that relate to these principles and value drivers. After methods, we provide evidence from industry, including 5 cases of leading corporations showing the range of approaches and configurations that have been used to identify, initiate, and implement CE at scale. Our CE implementation framework is presented as a heuristic for business transformation and discussed in terms of implications for OSCM.

2. Literature: circular economy and operations & supply chain management

Despite burgeoning interest in circular economy as a new foundation for business growth, research into CE implementation and circular operations practice remains fragmented (Chen, Hung, and Ma 2020; Marrucci, Daddi, and Iraldo 2019), and hampered by diverging perspectives (Kalmykova, Sadagopan, and Rosado 2018; Reike, Vermeulen, and Witjes 2018). This section starts therefore by defining the productivity opportunities presented by CE before identifying transformative operations approaches whose origins are traced across sustainable commerce & regenerative capitalism, value analysis, reverse supply chains, and business model innovation.

2.1. Circular economy, productivity and transforming operations

The economic and business opportunity as well as the need to make the shift towards circular economy has been featured in many reports and initiatives (EMF 2014, 2015a). The first report by EMF in 2013 demonstrated a shift to CE as a multi-billion pound economic opportunity, boosting economic growth, driving up resource productivity, creating jobs and substantially reducing externalities from linear product-consumption chains. This and related work has led to a number of international and national policy initiatives, including the European Commission's CE policy package, and research initiatives such as the UK NICER program (EC 2019; UKRI 2021). Yet the evidence base for CE value creation and capture remains fragmented, with multiple framings of CE and systems, different methods across academic fields and schools of thought (Chen, Hung, and Ma 2020).

The term circular economy has become increasingly familiar in business and academic arenas, much of the interest stemming from the work of the EMF whose reports (2013–2015) set out an overarching systems diagram referred to as the butterfly model. Two material spheres or 'wings': technical and biological, depict a series of feedback loops of materials, components, products and information through various value loops into the economy (EMF 2013). The goal of CE is to design industry systems to maintain the circulation or cascading of products, components, and resources at their highest value for the longest time. A second core objective is to restore and rebuild natural capital as the basis for the healthy functions of key planetary support systems (Velenturf and Purnell 2021). In doing so, rather than the polluter pays, the goal is to design out waste at the outset: everything designed should be a valuable resource for something else. Furthermore, do not extract materials in ways that pollute and degenerate natural capital and ecosystem services, but design systems that are built on the principles of regeneration and restoration, that rebuild natural capital rather than running down stocks or adding to the flows of greenhouse gases and other emissions beyond planetary boundaries (EMF 2013, 2014, 2015a).

Rather than addressing cost, efficiency, or operational components of closed loop systems in isolation (Guide, Harrison, and Van Wassenhove 2003), the circular economy is inherently more complex and boundary spanning, involving system innovation, new forms of partnering and coordination of OCSM actors and stakeholders across all functions (Henderson 2021). Growing OCSM research interest in closed loop systems provides a number of tools and approaches to model the tension between CE and system-wide costs (Hosoda, Disney, and Zhou 2021) or uncertainties in remanufacturing dynamics (Vlachos, Georgiadis, and Iakovou 2007). CE however is a broader value creation framework than closed loop remanufacturing, requiring synthesis and integration of important value drivers (EMF 2013, 2014, Zils et al. 2022). For example, co-author Zils co-created the following four value drivers with the Ellen McArthur Foundation (EMF) in 2013, which are directed towards the core goal of CE, to decouple economic growth and environmental degradation from resource consumption (Hargroves and Smith 2005; Hawken, Lovins, and Lovins 1999). The core metric for this approach is resource productivity which represents the amount of goods or service per unit resource consumed in monetary and biophysical terms. Hence, the underpinning value drivers for resource productivity in CE are defined as:

1. *The power of the inner circle* – means maintaining materials, components and products at their highest value

via maintenance: keeping them in their original form or as close to for as long as possible subject to exceptions where radical shifts or improvements in technology may produce desirable system benefits. The tighter the circle or less a product has to be changed during any refurbishment, and the faster it returns to use, the higher the savings on materials, labour, energy and capital;

2. *The power of circling longer* – involves extending the period of time during which product integrity is maintained and materials are kept in use for as long as possible via re-use, refurbishment, remanufacture;
3. *The power of cascaded use* – where value can be retained, created and captured when materials reach the end of their first use phase and can be cascaded across different supply chains, for example textile waste from fashion can become a feedstock for other sectors;
4. *The power of pure circles* – refers to a meta-requirement to avoid contamination of material streams via additives that reduce or destroy the value of those materials in subsequent life cycles due to their impact on material quality and health and the added costs involved in collection, separation, reprocessing and redistribution. To achieve this requires adopting a system perspective whereby material choices and product design decisions should be based on all future lifecycles and eventual productive return to the economy and/or biosphere, rather than low grade, low value, potentially harmful and wasteful landfill, incineration, down-cycling or leakage into the biophysical environment. For this reason, recycling is sometimes referred to as the 'loop of last resort' where the material value from our current linear economy is downcycled rather than upcycled (Comella 1993, 415). The test case for upcycling is whether the product made from recycled materials can be returned to its original or similar product. These changes are accompanied by a shift away from fossil fuels and towards renewable energy sources.

Operations theory in the 20th century developed within a linear paradigm with a focus on firm-centric, linear practices (Vargo, Wieland, and Akaka 2015). Companies were locked into institutional systems that evolved over many decades, based on heavy investment, internal strategies and cultures that are predicated on linear models such as selling more, lowering costs, incremental innovation and resource efficiency whilst staying compliant with existing legislation (Howard et al. 2007).

Circular economy repositions value beyond the narrower conception of value in OSCM as a cost reduction measure (Ferrin and Plank 2002; Gunasekaran and Kobu 2002), or moving downstream in the value chain (Oliva and Kallenberg 2003; Quinn, Doorley, and Paquette 1990). CE offers the potential for new ways of defining and delivering value, including circular models of manufacturing towards wider benefits which are more intangible and implicit, such as system stability, resilience, and behaviour change (Bag, Gupta, and Foropon 2019; Okorie et al. 2020). Hence, how business models deliver value to customers is changing, away from traditional linear patterns of production including closed-loop operations, towards a wider scope for CE implementation covering the whole production-consumption network across a range of scales (Govindan and Hasanagic 2018; Virtanen et al. 2019). To move from this position towards CE takes time, vision, and a fundamental shift in thinking around how to transform operations.

Despite their proliferation, case studies on CE are often not focused on value creation, but multiple non-aligned metrics such as waste and cost reduction (Dey et al. 2020). Further, there is increasing pressure for the business to act sustainably, but also a tendency to focus on incremental, isolated initiatives at sub-optimal scale (Jabbour et al. 2019). Similarly, visualization tools for circular business models, while offering product lifecycle reporting on energy, carbon footprint and social impact via questionnaire reporting, offers little sense of the underlying stages and scaling of CE implementation (Bianchini, Rossi, and Pellegrini 2019). Companies need to recognize that in the identification and initiation piloting, intended consequences are observed which limit the future scalability of CE interventions, such as emerging self-cannibalization, shifting the distribution of risk, and requirement to engage into longer term arrangements with suppliers and service providers (Jiao and Boons 2017). Given a key goal of CE is to reduce the absolute demand for resources within planetary boundaries (Haas et al. 2020), a key challenge is to avoid the potential for CE business models to incentivize greater overall consumption of resources. One way to track possible 'rebound' effects is to ensure that micro and meso- scale interventions and measurements are set within an overarching macro resource consumption and CE key performance indicator framework (Lysaght et al. 2022).

The consideration of CE value creation opportunities requires systematic re-thinking of operations and supply chain. With over 100 definitions currently in circulation (Kirchherr, Reike, and Hekkert 2017), recent work shows that the most successful CE value creation and capture is driven by a set of configurable building blocks or business architecture that varies in execution depending on the start point and specific business context (Henderson 2021; Hopkinson, De Angelis, and Zils 2020). These building blocks relate how to: (1) Design products and services (i.e. design for service, longevity, repair, disassembly); (2) Connect to business models to incentivize future high value circulation (e.g. shifting towards service, performance and access over ownership); (3) Reverse logistics, including collection, segregation, processing and return back into productive high value uses, and (4) Work with & adapt to a range of system enablers, including policy, education, regulation, and finance that influence many of the available behaviours in a specific content, but which themselves are dynamic and changing. The challenge for any business is how to utilize these building blocks as part of a phased approach involving 'initiation/decision, adoption and implementation' of value creation and capture opportunities (Moric et al. 2020, 2557), explored further in section 2.2.

Understanding the productivity opportunities of CE through transforming operations therefore requires not only new competencies from producers and suppliers, but managing firm behaviours based on a more systemic understanding (Jakhar et al. 2019; Lieder and Rashid 2016; Schröder, Lemille, and Desmond 2020). Whilst the idea of CE may be relatively new, there is no mystique to the building blocks or value drivers as described above. A common approach taken by literature on CE implementation involves descriptions of drivers and barriers, or business models presented as a one-size-fits-all approach (Amir et al. 2022; Lu, Zhao, and Liu 2022), which misses the complexity and wider context of boundary spanning, value chain based firm transformation. Value recapture and creation therefore require a radical diversion from the usual path of business and involves difficult strategic or policy decisions that may include elements of creative destruction (Kivimaa and Kern 2016).

2.2. Circular operations & supply chain implementation

Interaction between the field of OSCM and circular economy is a recent development (de Sousa Jabbour et al. 2019; van Loon and Van Wassenhove 2020; Kovács et al. 2020), with special issues in CE production systems and supply chain operations journals (Batista et al. 2018a; Santibanez Gonzalez, Koh, and Leung 2019). Common areas of research include CE literature reviews and theoretical fundamentals (Batista et al. 2018b; De Angelis, Howard, and Miemczyk 2018), supply chain design (Srai et al. 2018), regional studies on material recovery (Batista et al. 2019; Mangla et al. 2018), and barriers & enablers to CE business practice (Masi et al. 2018). While the role of Industry 4.0 digital technologies is recognized as important in CE implementation, details of the precise roadmap remain in development, with early predictions around use of various data sharing technologies and approaches, such as blockchain or data trust frameworks (de Sousa Jabbour et al. 2019; Kouhizadeh, Zhu, and Sarkis 2020; Zils et al. 2022). A wide range of case studies including construction, agri-food, electrical, FMCG and automotive provides evidence that CE for producers and consumers represents both a sustainable solution and an opportunity to recapture value at scale across multiple sectors (Abuabara, Paucar-Caceres, and Burrowes-Cromwell 2019; Hopkinson et al. 2018; Vlajic, Mijailovic, and Bogdanova 2018). Yet this growing body of research reveals a variety of circular approaches variously termed as closed loop, circular supply chain, and green SCM (Su et al. 2013; Subramanian et al. 2019). Although the principles and building blocks of CE are in place, details over adoption, defined pathways and role played by OSCM are incomplete.

Despite the lack of detail over implementation, the literature emphasizes supply chain, system, and stakeholder cooperation as successful factors for CE adoption (Genovese et al. 2017). If a system lacks value drivers aligned to the principles of CE (e.g. designing products and materials to circulate at their highest value for the longest time), then the creation of closed-loop supply chains in itself does not constitute a CE, especially if it is operated in conjunction with linear take-make-waste operations (van Loon and Van Wassenhove 2020). The relationship between circularity and sustainability is complex, with a long history of association in areas such as reverse logistics, green SCM, social responsibility, and sharing economy (Guide, Harrison, and Van Wassenhove 2003; Koh et al. 2017). While CE principles within sustainable supply chains can provide 'clear advantages from an environmental point view', this omits the practical considerations around how to build the CE business case (Genovese et al. 2017, 344). Using the 3 generic phases identified earlier (Moric et al. 2020), we now explore the methodological constructs of circular implementation which correspond with OSCM including elements such as value analysis, design, product lifecycle, reverse logistics, and business model innovation.

2.2.1. Identification

Value leakage analysis and opportunity spotting describes initial process improvement & waste reduction methods, reflecting the efficiency-orientated nature of classic operations tools in identifying causes of manufacturing waste such as bottlenecks, excess inventory and demand amplification (Hines and Rich 1997, Gardner and Cooper 2003). Value stream maps and flowcharts are often used as a diagrammatic representation of shop floor operations, providing a step-by-step solution to problems of process optimization (Rother and Shook 1988). While process improvement can be helpful in exposing waste across firms starting to explore circular practices, they must reflect the principles of CE in restoring value across the whole production-consumption system (EMF. 2013). The term Lean and Green is presented as a sustainable operations practice that merges waste elimination with reducing environmental impact but is limited to operating within linear production patterns, where recycling is a periphery or non-core activity (King and Lenox 2009; Mollenkopf et al. 2010). Materials reduction, recycle & remanufacture (3Rs) is a popular yet somewhat constrained circular approach in manufacturing because of its ease of applicability in conventional production scenarios to improve material usage and reduce cost, but often without altering the fundamental underlying linearity or throughput-based operation paradigm (ISO. 2006; Singhal and Kapur 2002).

2.2.2. Initiation & adoption

Design and eco-design reflect the unsustainability of approaches such as planned obsolescence in products, now challenged by more enlightened producers and consumers through the application of circular design principles such as prolonging product use, intensification of use, and extending product warranties. For example, WRAP's (2014) service model links service systems with extending product life, advocating for firms and their customers to shift away from traditional product ownership with limited lifespans towards leasing mechanisms to incentivize return loops so products and components are kept in circulation for longer. Using the UN's sustainable development goals, Mestre and Cooper (2017) take the idea of CE to slow and close material loops,

providing practical guidance for design. The systematic reduction of waste is the basis for Lean thinking (Womack and Jones 1996), which seemingly reflects the aims of CE to 'design out waste' (EMF. 2013, 7). However, whereas operations managers typically talk of step-by-step improvement and product end-of-life (Gunasekaran and Kobu 2002), CE advocates for restoration and regeneration, where 'waste does not exist' and products are designed around a continuous cycle of disassembly and reuse (EMF. 2013, 7). Hence, products must be designed from the outset so that components can be recovered, reconditioned, and reused in circular take-back schemes, helping to maintain a high value cycle (Bakker et al. 2014; Toyasaki, Boyacı, and Verter 2011).

Life cycle assessment (LCA) is historically used to evaluate and compare individual products, although broader applications are being applied today at product, organization and economy levels to inform the eco-design of process optimization, supply chain management, corporate sustainability strategy, consumer choices, and national production & consumption policies (Hellweg and Canals 2014). LCA is increasingly applied to CE, for example in combination with material circularity indicators to assess circular product strategies (Niero and Kalbar 2019). LCA quantitatively evaluates the environmental sustainability of a product over its entire life cycle, using a framework of four steps: scope definition, life cycle inventory analysis, impact assessment and interpretation (ISO 2006). As elements of CE are inherently included in LCA, even new or improved ways of interpreting LCA results can provide valuable insights (Rigamonti et al. 2017). Novel methods have been proposed to analyse and design complex regional level CE systems (Scheepens, Vogtländer, and Brezet 2016). Although there is some consensus that LCA should be used to evaluate options for CE solutions to ensure a positive balance of efforts and benefits in new product design for increased recycling, the most circular options may not necessarily be best in environmental terms due to the increase in return loop activity (Haupt and Zschokke 2017).

Reverse logistics covers management of the recovery and distribution of end-of-life products, with links to recycling literature that originates from the 1970s (Dekker et al. 2004; Rogers and Tibben-Lembke 2001). Reverse logistics includes the study of production planning, inventory control, and supply chain management, as part of closed-loop supply chain implementation (Blackburn et al. 2004, Seuring 2004; Guide and Van Wassenhove 2009). In addition to the challenges around CE integration, 'closing the loop' (Zhu, Sarkis, and Lai 2008, 1) involves considerable emphasis on forward operating chains, with less thought given to return based business models which tackle issues around value, profitability and environmental legislation (Carter and Ellram 1998; Guide, Harrison, and Van Wassenhove 2003; Mollenkopf, Frankel, and Russo 2011). What started as mapping the logistical elements of value chains (Christopher 2005; Gardner and Cooper 2003), is now reflected in circular strategies and indicators for regenerative supply chains (Howard, Hopkinson, and Miemczyk 2019). Terminology such as closed loop is still used today, referring to the proportion of direct (e.g. steel, plastic) and indirect (water, energy, gas) resources recovered during production and consumption (Ghisellini, Cialani, and Ulgiati 2016), despite instances of implementation within linear value chains to improve material efficiencies. Whilst it was common in the 20th century for discarded products to go to landfill, the practice has been increasingly restricted by UK and European law because of the environmental issues caused by toxin leakages and methane emissions (Frith 2022). While this move has created incentives to reduce scrap in production, it is in reality a variant of linear economy efficiency gains. Instead, CE offers opportunities for multiple streams and cascades material re-harvesting, creating new jobs while preserving natural capital, suggesting wide-scale operationalization and implementation are now central to the CE agenda (Stahel 2016).

2.2.3. Implementation

Circular business model innovation supports the principle of CE implementation but raises extensive challenges and barriers to the process (Antikainen and Valkokari 2016; Guldmann and Huulgaard 2020; Linder and Williander 2017). In their review of circular business model innovation for operationalization, Bocken et al. (2019) find while many sustainability tools have been developed and exist for generic phases (e.g. ideate & design, implement, test), only few approaches focus on circular business models as a whole. They reveal attempts to embed circularity within specific phases of the business, using tools comprising of process or conceptual frameworks, as predominantly qualitative in nature with limited testing. Chen, Hung, and Ma (2020, 1892) for example reveals a simple checklist 'before, during & after' approach to circular business model adoption, with only general reference to lifecycle thinking, brainstorming, and analysing. More promising is a framework for CE business models and supply chains which adopts an overarching view, connecting organizations with the value network, leading to a systems view described as the 'sustainable circular economy' (Geissdoerfer et al. 2018, 719). Here, the scope is ambitious, with overlapping sustainable and circular business models based on cases whose features include closing, slowing, narrowing, intensifying and dematerializing loops.

In summary, the literature reveals considerable interest in CE, with variants of the butterfly model offering the principal foundation and building blocks for business transformation (EMF 2013, 2015a). Despite long association with design and logistics, specifics on CE approaches for implementation using OSCM are lacking. CE represents a transformative process that must be scaled up to involve the whole value chain (EMF 2020), not just individual product lines, or as an add-on to linear production methods. While CE implementation clearly requires systemic and not incremental innovation, this approach is not reflected in current OSCM practice. Our review highlights individual practices such as LCA and process mapping as useful starting points for identification and initiation, but where a complete pathway or roadmap for CE implementation is missing. We argue many of the CE building blocks exist already in one form or another, such as eco-design or reverse logistics. As a result, a variety of

approaches for implementation already exist and – if coordinated together as a system or business architecture – can be deployed, adapted, and programmed to identify and build value-creating circular OSCM practices from the ground up.

3. Method

This study explores the emerging phenomenon of circular economy implementation by adopting a longitudinal multiple case study approach (Eisenhardt 1989; Pettigrew 1990; Yin 1994) and building a process framework from multiple sources of data (Eisenhardt and Graebner 2007; Langley 1999; Stuart et al. 2002). Case research has a strong tradition of advancing understanding in sustainable OSCM where the investigator has little control over contemporary events (Pagell and Wu 2009; Villena, Wilhelm, and Xiao 2020; Voss 2010; Wu and Jia 2018). A requirement of our investigation was to engage with the phenomenon through observation of and interaction with practitioners whose firms were undergoing CE implementation. This meant combining quantitative company data, with observations from participants during masterclass workshops and discussion forums to understand the process of change (Aktinson and Hammersley 1998; Lüscher and Lewis 2008; Näslund, Kale, and Paulraj 2010). Our approach enabled us to identify, evaluate and explore complex issues over time involving OSCM where, to enhance rigour, the cases incorporate qualitative descriptions and quantitative data (Bansal, Gualandris, and Kim 2020; Choi, Cheng, and Zhao 2016).

Multiple case studies allow a wider discovering of theoretical evolution and create more compelling evidence and convincing theory (Eisenhardt and Graebner 2007; Yin 1994). At a time when industry was beginning to take interest in the circular economy (EMF 2013, 2014), we selected five corporations, all large multi-nationals drawn from a range of different sectors (i.e. medical equipment, railways, automotive, printing, office furniture) and known to be facing the challenge of introducing and transitioning to the CE (Table 1). Our decision to adopt a multiple case approach was to get beyond the anecdotal evidence typically presented in single sector studies and base our research on replication logic 'analogous to that used in multiple experiments' (Yin 1994, 45). During the period 2018 to 2021, over 1000 senior practitioners participated in a Global CE Implementation Masterclass, designed and run by the co-authors focussing on practical CE implementation. Three of the case study examples were selected from the 100+ companies who participated and feature as long-term case studies with the course providing detailed insights into what works, the day-to-day challenges, and successful outcomes. Two further companies were selected based on extensive prior research. Our cases therefore cover five different sectors and demonstrate evidence of value creation and capture from CE implementation (Table 1). This inside-out perspective, in combination with workshops, discussion forums and quantitative data, allowed investigators to evaluate and observe the types of operations changes taking place and the methods used. Our approach of 'collaborative intervention' with the leaders and practitioners responsible for CE provided access to the reality and complexity of the implementation challenges and commercial pressures facing firms as they moved away from linear modes of operation (Lüscher and Lewis 2008, 222).

Our approach to data collection was conducted over time which progressively sensitized investigators to the issues that surfaced around CE implementation, promoting a sense of co-learning and interaction between participants in an environment of trust (Manning 1997; Touboulic and Walker 2015). The masterclass workshops were held three times per year with the companies, which included CE leaders, line managers and staff from a variety of roles and functional areas (e.g. Operations, Purchasing, Marketing). Online discussion forum questions relating to the participants own company and role provided rich data on the daily challenges, barriers, enablers, and pathways to initiate and implement CE in different contexts at scale. Discussions were also held with senior management (e.g. Vice President, Chief Executive Officer, Chief Procurement Officer) from the five case study companies to understand the context and implications of specific CE programs and why they were being initiated (Fleming and Zils 2014). Extensive notes were taken and compared after each interaction, including observations around general applicability of CE in terms of scaling the operation. Our research was also supported by secondary data collected from company reports, government working papers and NGO publications (APSRG 2020; BSI 2017; ISO. 2006; OECD. 2004). Three of

Table 1. Details of companies selected as cases of CE implementation.

Company	Period of CE development	Investigation method (2019–2021)	Description of CE initiative or programme	Measures adopted for value creation	Outcome
1. Philips	2014–2021	Workshops (9) Collaborative intervention during executive education	CE Transformation programme	CE key performance indicators based on total revenue	Target of 15% of revenues from circular solutions by 2020
2. SBB	2014–2021	Workshops (9), Business model studies, Value chain, OSCM diagnostics	CE Strategy and Transformation programme	CE value creation	50+ Million Euro CE value creation
3. Renault	2017–2021	Workshops (9) Collaborative intervention during executive education	CE Connected Ecosystem	CE metric based on resource savings (Euro)	100+ Million Euro CE value retention (2019–2021)
4. Ricoh	2015–2021	Workshops (9), Collaborative interventions during executive education	COMET Circle model	Value asset cascade based on profit	Annual revenues from remanufacturing & value retention
5. Steelcase	2015–2019	Workshops (8), Modelling, New business model generation	CE Strategy and supply-chain business building programme	Financial metrics	Dedicated business unit to offer integrated CE revalorisation services

these companies (Philips, Ricoh and Renault) became case studies for the masterclass to report *what was working and what wasn't* in relation to how effectively the business was changing in light of CE practice. These case studies were then presented and discussed within live webinar forums across the entire cohort, for comment and reflection. This has enabled us to iteratively expand and update the cases on a yearly cycle, taking on board new barriers, challenges, and solutions across the implementation journey. In addition, SBB, Steelcase, Philips and Ricoh were studied as part of separate research initiatives across a similar time period, combining strategic analysis with CE business case development on behalf of the company (e.g. Hopkinson et al. 2018).

The analysis was conducted by first constructing within case summary tables of the masterclass and discussion forum interactions for each of the five case studies on the approaches most commonly used and found to be effective (Miles and Huberman 1994). Figure 1 illustrates how an abductive process was adopted towards matching, directing and redirecting the multiple sources of data between the empirical world (e.g. workshops), theory, phenomenon definition and case development (Dubois and Gadde 2002; Kovács and Spens 2005; Langley 1999). Using this method of categorization, a picture emerged of the implementation tools and approaches adopted over time by each company, how they were combined, and how particular challenges such as CE scaling were addressed. After comparing and triangulating each case, a cross case analysis framework emerged highlighting the major phases and transition pathways towards CE value recapture and creation (Jick 1979). As the basis for our framework emerged from the research, we presented it back to the masterclass through webinar formats for review and shared the approach with other companies with whom we are engaged. We adopted a taxonomic process, where concepts around CE transformation were continuously tested in our interactions with the companies until saturation was achieved (Eisenhardt 1989).

4. Findings

This section presents the findings observed first from the most recent 10 cohorts (1000 participants) of the masterclass workshops from April 2018, where participants were asked to report their challenges and needs in the implementation of CE within their role, sector and value chain position (Figure 2). It describes the five cases and outlines their CE implementation journey. These results offer a detailed understanding of the challenges and common phases or stages of implementation experienced by practitioners across the cases, including approaches used in the CE adoption process.

As a summary heuristic, Figure 2 shows the typical barriers identified and the key stages that emerged in the implementation journey from the 5 companies. This comprised of early stages of exploration and identification of opportunity, moving towards initiation of pilots and proof of concept, and finally moving towards implementation at scale. In the initial stage, common barriers across all sectors and businesses are typically experienced, characterized by many ideas without clear networks or support to move forward, a lack of tools to know where to start, quantify the benefits, or know-how to overcome the linear mindset amongst colleagues.

> W*hen we first started to look into revalorization opportunities of our asset base, we were heavily challenged by our technical departments, who sensed significant upfront OPEX [operational expenditure] and potential compliance issues with existing company internal process descriptions.* (Senior Executive for CE, SBB)

Where action has been initiated, often through pilots, new challenges emerge. One common outcome is that progress stalls, as there is no mandate or budget for taking any successes forward. Often there is tension, suspicion, or threat from the linear side of the business driven by linear KPIs. A second reaction is a wave of enthusiasm, where colleagues, teams, business units or leaders see the potential and start to advocate or initiate more pilots without strategic

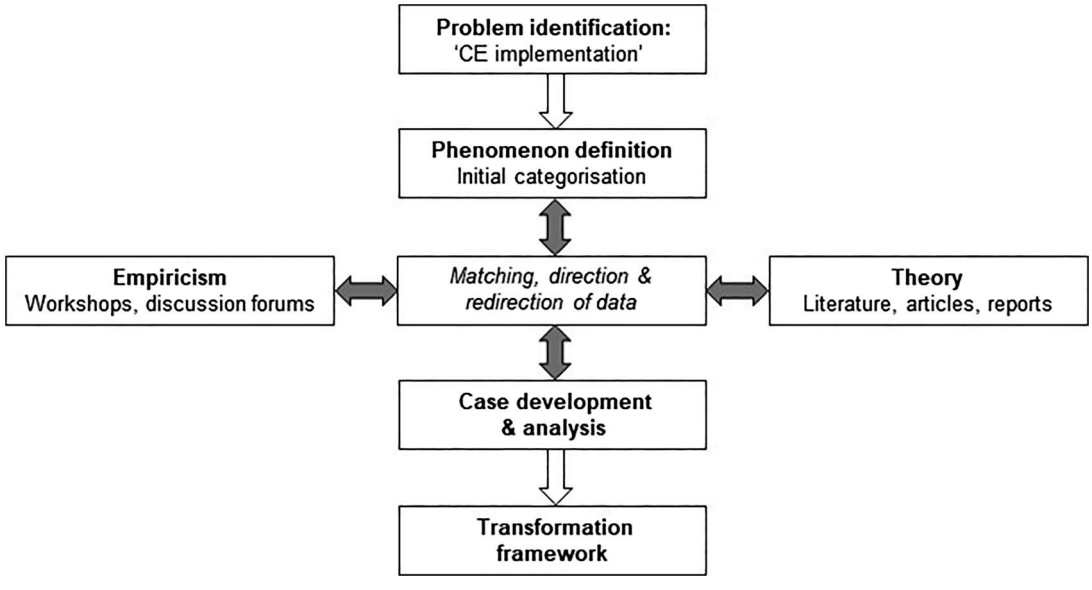

Figure 1. Abductive approach to case research (adapted: Dubois and Gadde 2002; Kovács and Spens 2005).

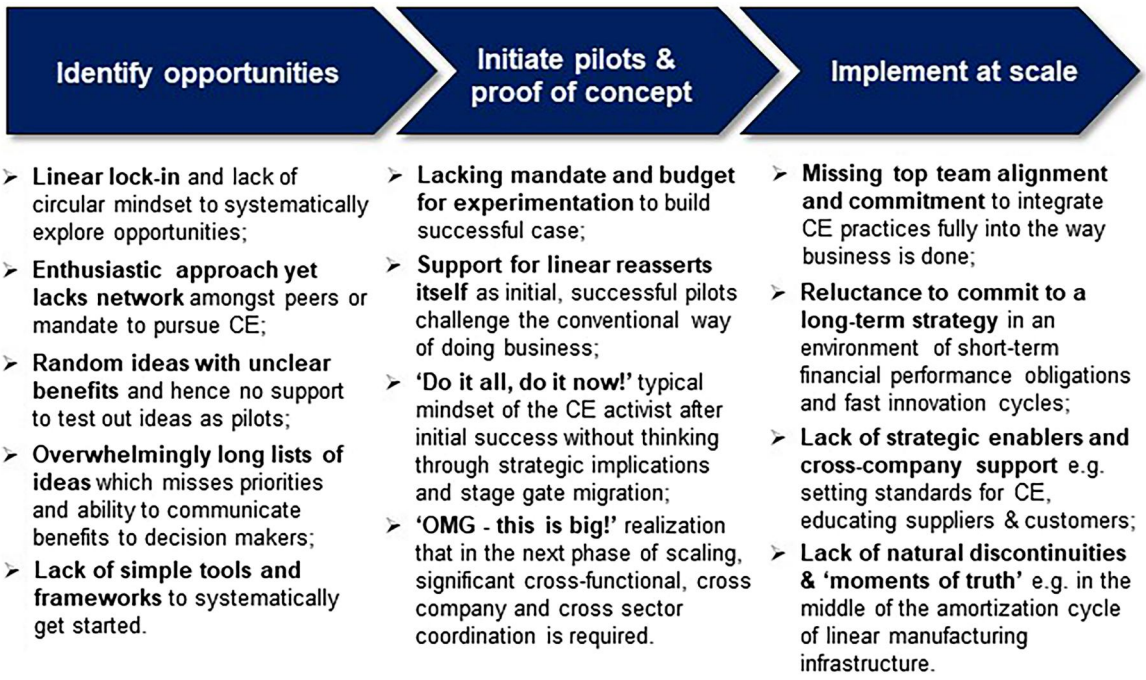

Figure 2. Typical barriers observed during CE implementation.

planning, stage gate methods, or the implications for cross-functional teams. The third stage, which offers the potential for increasing revenue growth, increasing profitability and margin and new opportunity occurs when initial successes start to offer the prospect of scaling. However, this stage can also lead to stalling.

> *We had run a business case simulation, which explicitly took into consideration self-cannibalization. …. Being able to validate the findings on showing superior deal-economics for CE-augmented solutions was a breakthrough moment for us to embed CE as one of the core pillars into our operating procedures.* (Senior Sustainability Executive, Steelcase)

The CE business logic often lacks integration within the current culture and there is a tension between the need for meeting short-term linear targets, leading to resistance to fully commit to CE investments, enablers, and cross-company support. In many situations, the lock-in to historic capital and asset investment means there are no points of discontinuity or disruption when the business faces strategic choices about its overall direction.

The companies that have made a successful transformation to CE by growing their portfolio of CE initiatives across divisions and applications have managed to traverse these challenges at the three different stages. Typical indicators or milestones of successful transition at each stage are summarized in Figure 2. In most successful examples, CE is identified as an opportunity to address strategic challenges, including market share, resource security, price volatility, climate change and changing customer needs. This is accompanied by a circular scan using variants of value stream mapping to look for value leakage and potential 'low hanging fruit' accompanied by some initial estimates of the size of the opportunity and value creation potential. At this stage, processes are not yet systematized or fully co-ordinated, but necessary to understand the potential size of the prize.

> *When we realized the transformational power of CE-enabled refurbishment operations, we recognized the need to also support this with a strategic re-alignment. …. As a result, we put significant investment into the build-up of a dedicated brand for refurbished products 'the green line' and a pan-European network approach to ensure steady inflow of used kit for cascading into secondary markets.* (Senior Executive, Ricoh)

Presenting circular economy as a system wide, strategic level change affecting all functions in the company provides a foundation to explore value creation opportunities around products and services or business model design or to extend existing reverse logistics operations such as returns, repair or refurbishment. It leads to a focus on initiating pilots which are supported and resourced by senior management, progress is formally monitored and evaluated, with clear foresight on scaling up potential, options and trade-offs and confirmation of business potential.

> *At Philips we recognized early on the need to embed CE firmly into our strategy and operational supply chain management to reap the full benefits. … Today we have very clear measures for tracking and steering the transformation towards a significant larger share of our revenues stemming from CE-businesses models.* (Senior Executive, Philips)

Building confidence and support builds top level management commitment, developing more formal targets and understanding of the trade-offs involved when pilots begin to scale CE specific products and services to become part of the core business and planned launch (Figure 3). Whilst the exact pattern, speed and embeddedness of these three stages and their milestones varies from case to case, they invariably involve the configuration, deployment and sequencing of tools and approaches, as the following case descriptions illustrate.

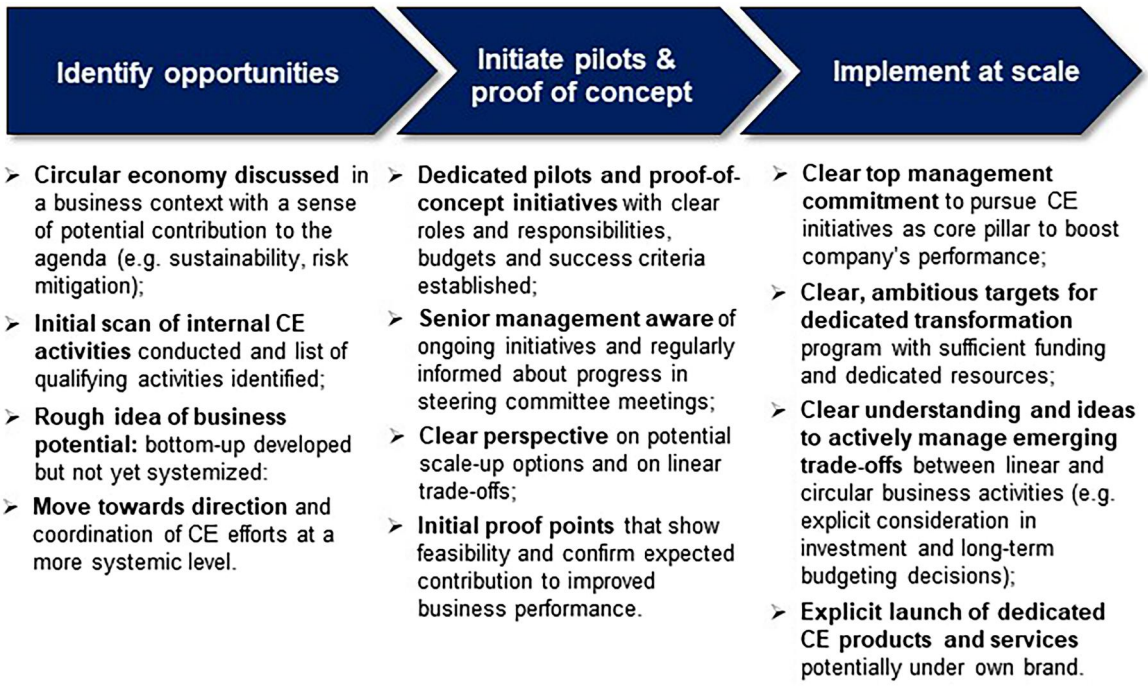

Figure 3. Typical milestones in the stages of a CE journey.

4.1. Company cases of CE implementation

Philips is a leading manufacturer and distributor of household and healthcare products. Since 1996, it has operated product refurbishment for many years for medical and other devices, although as a low profile activity. Philips has moved progressively from a product and technology focus to person-centered innovation. Their goal is to deliver new value proposition solutions that drive healthier and more circular outcomes. Philips embarked on their circular journey in 2012 as part of a new vision and mission. CEO Frans van Houten made the case for fast-tracking the move to CE and closing material loops. The refurbishment business became an initial focus of attention and realization that there was investment and infrastructure that had potential for growth, new customers, and new sources of revenue, as well as hitting environmental targets. Refurbishment, and then remanufacturing, became an early cornerstone of the Philips business and CE offer.

As awareness grew of the opportunities presented by CE, the company began a structured a process of actively mapping value leakage across a wide range of currently linear products. This process evolved starting with internal teams over time to progressively more structured and systematic application of tools and CE building blocks, involving cross functional project teams to explore material take back value and refurbishment costs for existing product, using data from the existing service network, bill of materials breakdown, and product lifetime to generate refurbishment scenarios. This approach was linked to analysing new value capture options (e.g. business model development workshops), such as leasing of product and what changes in product design might be needed to improve profitability, including modelling different lease periods and monthly fees, comparing profit to base case direct sale/purchase. Progressively more detailed analysis of factors affecting the business sequentially and collectively was undertaken, including LCA to assess component quality, product life, and customer acceptance of reused parts. To accelerate the transformation to circular principles, Philips created a Centre of Expertise: a permanent internal group to help with methodologies and programs. The alignment of the value creation process and CE is shaped around the Design for Excellence program, promoting design for recyclability, upgradability and serviceability. The process is stimulated by setting criteria for every product to challenge business unit managers. To reach their targets, businesses must meet criteria associated with CE, and stretch the targets year on year. In 2016, Philips launched a 5 year sustainability program that sought to generate 15% of revenues from circular solutions by 2020.

Philips has worked to create and scale value in its CE propositions. To drive the transition it established a dedicated CE unit directly linked to business development. The result of these efforts is that by 2021, CE has started to reach scale and is becoming embedded as a core element growth strategy, supported by a leadership program of over 1000 employees. This is integral to the company strategy in recognition that CE needs to be intrinsic in the end-to-end value chain, and embedded across all structures, processes and metrics. CE performance is now driven across three interlinked offers: hardware, software and digital solutions. The company is now at a stage where CE thinking and practice are central for driving new value proposition and value creation activities at varying scales and in different parts of the business. To monitor progress and fast-track development Philips is establishing monitoring and steering KPIs to further boost circularity. Sales revenue KPI has been updated from

20 to 25%, and Philips has embarked a series of new partnerships such as the Capital Equipment Coalition, and PACE: Platform for Accelerating the Circular Economy.

SBB (Schweizer Bundesbahn) is a fully integrated railway operator in Europe comprising an infrastructure, real-estate, cargo and passenger transport division, with a strong corporate centre providing many of the cross-functional support services. Given the substantial material base of the rail operator, the sustainability department commissioned a number of LCA diagnostic studies initially across large volume and critical material streams (e.g. ballast, concrete, steel) to comply with environmental reporting needs. With the emergence of CE principles in the wider discussion since 2013, the company's management commissioned focused, material-oriented and dedicated CE business model diagnostics for large material and product streams in the infrastructure division. Using cross-functional idea generation sessions for selected value streams, the rail operator detected substantial cost savings potential by improving reuse and recycling rates, with high potential to improve CO_2 emissions and providing substantial reductions in the emission of other pollutants.

To validate the full potential of CE beyond the original test cases, SBB commissioned material flow and CE diagnostics across all divisions and most relevant asset classes, ranging from track to trains, clothing, IT equipment, and food packaging, ultimately comprising all its stocks and material streams. Together with business partners, pilots were launched to co-create dedicated CE solutions ranging from closed-loop recycling of building components to opportunities scaling up refurbishment operations for high value asset classes and offering dedicated resale packages. The rail operator is now entering implementation at scale with the confirmation of the feasibility of economic and ecological benefits.

Recognising that further scaling of these successful pilots would require profound changes to the underlying processes and an alignment with the overall strategy, a dedicated strategy program was launched to complement existing ideas across all divisions and formulate the business rational. As a result, a dedicated Centre of Competence for CE was installed. This centre is currently driving a large number of piloting and scaling projects, which address underlying improvements for each of the building blocks from design, reverse logistics, business model innovations, and ensuring establishment of critical enablers, such as process definition, and improved financial reporting to account for residual value. To focus these activities the company has performed an internal mapping of key stakeholders to ensure buy-in into the planned embedding of CE initiatives in line with the corporate strategy.

Renault is a globally operating car and truck-manufacturer with a focus on long lasting and durable vehicles aimed for the mid-range consumer and commercial customer base. In the wake of the 2008 financial crisis, Renault recognized that the buying cycles of vehicle owners were becoming extended, leading to a drop in new sales. At the same time, demand for more repair and leasing-based services was increasing. Using this market discontinuity, Renault studied individual vehicles along the full value chain, including their LCA footprint using cross functional teams. It became apparent that prolongation of higher performance would hinge only on improving the remanufacturing of critical component assemblies (e.g. engines, gearboxes). Validation of these opportunities via business case modelling on the basis of mapping the full value chain of vehicles across their use phases confirmed the attractiveness of entering into these areas for remanufacturing.

As a result of the business model study, with mission-critical capabilities identified using CE maturity assessment, Renault repurposed a former factory to fully concentrate on refurbishment of engines and gearboxes. To secure sufficient supply, Renault partnered with suppliers along the vehicle value chain and jointly invested with end-of-use scrap yard operators to build a nationwide return system to ensure sufficient access to feedstock for its refurbishment operations. Systematic screening along the full range of vehicles and services using co-creation workshops with business partners resulted in the conviction that the discontinuity of moving away from internal combustion engines to electric vehicles (EV) would create a systemic disruption, allowing the installation of CE principles throughout the new business model.

Renault is now aiming to operate a fully CE-inspired system for its new EV platform, which explicitly takes into consideration end-of-first-use valorization of the most expensive components (i.e. batteries) for secondary use as energy storage devices, offering high-yield revalorization of precious materials with business partners. To manage, trace and steer this CE-based new business model system, Renault has formed a dedicated unit and put location-specific, KPI tracking of material, component and product data across different use phases by leveraging their industrial transformation toolbox.

Ricoh is the world's leading document management and print business. Operating largely in the business-to-business sphere, the heart of their business model is design and manufacture of high quality imaging and print products, combined with a product-service business model (i.e. print-per-page) providing high quality customer service. The Ricoh 'Comet circle' has been a guiding framework for circular economy value retention and recovery since 1994.

Large-scale refurbishment and resale of printing equipment at the end of contract life grew steadily through the 1990 and early 2000s. Here the business began to invest in dedicated facilities and build a team focused on higher value remanufacturing, towards reengineering print machines and toner cartridges to a standard equivalent, and sometimes better, than a new machine. Enabled by a new British Standard (BS8887-220) that set out clearly the definition and quality assurance requirements to differentiate remanufactured from refurbished, the company attracted new price conscious and environmentally aware customers. LCA modelling showed the significant reduction in material footprint of each machine, and the lower cost of production versus new, which allowed machines to be sold at a discount under a dedicated green-line brand.

As the concept grew, the European side of the business had to address a range of challenges, notably the complexity of working across multiple territories, and the scaling up of a cost-effective reverse logistics network. This involved setting up a dedicated '3 R Unit' to co-ordinate activities across the supply chain, distribution network and field engineers, who provide the in-house servicing of machines. The alignment of the value creation and capture process is an asset value cascade methodology, allowing any machine or product in the field to be returned at end of contract and allocated to a specific value retention or recovery channel (i.e. remanufacture, repair, refurbishment, cannibalization or recycling). This cascade method is continually iterated to maximize profit pools, respond to changing customer demand or external competition and price changes.

The European manufacturing business by 2010 had scaled to around 10% of total Ricoh sales of new equipment: core to Ricoh's 2050 vision to reduce total material footprint by 80%. Maintaining a viable remanufacturing business during the economic downturn and rapid technological innovation in print and software required constant modelling and calibration of end-to-end system value metrics, horizontal diffusion of new practices across the global business, and balancing the economics of investment in manufacturing of new products in the Far East with CE opportunities in Europe.

Steelcase is a leading manufacturer and distributor of premium office furniture solutions that operates globally. It discovered the benefits of creating lasting and sustainable office furniture by embedding design-for-disassembly in all its products and has since scaled up its CE program. Steelcase recognized that office furniture would last significantly longer than the typical first usage period, which was frequently dictated by developments in the configuration and growth of a business requiring frequent changes to office space layout. As a result, residual usage periods exceeded first time installation. On the basis of comprehensive LCA and value stream mapping of its products, the company identified substantial value recapture potential of deployed stocks. During cross-functional idea generation sessions, Steelcase derived a list of potential interventions, ranging from further design improvements, to required reverse logistics operations to intercept valuable stocks from entering the grey market as direct competition for new-builds, with options to harvest residual value via non-sales, asset-based service offerings such as renting of repossessed equipment.

Based on business modelling analytics and successful experimentation in the field, Steelcase conducted a comprehensive maturity assessment along its value chain to detect capability gaps. The company engaged with business partners around well-defined pilots to refine local market specific CE solutions. As a result, Steelcase began to scale up dedicated end-of-use operations in European markets, with stringent take-back requirements for furniture (e.g. Extended Producer Responsibility 'ERP' schemes).

To ensure strategic fit and sufficient cross-functional quality, Steelcase introduced a new business development stage gate process to screen and validate CE interventions. KPI monitoring has been put in place and explicit internal management of stakeholders maintained, meaning CE innovations are embedded into existing line functions and geographic sales organizations, to ensure integration with existing business objectives. Unlike many other operations-driven businesses, Steelcase considered CE service options as a means to close the full journey of their products around their customer needs. This includes the explicit management of furniture exchange and dealing with reverse options during reconfiguration of office layout and usage, and not as a threat to replace linear with circular operations which could cannibalize sales.

5. Discussion and analysis

The five cases represent high value, materially intensive supply chain and operations sectors who are finding new forms of value creation and capture from CE. Their transformational journeys have different start points and periods of acceleration and consolidation, but in each case it is possible to generalize in the form of a signature project, product case study or value retention story such as remanufacturing that provides the initial catalyst for strategic growth and innovation. Our depiction of how the companies have made a successful transformation to CE across three different stages is based on generalizations of how opportunities were initially exploited, and challenges tackled and overcome, with implications for OSCM discussed below.

At the outset of implementation, the concept of CE and its implications are often not well understood, such as traditional associations of recycling as a non-value adding activity (Guide, Harrison, and Van Wassenhove 2003). As the cases have shown however, there are tools that in combination provide the approach and organizational design to translate the CE building blocks of value creation and capture into practical reality at scale (Table 2). This is important because our contribution does not relate to the development of new tools *per se*, but the flexibility derived from a toolbox approach, supported by CE principles where specific combinations can be applied to any business situation. Moreover, the transformational process is not based on optimizing cost or improving the efficiency of specific functions in isolation but requires an understanding of the entire value chain and mechanisms for internal and cross value chain collaboration and value distribution. This represents a departure from previous recycling initiatives, where solutions were often bolted on as an afterthought to existing operations as a convenient workaround, without changing the underlying linearity of the business (Spicer and Johnson 2004). In several of our cases, SBB and Steelcase for example, there was the risk of stalling early on due to ingrained linear operations and patterns of investment, with a particular resistance from technical functions. It was a business case simulation run by Steelcase that tipped the balance towards convincing executives of the viability of CE. The business logic of CE often lacks integration with current company culture, resulting in tension with short-term linear targets. Overcoming such

Table 2. CE tools, practice and transforming operations by case.

	Identify				Initiate					Implement				
	Tools & practice		Transforming operations		Tools & practice			Transforming operations		Tools & practice		Transforming operations		
	Value stream mapping	Life cycle analysis	Cross functional idea generation workshops	Business model development workshops	CE maturity assessment	Circular product & service design	Business model simulation	Business partner co-creation workshops	Systematic screening of CE building blocks	Trans-formation toolbox	Agile IT & process development	Circular KPI development & monitoring	Stakeholder management & analysis framework	Dedicated CE unit
Philips	×	×	×	×		×	×	×	×	×	×	×	×	×
SBB	×	×	×	×	×	×	×	×	×		×	×	×	×
Renault	×	×	×	×		×	×		×	×	×	×	×	
Ricoh	×		×	×		×	×	×	×	×	×	×	×	
Steelcase	×		×	×	×	×	×		×	×	×	×	×	×

resistance through internal cross-functional activities such as workshops and value mapping are vital for commitment to CE investment. Once support is gained, CE implementation is a not a process of incremental change because it involves a transformation of operations and supply chain, requiring radical innovation to value creation in areas ranging from product strategy, manufacturing, and exploring how to reconnect with business partners and suppliers and their deep embedding into operational supply chain management (Kivimaa and Kern 2016).

Moving beyond addressing cost, efficiency, or operational components of closed loop systems in isolation therefore requires rethinking the transformation process as whole system innovation, whose architecture can be reconfigured according to specific operating conditions (Henderson 2021). Our findings show that in most cases, OSCM functions were at the core of these transformations as they possess the skills and transverse perspective to coordinate different needs of customers, suppliers, and the commercial aspects of the company. For example, Ricoh realized the potential for refurbished goods as a dedicated product line with its own revenue stream. Philips generated refurbishment scenarios by analysing new value capture options such as product leasing and what changes in product design might be needed to improve profitability. Hence, our CE implementation framework (Figure 4) is presented as a culmination of our findings and heuristic for business transformation with implications for OSCM. We argue models of CE implementation must go beyond descriptions of drivers and barriers or presented as a one-size-fits-all approach (Amir et al. 2022; Lu, Zhao, and Liu 2022), and instead capable of reconfiguration according to business sector and circumstance. Figure 4 synthesizes the role and relevance of different tools and operations across the phases, and is relatable to the key building blocks described earlier (EMF 2013, 2014, Zils et al. 2022):

The *identify opportunities* phase uses variants of value stream mapping and LCA facilitated via cross-functional and business model development workshops to provide systematic analysis of opportunities, options for early adoption, and shared understanding of CE. For example, LCA can be used to detect the areas of greatest value leakage in products and services, or most significant environmental impacts to be designed out and positive impacts designed in. In Philips and Steelcase, this stage can be focussed on specific products or product categories, but then enlarged to cover all new products. These tools help overcome the tendency to generate large number of ideas which are then difficult to co-ordinate or place within a long-term systemic value creation program. It also connects key functional teams critical to driving CE innovation. Business model simulation is an important tool which spans all three phases but is especially important in this initial phase to ensure functional teams don't lose sight of the overall CE framework, and the interconnectedness of the four building blocks.

Initiate pilots & proof of concept phase uses dedicated product and service design tools to develop the value creation process. Here, resources, materials and LCA components of products and services meet the customer value

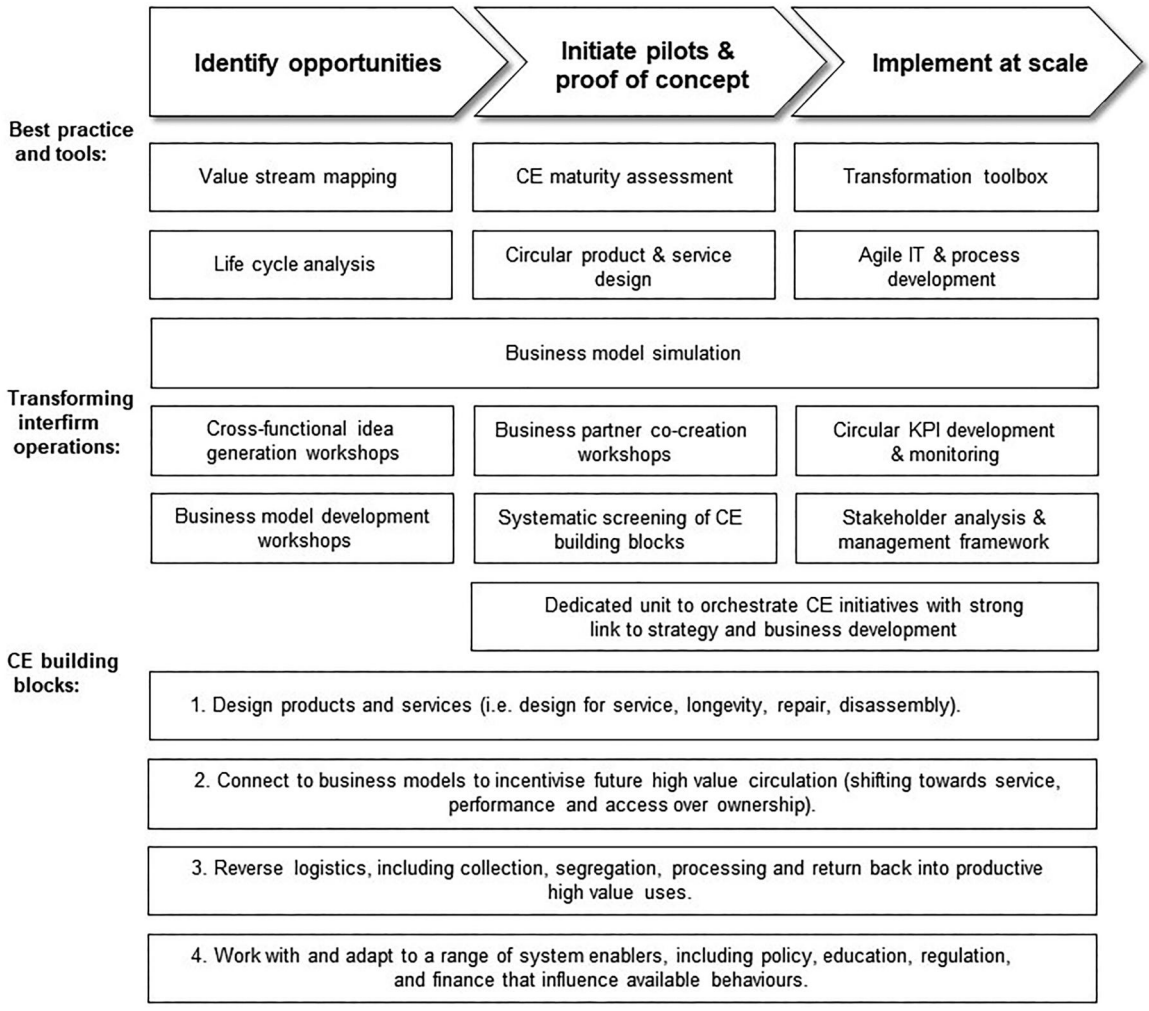

Figure 4. Framework for CE pathways to business transformation.

proposition and additional value drivers. The four building blocks are screened and embedded systemically within a business model simulation exercise. At this stage, a business often finds it is lacking or missing some key capabilities and competencies, such as deep understanding of CE principles but broad leadership and change management skills to drive the process. CE maturity assessment can map the capacity and capability gap and put in place an internal transformational programme. The nature of CE requires the need for whole supply chain interaction, but in a different way to traditional supply chain partnering. Collaboration in CE involves potentially new forms of value creation and sharing; hence it is essential to bring in existing and new partners. In Renault's case, this involved an entirely new CE value ecosystem with many new suppliers and subsidiaries. These arrangements involve various forms of business partnering workshops. In parallel with more linear operations, as CE becomes an accepted business logic, there is the need to set up dedicated units to co-ordinate and orchestrate overall strategy. In our examples, these units differ from traditional sustainability units by being closely aligned to the business development unit as a profit rather than a cost centre.

As the *implementation at scale* strategy matures, a wider set of tools are required to manage the complexity and inevitable trade-offs that occur to navigate the transformation alongside the linear business. As the concurrently active CE initiatives increase, the number of involved parties and reporting requirements start to raise significantly, where it is important to deploy dedicated program management instruments (i.e. toolbox), as well as putting dedicated staff in place to build and pool knowledge to manage large-scale transformations which often cut across different business units. In the case of the rail operator SBB, the pooling took place in a dedicated cross-divisional Centre of Competence with direct links to the top management and the business development function to ensure that emerging trade-offs can be quickly resolved in dialogue with the different corporate functions and divisional interests. To embed these changes, the company engaged in an agile IT-based process initiative and explicitly modelled reverse options into the company's workflow and documentation process. This ensured that operators in the field could detect and use circular reverse value chain options as fully operationally supported standard processes, for example registering refurbished products back into the inventory system for redeployment as good-as-new. Digitization also plays a core role in this transformation process, both in terms of embedded in product-service business models, managing

assets, and co-ordinating information flow across the value chain. In the case of Ricoh, the success of their CE value asset management system required real-time information on location, condition, contract duration and maintenance of the product before its return for remanufacturing. This requires agile IT and process development, ensuring the CE activities are embedded into the mainstream business systems. Thus, third-party resource enterprise tools play an increasingly important role in the co-ordination effort. The design of CE specific targets and KPIs is a characteristic of the most advanced business in CE implementation, used to communicate financial benefits and performance, incentivize sales teams, and shift internal culture and manage relationships with external stakeholders.

Our framework presents CE implementation as a transformation whose building blocks or architecture is reconfigurable to suit specific company challenges, supporting the idea of CE as a dynamic, systems orientated innovation (Bag, Gupta, and Foropon 2019; Henderson 2021). The workshops with practitioners revealed that these tools are never deployed in a neat, linear, or progressive fashion, but evolve iteratively as pathways across varying timescales and sequencing (Figure 5). While the pathways are case specific in terms of the combination of tools and timings around decision points and partner involvement, further research could reveal patterns in their configuration according to factors such as business sector or firm size. Our wider experience of working with companies from the 'inside out' through our masterclass, suggests a structured approach towards tools and processes are the hallmark of companies that have managed to move past simple notions of change or cost reduction, to CE transformation as a viable proposition that is first initiated and supported through scaled implementation. Following the principle of our framework therefore, each company's transition will not be the same, but may adopt some, or all, of the building block architecture. Only by connecting and understanding the process, challenges, and practical approaches to CE systemically will companies configure their own OSCM pathway to capture the full value creation opportunity towards business transformation.

6. Conclusion

In this paper we tackle the question of how does taking an operations & supply chain management approach enable transformation of circular economy implementation. Operations resides at the core of any business paradigm and for decades has driven the engine of mass production and consumption, which must now change (de Sousa Jabbour et al. 2018, Jabbour et al. 2019). We apply CE in the context of operations practice (Kalmykova, Sadagopan, and Rosado 2018; Mishra, Hopkinson, and Tidridge 2018), starting with understanding how value chains in the traditional linear sense involve adding value at each step of the process, while optimizing, reducing, or reconfiguring costs along the chain. Yet CE is more than about cost, recycling, or reverse logistics in isolation (Guide, Harrison, and Van Wassenhove 2003), but represents a new system for value capture delivered through remanufacture, servicisation and product life extension, decarburization & dematerialization, digitization, and cascading product: all of which maintains components and materials across value chains for the longest period at the highest value (EMF 2013, 2014). Our paper therefore represents a synthesis between OSCM and CE. Whilst OSCM provides many long-standing tools which can be applied in the framework, it is circular economy that provides the underlying principles and foundation which supports the reconfigurable system architecture used in business transformation.

Our theoretical contribution is to present the CE implementation challenge as a complex pathway consisting of building blocks whose transformation hallmarks are reflected in architectural business change, dynamic boundary spanning and systemic innovation (Bag, Gupta, and Foropon 2019). We reject the idea of change towards CE involving one part of the system as in remanufacturing or recycling,

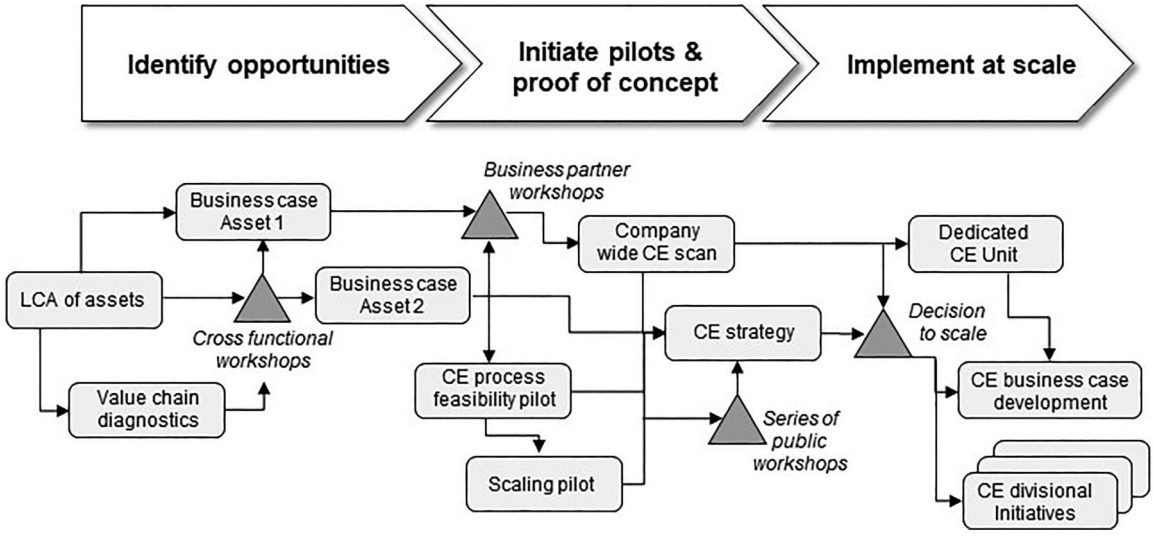

Figure 5. Example of a CE pathway.

instead advocating a new operating principle using a reconfigurable architecture approach that is adaptable to suit multiple business applications (Henderson 2021). Our research goes beyond exploration of traditional operations metrics such as waste and cost reduction, instead highlighting the opportunities in resource productivity for firms presented by value recapture and creation (Dey et al. 2020). Our findings illustrate that value recapture and creation require a radical diversion from the usual path of business and often involve difficult managerial decisions and trade-offs. CE implementation therefore is a not a process of incremental change, but requires a transformation of the company's approach to operations, requiring radical innovation to reconnect value creation across product strategy, manufacturing, and supply chain partners (Kivimaa and Kern 2016). Hence, while current literature on CE implementation includes drivers, barriers, and one-size-fits-all models, we argue a more flexible and embedded approach is required from OSCM, where our CE framework of building block architecture can be reconfigured and adapted to suit specific company contexts and challenges.

For the practitioner, our contribution is represented by the framework in Figure 4 as a guide to how and where OSCM and CE practices intersect, and the stages of implementation which, when combined together at system or supply chain level can realize a business transformation. We explore the dynamics of CE implementation across companies that place the experience of the firm in the context of a system level challenge. OSCM has a long-standing relevance to CE but is missing the bigger picture in terms of what we term building blocks. Hence, the tools and approaches we identify and describe are not new, but do represent a combination of methods, with some revitalized to drive the CE business transformation. Our practical recommendations for business on the linear to CE transition path include:

- Translate your sector or business into the CE butterfly diagram, identify its position in the value chain and core business activities, as the application of CE will differ in each case. If your primary material, component, and product flows are technical materials or products of service such as the five cases presented here, this will point towards different CE design, business model and reverse logistics interventions. If you are a cross-cutting boundary spanning service company (e.g. data, technology, finance, marketing), you need to be clear which sectors or value chains present the most opportunity to intervene and collaborate;
- Be clear about your ambition, levels of internal support, and outcomes at each stage of the process of transformation. Fully understand the principles of CE to avoid it becoming another recycling initiative or a potentially regrettable material substitution (e.g. moving from single use synthetic plastics, to single use non-biodegradable bioplastics);
- Start with a focus on a relevant signature product or service area by implementing CE to create early proof-points and the licence to scale across the company. Look for pilots and initiatives that may already be taking place, that align with CE, and find out what has been achieved, key successes, learning points and failures which can help avoid repeating mistakes.
- Undertake a baseline material flow as part of a comprehensive and systematic value leakage mapping. From this, evaluate whether you measure, quantify and visually represent the stocks and flows of those materials, components and products that you control, as well as the overall value chain of interest. If not, then build up rough orders of magnitude and work with the best data you have available. This mapping exercise starts the search for ideas for value creation opportunity and rapid scoping of a potential positive business case. The process of visual representation also helps tell a strong and coherent story to different internal audiences, keeps data collection and analysis manageable, and avoids becoming overwhelmed with complexity and too many ideas, which can create confusion and loss of momentum;
- Involve cross-functional teams from the start of the opportunity identification right to the scaling of the implementation process. This creates and maintains the need for whole system thinking and ensures all key building blocks (i.e. design, business model, reverse logistics, and system enablers) for successful CE transformations are designed into the process at the outset. Missing out one or more of these building blocks is likely to stall progress and limit the overall value capture potential;
- Be inspired by other companies but focus on your company and supply chain specific opportunities to develop your own pathway to CE. Identify key capabilities and competencies that will be required and where there are knowledge or skills gaps, and create an internal training and skills development process or look for additional external support;
- Accept CE implementation as a radical transformation requiring investment and top-management buy-in over time. Continuity of budgets and embedding the change process in KPIs and metric frameworks will help to buffer changes in leadership and management teams;
- Engage early with key business partners & suppliers along your operational supply and value chains to ensure continued boundary spanning collaboration and innovation both upstream and downstream;
- Accompany the transformation with CE financial, environmental, and social metrics and indicators measures around value creation and recapture to guide agile decision making and firm datasets for potentially tough trade-off decisions in the scaling phase, such as potential cannibalization of the linear business.

The limitation of our research is reflected in the manufacturing orientated nature of the companies selected (although four of the cases: Phillips, Ricoh, Renault and Steelcase also have a strong service orientation), where more focus on service-based organizations could provide an

interesting comparison in future. Further research includes exploring the paradox that exists between linear and circular operations where – despite their discontinuities – the transition to CE requires companies to run both in tandem before circular capacity increases. The same traditional production methods that ultimately will be phased out are also the source of funding which supports CE programs and initiatives across the company. Managers engaged in CE implementation therefore need to be aware of the impact of human factors relating to changes in functional orientation as well as technical challenges during the linear-circular paradigm shift. It is expected in time that other tools and processes will be developed to respond to the rapidly changing policy landscape, such as digital material passports, or continuing concerns about commodities and global supply chain risk. The common unit of analysis in all successful CE implementations at scale is the value chain and the ability to shift the focus of value (and loss of value) from firm centric, to boundary spanning systems. OSCM has a vital role to play in developing the science and practice of future CE system design and overcoming the many barriers and research challenges during the multi-phase transformation of our economies.

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