Article:

Okorie, O., Charnley, F., Russell, J. et al. (2021) Circular business models in high value manufacturing: Five industry cases to bridge theory and practice. Business Strategy and the Environment, 30 (4). pp. 1780-1802. ISSN: 0964-4733

https://doi.org/10.1002/bse.2715

Received: 30 June 2020 | Revised: 24 November 2020 | Accepted: 7 December 2020

DOI: 10.1002/bse.2715

RESEARCH ARTICLE

Business Strategy and the Environment WILEY

Circular business models in high value manufacturing: Five industry cases to bridge theory and practice

Okechukwu Okorie[1] | Fiona Charnley[1] | Jennifer Russell[2] | Ashutosh Tiwari[3] | Mariale Moreno[1]

[1]Exeter Centre for the Circular Economy, Science, Innovation, Technology and Entrepreneurship Department, Exeter Business School, University of Exeter, Exeter, UK

[2]Department of Sustainable Biomaterials, Virginia Polytechnic Institute and State University, Blacksburg, Virginia, USA

[3]Department of Automatic Control and Systems Engineering, University of Sheffield, Sheffield, UK

Correspondence
Okechukwu Okorie, Exeter Centre for the Circular Economy, Exeter Business School, Streatham Court, University of Exeter, Rennes Drive, Exeter, EX4 4PU, UK.
Email: o.s.okorie@exeter.ac.uk

Funding information
Engineering and Physical Sciences Research Council, Grant/Award Number: EP/R032041/1; Circular4.0: Data Driven Intelligence for a Circular Economy

Abstract

The transition to a circular economy (CE) requires companies to evaluate their resource flows, supply chains, and business models and to question the ways in which value is created. In the high value manufacturing (HVM) sector, this evaluation is critical, as HVM enables value in nonconventional forms, beyond profit, including unique production processes, brand recognition, rapid delivery times, and highly customized services. We investigate the role of value, cost, and other factors of influence in the selection of a circular business model (CBM) for HVM. Explored through five case studies using a qualitative evaluation of circularity, we then contribute to the emerging field of CBMs by modifying the CBM canvas that can capture the nontraditional value, traditional value, cost, and other influencing factors enabled via CBM adoption in HVM. Finally, the important role of digital technologies for incentivizing and enabling CBM adoption, is clarified.

KEYWORDS

circular business models, circular economy, digital technology, factors of influence, high value manufacturing, value creation

1 | INTRODUCTION

Circular business models (CBMs) have received increasing attention from industry practitioners and academic researchers alike (as evidenced on SCOPUS and Web of Science databases), as they constitute a key enabler in the advancement of circular economy (CE) research as a way for the industry to profitably achieve a radical increase in resource productivity (Linder & Williander, 2017). In addition, CBMs are being proposed to address economic challenges originating from the dominant linear economic model (Circle Economy, 2018; Jackson, 2009; Sachs, 2015). These risks include volatile market prices, problematic ownership structures, and the availability of resources. Other issues associated with the linear economic model include environmental impacts (e.g., water, air and soil pollution, biodiversity, and land resource depletion) (Jackson, 2009; Meadows, Randers, & Meadows, 2004; Rockström et al., 2009), and societal impacts (e.g., soaring unemployment and broadening inequalities) (Prahalad, 2004). Thus, the CE, while not entirely new (Geissdoerfer, Savaget, Bocken, & Hultink, 2017), has seen a significant increase in research in recent years (Okorie et al., 2018).

The CE concept proposes a circular system where the value of products, materials, and resources is retained in the economy for as long as possible (Merli, Preziosi, & Acampora, 2018). Although *value* is a key theme within CE literature, *value* is also an important theme within business models (BMs) literature (De Angelis, 2018).

Several authors base their definitions and frameworks for BMs on the concept of value (Amit, Massa, & Zott, 2011; Osterwalder & Pigneur, 2010; Richardson, 2008; Teece, 2010). For instance, Osterwalder and Pigneur (2010) argue a BM to be the rationale of how an organization creates, delivers, and captures value, while Amit, Massa, and Zott (2011) definition can be summarized as the means to create and capture value. When placed within the context of a CE, De Angelis (2018) argues that CBM implementation will affect all the elements of the framework.

Although there have been several studies on CBMs in literature, none have clearly positioned the adoption of CBMs within manufacturing. Manufacturing, including high value manufacturing (hereafter "HVM") (MacBryde, Paton, & Mendibil, 2011), plays a central role in the realization of CE, and yet CBM research by Linder and Williander (2017, p. 186) noted, "… *the adoption of CBM within manufacturing is not widespread* …" (Linder & Williander, 2017). In the absence of a clear framework for transforming existing manufacturing BMs into CBMs, organizations willing to become circular must still figure out how to adapt their existing BMs or create new ones (Urbinati, Chiaroni, & Chiesa, 2017). Further, given that the risk of pursuing CBMs is typically tied to perceptions of potential high uncertainty and unknown associated costs, business leaders may be reluctant to arbitrarily implement CBMs (Linder & Williander, 2017; Mendoza, Gallego-Schmid, & Azapagic, 2019).

We seek to test and evaluate the relationship and alignment of CBM theory with actual CBM adoption and practice in the HVM sector. Drawing from the work by Jensen, Prendeville, Bocken, and Peck (2019) and Bocken, Schuit, and Kraaijenhagen (2018), we evaluate five HVM industry cases to explore the value, cost component, and factors of influence (FOIs) elements that most significantly affect the CBM that is ultimately selected by organizations seeking to engage in CE. In doing this, we identify whether and how tools such as the CBM canvas can be refined to support and facilitate CBM adoption specifically for underrepresented HVM organizations. Through these cases, we clarify and extend the CBM literature (Linder & Williander, 2017; MacBryde, Paton, & Mendibil, 2011), by identifying the primary barriers to adoption of CBMs by manufacturers and HVMs. Further, we discuss the role and opportunity for a modified circular business model canvas (CBMC) framework (Osterwalder & Pigneur, 2010) to enable barriers mitigation and provide structure for CBM adoption by manufacturers and HVMs.

The rest of the paper is structured as follows: Section 2 presents a review of relevant literature in which the key concepts of CBMs, and CBM selection, are identified. Section 3 describes the case study companies, including characteristics and rationale for inclusion in our study. Section 4 describes the rationale for using CBMs as a conceptual classification matrix and case study results. Section 5 presents a discussion of the findings and insights from both the literature and industry case studies, as well as limitations of this work. Finally, in Section 6, the implications of our research, and future research paths, are highlighted.

2 | LITERATURE REVIEW

The keywords relevant to this research ("Circular Business Models," "high value manufacturing," "Cost" and "Value"[1]) have been described as lacking an accepted definition (Livesey, 2006; Sminia, Ates, Paton, & Smith, 2018) and as lacking a common understanding of the concept (Nußholz, 2017). As an example of differing terminology, what is referred to as "high value manufacturing" in UK policy, is, in the United States, South Korea, and European policy referred to as "advanced manufacturing partnership," "manufacturing 3.0," and "factories of the future," respectively. The same challenge exists for the term "circular business models" (CBMs), which is often used interchangeably with "sustainable business models" and "business models for sustainability" (cf. Bocken, Short, Rana, & Evans, 2013; Bocken, Short, Rana, & Evans, 2014; Bocken, Rana, & Short, 2015; Boons, Montalvo, Quist, & Wagner, 2013; Lüdeke-Freund & Boons, 2013). Of key interest here is that CBMs possess qualities and characteristics that are distinct from BMs that are simply oriented toward "sustainability" outcomes (Bocken, Rana, & Short, 2015). Our review adopts a similar approach to that by Nußholz (2017), with a search strategy limited to academic studies with explicit reference to the concept of "circular business model" (Table 1).

2.1 | CBMs in HVM

This section examines the question, "*what are CBMs and how are they relevant for HVM?*" According to Björkdahl (2009) and Osterwalder and Pigneur (2010), the term *business model* (BM) refers to the conceptual logic of how a firm creates and appropriates economic value across three value dimensions: (1) value proposition, (2) value creation and delivery, and (3) value capture. Several detailed ontological frameworks exist for BMs, often organized according to the key activities and resources controlled by the firm, customer needs and segments, cost structure, and revenue model (Osterwalder, 2004). During the BM innovation process, an iterative approach is used by firms to devise, refine, test, and realize new ways to create and appropriate value after studying the relevant market conditions (Blank, 2005; McGrath, 2010) (Govindarajan & Trimble, 2010; Ries, 2011; Sarasvathy, 2001). Once key assumptions have been validated, firms typically proceed to heavily invest in scaling the innovative model (Linder & Williander, 2017).

In recent years, and through this iterative process, the related concept of "circular" BMs (hereafter CBMs) has emerged (De Angelis, 2016) as a BM innovation in the context of the CE. This paper adopts the definition of CBM from (Linder & Williander, 2017, p. 183), as a "… *business model in which the conceptual logic for value creation is based on utilizing economic value retained in products after*

[1]Authors utilized SCOPUS and Web of Science for review of existing literature. Using "Circular Business Models" as search words, 62 articles were found for the period between 2014 and 2018 on SCOPUS. While there were 4 articles for 2018, there were 17 articles for 2017 and 40 articles for 2018. Web of Science showed similar increase. The search was performed in October 2019.

TABLE 1 Literature search criteria and rationale

Selection criteria	Rationale for selection
Units of analysis	Publications were sourced from highly ranked, peer-reviewed journals and were published in the research areas of circular economy, CE in manufacturing, high value manufacturing, and circular business models.
Type of analysis	Qualitative
Period of analysis	No specific time period was defined
Search sources	Journals listed in ABS 2018 list. A significant number of non-ABS listed journals were included. Focus was on Scopus; however, Web of Science, Elsevier, Emerald, and Science Direct database were used for secondary journal search.
Keywords used for searches	Authors have employed the following terms to identify the articles for appraisal in this study: Circular business model; high value manufacturing; "high value manufacturing" and "cost"; "circular business model" and "value"; "circular business model" and "cost"; "circular business model" and "high value manufacturing."
Total number of articles considered in this study	323 articles were included.

use in production of new offerings." In a CE, the concept of value is distinguished and differentiated on the basis of the inherent material and economic value that is retained in products through life extension and other CE activities, enabled by CBMs. In other words, CBM literature suggests that central motives and dimensions of organizations making the transition to CBMs involve moving beyond the conventional model, expending on stakeholders, flows, influence, and conceptions of what value and cost actually consist of.

CE is described as an industrial system "*… that is restorative or regenerative by intention and design. It replaces the 'end-of-life' concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse, and aims for the elimination of waste through the superior design of materials, products, systems, and, within this, business models*" (Ellen MacArthur Foundation, 2013, p. 7). Accordingly, CBMs are derived from the main principles and elements of CE (De Angelis, 2018; Mathews & Tan, 2011; Urbinati, Chiaroni, & Chiesa, 2017; S. Yang & Feng, 2008) and are often described via the ReSOLVE framework (Ellen MacArthur Foundation, 2013, 2015), which clarifies the roles of Regenerate, Share, Optimize, Loop, Virtualize, Exchange, as CBM options. Application of the ReSOLVE framework to contemporary BMs requires consideration of circular value creation (Lewandowski, 2016; Van Renswoude, Wolde, & Joustra, 2015), normative requirements for BMs (Lüdeke-Freund & Boons, 2013), and areas of value proposition integration (Laubscher & Marinelli, 2014) as other important constituent elements of CBMs.

Given increasing concerns regarding materials scarcity, materials market uncertainties, and regulatory trends grounded in CE structures, CBMs present an increasingly important option for HVMs to consider. Depending on the firm, CBMs utilize configurations intended to optimize product aftermarkets, ownership models, and/or shared-use opportunities that can facilitate the implementation of a circular strategy while also capitalizing on the associated value that is created (Nußholz, 2017). Thus, the successful transition to a CE requires companies, in general, to make systemic changes in the way that they create, deliver, and capture value through their business activities (Pieroni, Pigosso, & McAloone, 2018). Specifically, the evolving CE and CBM landscape requires that manufacturers shift from a *firm-centric* to a *network-centric* operational logic (Bocken, de Pauw, Bakker, & van der Grinten, 2016; Ranta, Aarikka-Stenroos, & Mäkinen, 2018).

CBMs take a variety of formats, some of which are included in our HVM case studies, including but not limited to product life extension (De los Ríos & Charnley, 2015; Nußholz, 2017; Ranta, Aarikka-Stenroos, & Mäkinen, 2018); recycle, reduce, and reuse (3Rs) (Ranta, Aarikka-Stenroos, & Mäkinen, 2018); product-service systems (PSS) (De los Ríos & Charnley, 2015; Rosa, Sassanelli, & Terzi, 2019a; Upadhyay, Akter, Adams, Kumar, & Varma, 2019); next-life sales, product modification and renovation, recycling, and consumption collaboration (Upadhyay, Akter, Adams, Kumar, & Varma, 2019); access, performance, and hybrid models (Nußholz, 2017); slowing and closing of resource loops (Moreno, de los Rios, & Charnley, 2016); the ReSOLVE framework (Lewandowski, 2016); and sharing platforms (De los Ríos & Charnley, 2015).

In our review, we noted that BM literature tends to frame costs and value in very conventional ways that to not appropriately account for the system of stakeholders and flows that are enabled via CBMs. Further, utilizing the conventional structure of the BM canvas format inherently subjected innovative CBMs to "fit" within conventional priorities and perceptions. Iterations of the "CBM canvas" have predominately worked within the original BM framework; this may have served to overemphasize elements of perceived cost and risk associated with the CBM and to underemphasize the nonconventional value enabled and captured by the CBM. We argue that an adjusted canvas that is able to meaningfully account for these nonconventional forms of costs, value, and FOI is needed.

2.2 | Value creation in CBMs

This section examines the question, "*how is value understood in the context of BMs and CBMs, and what types of value are relevant for*

TABLE 2 Views on types of value from CBM adoption as captured in CBMs literature

Author, year	Paper	CBM	Value component	Sub-components
Ranta, Aarikka-Stenroos, and Mäkinen (2018)	Creating value in the circular economy: A structured multiple-case analysis of business models	Product life extension strategies: recycle, reuse, and reduce (3Rs)	Value proposition Value delivery Offering Value creation	Value prop: Customer, 3Rs closed loop program, and pricing, delivery Value delivery: Unique supply chain, experience, and distinct capabilities Offering: 3R capabilities as well as offering value-adding services to customers such as provision of cheaper materials Value creation: Technology/equipment and efficiency in capabilities
			Financial aspects	Financial aspects: Cost structure, revenue model, and sale of recyclables
Upadhyay, Akter, Adams, Kumar, and Varma (2019)	Investigating "circular business models" in the manufacturing and service sectors	PSS; next life sales; product modification and renovation; recycling; and consumption collaboration	Value proposition Value delivery Offering Value creation	Value prop: Customer segments, improved processes and technologies, and use of product's raw material as part of new production process Value delivery: Distinct capabilities and bespoke delivery of service to customers Offering: Product/service type. Value creation: Sustainable business practices and optimum use of resources
Nußholz (2017)	Circular business models: Defining a concept and framing an emerging research field	Product life extension; access and performance model; and hybrid model. (16 different CBMs were captured in the review	Value proposition Value creation and delivery Value capture	Value prop: Customer segments, customer relationships, and product/service offer and value proposition Value creation and delivery: Key partners, channels, key resources, and key activities Value capture: Cost structure and revenue streams
Moreno, de los Rios, and Charnley (2016)	A conceptual framework for circular design	CBM categorization: CBM focused on closing loops; PSS; CBMs to slow and close resource loops; and BMs for circular advantage	Value proposition Value delivery Offering Value creation Financial aspects	Paper focused on value within circular supplies, resource value, product life extension, and extension of product value and value from shared platforms

(Continues)

TABLE 2 (Continued)

Author, year	Paper	CBM	Value component	Sub-components
Rosa, Sassanelli, and Terzi (2019a)	Circular business models versus circular benefits: An assessment in the waste from electrical and electronic equipment sector	PSS	Economic value Environmental-industrial value Social-industrial value	Economic value: Reduction of overall costs, reducing business risks, opening new revenue streams, reducing product/process complexity, and improving competitive advantage Environmental value: Complying with environmental regulations, reducing environmental impacts, improving resource efficiency, and improving supply chain sustainability Social value: Enhancing reputation and brand value, reaching new markets and countries, improving health and safety in the workplace, and developing innovative skills and knowledge
Lewandowski (2016)	Designing the business models for circular economy-toward the conceptual framework	26 CBMs identified across the regenerate, share, optimize, loop, virtualize, and exchange classification criteria	Value propositions Channels Customer relationships Revenue streams Key resources offering, value creation, value delivery (key resources)	Value prop: Ownership based, traditional form of service to virtual form, cost savings, customer bespoke services, and incentives Channels: Virtualization of sales and communication channels Customer relationships: Products on order, customer engagement, and social-marketing strategies for customers Revenue streams: Pevenue generated from products, components, and from raw materials collected back Key resources: Input choices (related to changing input materials and products), substitution of resources with better performing materials, and direct virtualization of materials
De los Ríos and Charnley (2015)	Skills and capabilities for a sustainable and circular economy: The changing role of design	Product life extension, product as a service, and sharing platforms	Economic value Environmental value Social value	Economic value: Material efficiency, product life extension activities for goods, value from sharing platforms. Environmental value: Initiatives such as car sharing help reduce the number of cars on the road and consequently fewer CO_2 emissions from cars. Social value: CE models allow manufacturers to obtain benefits while reducing the amount of materials going to landfill.

Note: Based on Ranta, Aarikka-Stenroos, and Mäkinen (2018).

HVM?" Numerous studies have investigated value within conventional BMs;[2] however, few studies have investigated value in the context of CBMs. As summarized in Table 2, relevant research worth noting includes theoretical perspectives on CBM value creation (Lahti, Wincent, & Parida, 2018), the reconfiguring of CBM elements to capitalize on associated economic, customer, and environmental value (Nußholz, 2017), and a structured multiple explorative case analysis of BMs, in which the authors argue that value can be created through five different research propositions (Ranta, Aarikka-Stenroos, & Mäkinen, 2018).

As inferred in Table 2, the existing literature broadly approaches the concept of value within the context of BMs as *value proposition, value created, and delivered;* and *value captured*, across *economic, social,* and *environmental* dimensions. The addition of social and environmental dimensions to the original BM canvas developed by Osterwalder and Pigneur (2010) has been proposed as way to clarify and demonstrate a framework for the evolving and expanding dimensions and constructs that are needed within a CE (Joyce & Paquin, 2016). Notably, a detailed adaptation of the eco-canvas for CBMs has been proposed by Daou et al. (2020), adding new dimensions for social and environmental foresight and impact, as well as CBM innovation.

However, when organized around the principles of circularity, HVM firms in particular have been noted to extract *new* forms of value from the CBM that are not adequately captured by just the addition of social and environmental dimensions, that is, the use of Industry 4.0 tools within the construct of the ReSOLVE framework strategies (Huaccho Huatuco, Martinez, Burgess, & Shaw, 2019; Luiz et al., 2018; Sminia, Ates, Paton, & Smith, 2018).

As proposed by Bocken, Short, Rana, and Evans (2013), effective differentiation and competition of CBMs on the basis of cost require a fundamental rethinking of the value proposition, particularly for HVMs. This is because CBMs *expand* traditional stakeholders to include (1) customers, (2) investors and shareholders, (3) employees, (4) the environment, and (5) society. There is general consensus in the literature that the use of CBMs in the context of HVM creates opportunities for new forms of value (Livesey, 2006; Luiz et al., 2018; MacBryde, Paton, & Clegg, 2013; Martinez, Neely, Ren, & Smart, 2008; Sminia, Ates, Paton, & Smith, 2018; Upadhyay, Akter, Adams, Kumar, & Varma, 2019). Per Sminia et al. (2018, p.522): "… *there seems to be more to HVM than manufacturing firms simply exploiting their manufacturing core capabilities and pursuing a focus or differentiation strategy to avoid competition on price*" (Sminia, Ates, Paton, & Smith, 2018).

However, the current literature regarding original and adapted BM canvases does not adequately clarify what new forms of value may be possible for HVMs through the adoption of CBMs. As this has not been fully explored, we posit that the FOIs affecting design and implementation of CBMs, and the potential reframing of what constitutes value and cost for HVM CBMs, can also provide valuable insights for the continued evolution of CBM canvases.

[2]Using SCOPUS and keeping the time period as undefined, the authors found there to be 348 articles when "business models" and "value" were used as search words. The search words were restricted to article titles only.

2.3 | Costs factors associated with CBMs for HVMs

This section examines the question, "*what are the associated costs that high value manufacturers would face in adopting circular business models?*" BM ontology refers to "costs" and "cost structure" as an inclusive term generally defined as "all costs incurred to operate a business model" (Osterwalder et al., 2014). Given that costs are incurred as a necessity of value creation, delivery, and capture, there is a clear link between value and cost structure, suggesting that *costs and revenue are sub-components of the value capture mechanisms* (De Angelis, 2018; J. Vogtlander, Mestre, Scheepens, & Wever, 2013).

For example, Schröder, Falk, and Schmitt (2015) identify the cost factors in the adoption of additive manufacturing activities as including fixed costs (machine costs and software and hardware costs) and variable costs (production, material, labor, maintenance, and printing costs). Alternately, cost factors are identified and distinguished as "production costs" versus "product costs" for more general CBM adoption (Bressanelli, Perona, & Saccani, 2017; Giannetti, Risso, & Cinquini, 2016). A sample of cost factors identified from available literature is presented in Table 3.

From our sample of literature, it is clear that cost factors are clearly tied to the type of CBM being adopted. Thus, related to, and influencing CBM cost structure decisions, manufacturers face significant and distinct cost-related challenges that must be overcome for CBM adoption. Among these, the perceived higher investment risk, and therefore cost, of CBMs (Linder & Williander, 2017), the risk of sales cannibalization by circular product offerings (Daniel, Guide, & Li, 2010), the challenge of operating cost-efficient return flow and reverse logistics (Raci & Shankar, 2005), the inherent operational risks tied to inventory management and evolving asset ownership models (Kuo, Ma, Huang, Hu, & Huang, 2010; Linder & Williander, 2017), and tax disadvantages tied to labor-intensive CBM activities (Stahel, 2010). Often not addressed within the literature is the associated traditional and nontraditional value creation that accompanies these additional risks, uncertainties, and costs.

2.4 | Other FOIs

This section addresses the question "*what other factors, besides costs and value, should high value manufacturers consider before adopting any circular business model?*" According to Upadhyay, Akter, Adams, Kumar, and Varma (2019) and Huang, Tan, and Ding (2015), manufacturers are motivated to adopt CBMs for a variety of reasons that include but are not limited to increasing environmental regulations, access to reverse supply chains, utilization of product residuals at the end of product-life, and pressure from customers and suppliers. Unrelated to cost and traditional measures of value, these constitute FOIs that can motivate a decision for an HVM to adopt a CBM and affect the design of the CBM. In some cases, CBM innovation and adoption may present a pathway to competitive advantage for a firm, if the CBM is distinctly differentiated and difficult to replicate (Teece, 2010). However, despite their relevance

TABLE 3 Views on types of cost from CBM adoption as captured in CBMs literature

Author, year	Paper	CBM	Industry	Cost component
Schröder, Falk, and Schmitt (2015)	Evaluation of cost structures of additive manufacturing processes using a new business model	Product service system	Additive manufacturing	Cost of machine, production cost, material costs, labor costs, maintenance, software, hardware, and printing
J. G. Vogtlander, Scheepens, Bocken, and Peck (2017)	Combined analyses of costs, market value and eco-costs in circular business models: Eco-efficient value creation in remanufacturing	Remanufacturing is identified as a CBM, product service system.	Remanufacturing for mainstream consumer markets	Eco-efficient value creation method (J. Vogtlander, Mestre, Scheepens, & Wever, 2013) is used to identify "Eco-costs[a]," a cost component that expresses the amount of environmental burden of a product on the basis of prevention of that burden. Other costs identified include R&D costs, marketing costs, and production costs.
Lee, Suckling, Lilley, and Wilson (2016)	Reshaping the washing machine industry through circular economy and product-service system business models	Product service system	Manufacturing (washing machine manufacturing)	Material cost and connected inventory costs
Giannetti, Risso, and Cinquini (2016)	Managing costs by business model: issues emerging from the case of E-Car	SDL, where goods are seen as merely a means or delivery mechanism for service provision	E-car industry	Cost structure, described as cost drivers. These includes cost of items (insurance premiums, maintenance, or materials); labor and over-head costs; scale and learning; and production costs
Susarla, Barua, and Whinston (2009)	A transaction cost perspective of the "software as a service" business model	"Software as a service," a variant of PSS	Computing/information technology	Adaptation and monitoring costs, described as transaction costs; contracts costs (haggling, dispute resolution, bargaining, and renegotiation); product costs

Note: Based on Ranta, Aarikka-Stenroos, and Mäkinen (2018).
Abbreviations: SDL = Service-dominant logic.
[a]Eco-costs have been introduced in the International Journal of LCA, which was last updated in 2012. Mathematically, it is defined as the sum of the "midpoints" (12 environmental and 5 social) (van der Velden & Vogtländer, 2017).

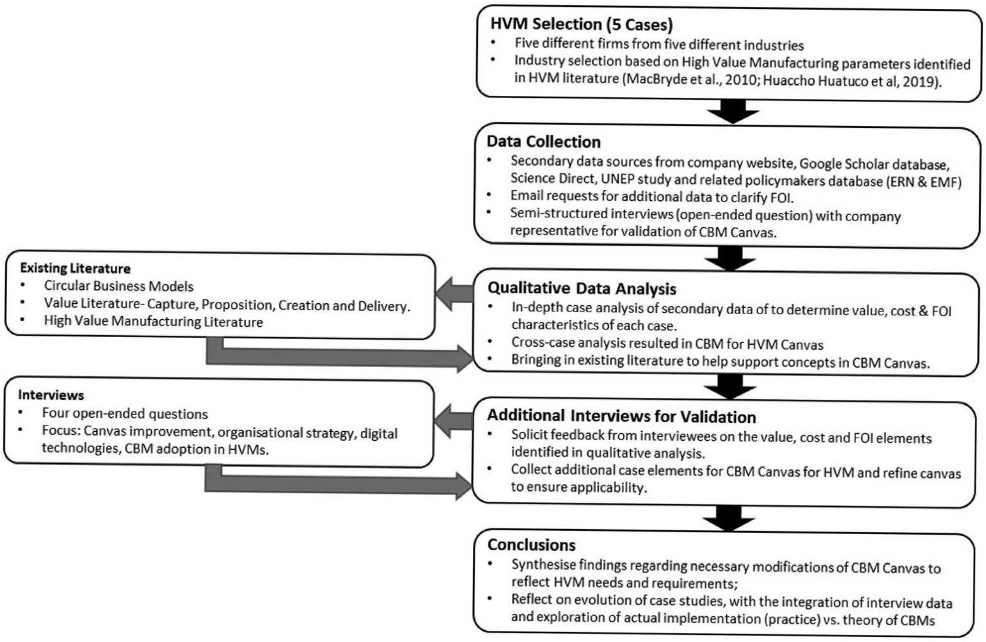

FIGURE 1 Methodological process for HVM case studies and synthesis. CBM = circular business model, FOI = factor of influence, HVM = high value manufacturing

and importance, our literature search revealed no papers that clearly identified and delineated the FOI for CBM adoption in HVM firms. At best, where identified, these factors are typically lumped together within general cost or value dimensions.

The rapid spread of CBMs as a business strategy has given rise to the need for standardized understanding of the contextual elements that are necessary for identifying and implementing CBM practices (Chen, Hung, & Ma, 2020). A clear framework for connecting CBM theory to CBM practice is following our review of existing literature, there is a clear need to establish relevant and common understanding of value and cost factors for ontological, normative and operational aspects of CBMs for HVM (Chen, Hung, & Ma, 2020). Further, there is a need to systematically account for important FOI that affect different dimensions of the CBM and that cannot be sufficiently addressed within conventional value or cost perspectives (Frishammar & Parida, 2019; Sarasini & Linder, 2018).

3 | RESEARCH DESIGN AND METHODOLOGY

In accordance with existing CBM research, we assume a qualitative case study methodology (Bocken, Schuit, & Kraaijenhagen, 2018; De Angelis, 2016; Jensen, Prendeville, Bocken, & Peck, 2019). Given emerging nature of research into CBMs and HVM, the use of multiple case studies facilitates a wider exploration of relevant research questions and thus a more convincing theory (vs. single-case studies) (Gustafsson, 2017). Case studies are considered as one of the most important methods for inductive research and have been utilized in several studies investigating firm value (Bititci, Garengo, Ates, & Nudurupati, 2015; Eisenhardt, 1989; Huaccho Huatuco, Martinez, Burgess, & Shaw, 2019). We capture this case study protocol in Figure 1 below.

Appropriate candidate companies for the case studies included those reported to be pursuing circularity principles (Zucchella & Previtali, 2019). Several sources for industry case study candidates were identified: (1) HVM companies that had received awards recognizing their CE implementation, (2) search engines[3], (3) companies cited in CE and sustainability reports, (4) companies that had comprehensive case study documents in the Ellen McArthur Foundation database[4], and (5) companies that had comprehensive case study documents in the European Remanufacturing Network database.

As captured in Table 4, we restricted our selection of case studies to five companies, anonymized as following: Company A (a Small or Medium-sized Entreprise automobile manufacturer), Company B (a global leader in transport mobility), Company C (an ICT refurbishment company) Company D (an automobile parts remanufacturer), and Company E (a global lighting company). These case study companies provided representation of diverse sizes, product offerings, and value-chain positions. Further, in addition to pursuing circularity principles, these case study companies are aligned with some of the conditions of HVM, key of which is the continued engagement in manufacturing while avoiding price competition (MacBryde, Paton, & Mendibil, 2011; Sminia, Ates, Paton, & Smith, 2018). All companies accepted our invitation to be included as an industry case study, and each reviewed the final results. An initial review of publicly available documents for each case study was completed, with descriptions highlighting the company's familiarity with CE and CE concepts, their existing CBMs, and project focus (cf. Bocken, Schuit, & Kraaijenhagen, 2018). After the initial review was completed, requests for additional data were made to all companies to clarify their company-specific perspectives regarding costs, value, and FOI. All five (5) responded, initially providing

[3]Online search for these case studies were made and accessed for research on October. 03. 2019

[4]Ellen MacArthur Foundation case study database can be accessed at https://www.ellenmacarthurfoundation.org/case-studies (Accessed for research October. 03. 2019).

TABLE 4 Description of selected five industry case study companies

	Company and structure	Industry	Familiarity with implementing the CE	Identified CBM	Project focus	Case study secondary data source
1	Company A, >21 employees (UK)	Automotive Hydrogen fuel-cell car	Detailed awareness of the circular economy concept. Implements CBM into manufacturing and governance structure	PSS Ownership of car is retained with mobility as a service.	Incentivizing existing supply network	Company website, EMF database
2	Company B division >34,200 employees (global)	Intelligent transport division of Company B	Good awareness of CE concept. Siemens CE position statement. Focused on environmentally focused CE initiatives such as zero waste to landfill.	Product life extension model based on predictive maintenance	Implementing sustainability standards, enabling manufacturing with I4.0	Company website, PowerPoint presentation
3	Company C, >146 (UK)	Refurbished Servers and Data Centre Equipment	Understands circular economy changes their business model. Involved in a 3-year Interreg-funded research project, "Circular Economy in the Data Centre Industry"	Product life extension model: Refurbishment	Interreg-funded research project, as associate partner. Public sector circular IT frameworks (ongoing)	Company website. Secondary data sources
4	Company D, >100 employees (UK)	Automotive remanufacturers	Excellent awareness of the CE. Part of the ERN. Currently works with academia in CE related initiatives for company.	Product life extension model: remanufacturing	Merging remanufacturing and manufacturing sites	Company website. ERN database.
5	Company E, >1000 employees (global)	Energy (lighting)	Company possesses excellent understanding of CE principles. Involved with academia at TU Delft, Lund University and across Europe.	Selling of light as a service. PSS.	Developing the business model of the "pay per lux" project and the platform that facilitate resource management between manufacturer, supplier and end-user. Integrate the CE in business operations and daily way of working as well as building CE leadership competencies	EMF database, Google Scholar, Science Direct, UNEP study

Abbreviations: ERN = European Remanufacturing Network, PSS = Product-service systems.

additional public documents that were included in the analysis, as well as addressing follow-up questions by email where needed. Additional data and information from secondary sources were collected to facilitate the triangulation of information and important cross-case comparisons (Saunders, Lewis, & Thornhill, 2012; Urbinati, Chiaroni, & Chiesa, 2017). Finally, the research protocol was concluded with a semi-structured (30–60 minutes) interview with respondents from case companies as well as 3 academics to ensure a measure of triangulation. The case study results were discussed and validated with the respondents. Demographics for the respondents are given in Appendix A and we capture the semi-structured interview questions in Appendix B (Binder & Edwards, 2010; Mäkelä & Turcan, 2007). This facilitated the development of our proposed expanded framework that links CBM theory to circular HVM practice.

4 | RESULTS OF CASE COMPANIES

Although the implementation pattern of CE principles, and the understanding of BMs differed, all case companies possessed a detailed and practical understanding of CE, had a defined CE purpose, and had incorporated CE thinking into their mission and goals (Table 4). The five industry case studies were analyzed on the basis of CBM value (Table 2) and CBM cost (Table 3). Analysis of supplemental documents, secondary research, and interview results was used to assess FOI for HVM company-specific adoption of CBM.

4.1 | Company A case study

Company:	Company A
Description:	SME automobile manufacturer
Number of employees:	21
Year founded:	2007
Operations:	UK based

4.1.1 | CBM/evidence of circularity

Company A has sustainability at its core, across manufacturing, design, structure, and governance elements of the business. Specifically, Company A provides the value proposition of mobility at zero cost to the planet via a hydrogen fuel cell vehicle (HFCV). The innovation-driven car has been created for "efficiency, simplicity, lightness, strength, affordability, safety and sustainability." Company A's BM is built on an understanding of the direct proportionality between elimination of environmental damage and business success as a source of competitive advantage. This "sale of service" BM includes the HFCV car and all associated operational costs, including fuel.

The BM can be regarded as a PSS model, given its emphasis on "sale of use," rather than "sale of product" (Baines et al., 2007). This value proposition is embedded into a circular value network, that consists of a mining company, a membrane electrode assemblies (MEAs)[5] supplier, a fuel cell manufacturer, and Company A. In the cost structure, the customer pays Company A via a monthly direct debit that accounts for a fixed monthly base rate and a mileage rate; the fuel cell is leased to Company A, who pays for installed kilowatt hours of electricity; the fuel cell manufacturers do not buy the MEA, and instead, have a contractual leasing agreement with the MEA supplier; and the platinum needed in the MEA is leased to the MEA supplier by the mining company. Thus, by Company A's suppliers maintaining ownership of different components of the HFCV all circular value network stakeholders, and the customer, benefit from a restructuring of the risks, responsibilities and costs normally associated with asset ownership, and a lower environmental impact of the product is expected (Baines et al., 2007; Bech, Niero, McAloone, Kjaer, & Pigosso, 2018; Lindkvist & Sundin, 2016).

For Company A, this CBM is adopted throughout the supply chain by the firm's suppliers; hence, there is greater alignment of interests across suppliers, Company A, customers, and the environmental goal. To support this CBM, a "distributed manufacturing model" uses small, flexible, and scalable manufacturing units, that are located within distributed production networks (Matt, Rauch, & Dallasega, 2015; Moreno & Charnley, 2014). According to the CEO of Company A, they will "*build human-scale, profitable operations near the markets they serve – each will produce around 5,000 cars a year*."

4.1.2 | HVM-specific HVM features

Company A qualifies as HVM via the technology of the HFCV car, as well as their CBM in which they compete primarily on different forms of value, not cost. The HFCV car is lightweight, weighing just 580 kg; motors are used as brakes, hence recovering over 50% of kinetic energy when braking; the body of the car is made of lightweight composites; the car is powered by a low-powered hydrogen fuel cell (8.5 kW) with zero tail-pipe emissions. In Table 5, we identify the various value, cost, and FOI considerations for Company A, adapting the conceptual framework from (Ranta, Aarikka-Stenroos, & Mäkinen, 2018) and expanding on the CBM canvas. Company A's CBM maintains CE principles by ensuring that used products and materials are returned back to the manufacturer. Each manufacturer within the circular value network is responsible for repairs and replacement of worn-out materials, ensuring that minimum amounts of virgin materials are consumed.

4.2 | Company B case study

Company:	Company B
Description:	Global leader in transport mobility
Number of employees:	34, 200
Year founded:	2018
Operations:	Global

[5]MEAs are embedded in the fuel cell (Okorie, Salonitis, Charnley, & Turner, 2018).

TABLE 5 Value, associated costs, and other factors influencing CBM adoption in Company A

CBM	Value prop	Value creation and delivery	Value capture	Cost components	Other factors influencing CBM adoption
PSS	Offering: transport mobility through hydrogen fuel-cell car as a service. Ensuring efficiency is profitable. Target customer: stakeholders on circular value network (mining company, MEA supplier, fuel cell manufacturer, and individual customers)	Value creation: Environmental, customer, economic, and information Resources and capabilities: R&D lab, good company structure Organization: Coordinates relationship between mining company, MEA supplier, fuel cell manufacturer, and external stakeholders Position in the value network: base member of the value network	Revenue sources: Government Grant. Crowd funding. Economics of the business: Distributed manufacturing model	Associated costs: labor, material, production, technology, data cost (capture, storage, analysis), information, pricing structure, transportation and logistics costs, and contracting	Customer acceptance, circular value network structure, environmental factors, industry 4.0 technologies, lower economic barriers as being competitive is not dependent on the build cost of the car but its lifetime cost.

4.2.1 | CBM/evidence of circularity

The parent company of Company B presents a value proposition that is grounded in CBM mobility services and embedded with Industry 4.0 technologies (Table 6). A separately managed company, dedicated to rail technology, railway electrification, intelligent traffic systems, road solutions, turnkey projects, and electrification and intermodal solutions, was created. These technologies are served by "Portfolios," which are what Company B describes as "services to support these technologies." Company B Portfolios for the installed base of mobility equipment include maintenance, spare part, upgrade, and operations services. The customer experience for Company B customers incorporates a three-pronged approach focused on efficiency (increase of efficiency through optimized processes), sustainability (ensuring sustainability through leveraging of experience), and reliability (ensuring high reliability through innovative maintenance concepts).

4.2.2 | HVM-specific CBM features

Company B's CE position statement focuses on utilizing digital technologies to drive the transition to a CE, and as digital technologies

TABLE 6 Value, associated costs, and other factors influencing CBM adoption in Company B

CBM	Value prop	Value creation and delivery	Value capture	Cost components	Other factors influencing CBM adoption
PSS; resource efficiency through IoT solutions; product life extension using predictive-based maintenance	Offering: rail solutions, road solutions, intermodal solutions, and consulting. Target customer: Government through public transport and infrastructure.	Value creation: Environmental, economic, social, customer, waste, and information and generated data Resources and capabilities: R&D labs, international operations, mobility-focused solutions. Organization: 3 way [Company B customers] Position in the value network: Central	Revenue sources: Customers (mainly government and passengers) Economics of the business: enabled by digitalization (IoT, additive manufacturing, augmented reliability, and data-driven predictive maintenance)	Associated costs: labor, data cost (capture, storage, and analysis), repair and maintenance cost, and transportation and logistics costs	Digital technologies, adoption, deployment is the main factor influencing, ability to integrate CBM with government policies, for example rail policies, sustainability policies, CBM model is ideal to product offering.

become pervasive, this trend is expected across manufacturing companies (Beatriz et al., 2018; Okorie et al., 2018; Rajput & Singh, 2019). For Company B, a PSS is used alongside Internet of things (IoT) solutions, to ensure improved resource and product life extension options via predictive and preventative maintenance. Company B creates value that manifests in environmental (sustainability), economic (optimization), information (product-level, installed-base[6]), and customer (service) forms (Schenkel, Krikke, Caniëls, Laan, & van, 2015). The industry case study analysis revealed two other manifested forms of value creation: resource utilization, that is, solid waste is collected, and utilized as an energy-from-waste input; and generated data (product and system levels and analytics), that is, generated data are used to drive IoT-based CE solutions, including predictive maintenance and digital twinning used to extend product and component life cycles. This is different from information value (see Footnote 6), which includes information about the installed base (Schenkel, Krikke, Caniëls, Laan, & van, 2015). Thus, digital technologies can influence the choice of CBM that HVM companies make and require expanding the dimensions of the existing CBM canvas (Table 6).

4.3 | Company C case study

Company:	Company C
Description:	ICT refurbishment
Number of employees:	146 (2019 numbers)
Year founded:	2005
Operations:	EU, North America, Asia Pacific

4.3.1 | CBM/evidence of circularity

Company C began selling new and refurbished ICT equipment in 2005. However, rising demand for refurbished equipment during the 2008 financial crisis enabled the company to pivot into a specialized, comprehensive refurbishment-focused CBM that continues to sell a small amount of new product. The comprehensive refurbishment process at Company C includes several stages: (1) business-to-business (B2B) purchase of redundant ICT equipment, (2) restoration of IT equipment to factory conditions, (3) securely erasing data bearing devices, and (4) shipping components and/or fully configured refurbished servers to new customers. Product quality is signaled and supported via a manufacturer-comparable three-year warranty. Becoming a CBM specialist in a growth sector has benefitted the firm, with staffing levels rising from 48 to 146 between 2016 and 2019,[7] and revenue increasing from £14 m in 2015 to £36 m in September 2018 (Insider Media Limited, 2018). The associated value, cost, and FOI for Company C are described in Table 7.

[6]Information at the product level, regarding the installed base, includes data regarding product age, technical status, physical location, spare parts consumption, maintenance and service status, and life-cycle performance.

[7]Secondary data were collected from Company C in August 2019.

4.3.2 | HVM-specific CBM features

Value creation by Company C can be summarized as both "observable" and "hidden." *Observable* value derives from the fact that enterprise ICT equipment continues to be traded in secondary markets long after original owner corporations write it off as zero value after a three-year or "live" accounting period. According to the CEO of Company C, "*With a typical corporate, once they have written older kit off, after three years it is no longer on the balance sheet or of any interest and their recycler will charge X pounds to collect it. But there is value in it. We have been saying 'don't give it to your recycler', give it to us and we will give you fair market value for it*" (Insider Media Limited, 2018). Hidden value creation manifests in both economic and environmental forms, via a value proposition for Company C's management team stakeholders (M. Yang, Evans, Vladimirova, & Rana, 2017) that is grounded in dematerialization, for example, the reduction in unit-level and aggregate material use required to generate revenue. In addition to previously identified initiatives (Table 4), Company C is involved in several education efforts targeting the increase of recovery rates for precious materials from ICT using nonmechanical techniques. They describe these initiatives as value-creating initiatives and classify the "education" value among the intangible, hidden value. Unlike "value missed" (Bocken, Short, Rana, & Evans, 2013; M. Yang, Evans, Vladimirova, & Rana, 2017), which posits that "value missed" is value that is not explored or adequately captured by the BM, Company C regards the education/research value and the dematerialization value deriving from their HVM activities as being *hidden* value. Thus, although these forms of value were "… not envisaged when we first developed the business model …" (Sustainability Manager, Company C), this case company is currently working to integrate these forms of value effectively into their CBM.

4.4 | Company D Case study

Company:	Company D
Description	Automobile parts remanufacturer
Company size:	55
Year founded:	1971
Operations:	UK based

4.4.1 | CBM/evidence of circularity

Company D is a UK-based independent remanufacturing firm serving customers across the United Kingdom, Europe, and North America since 1971. Their remanufacturing vehicle fleet includes off-highway, heavy goods vehicles (HGVs), and trucks, buses and coaches, vans and light commercial trucks, and automotive cars. As a remanufacturer of steering boxes, pumps, racks, and original equipment manufacturer (OEM) steering columns, Company D's value proposition stems from

TABLE 7 Value, associated costs, and other factors influencing CBM adoption in Company C

CBM	Value prop	Value creation and delivery	Value capture	Cost components	Other factors influencing CBM adoption
Product life extension via refurbishment	Offering: refurbished goods at a cost and environmental benefit for customers. Remanufacturing of laptops to deliver carbon neutral Target customer: OEMs for IT equipment and individual customers.	Value creation: environmental, economic, social, hidden value (value in materials usage and education value), generated data, and social. Resources and capabilities: technical factories across three continents, sales offices Organization: B2B, B2C Position in the value network: Central	Resources sources: customers (OEMs and individuals preferring refurbished equipment) Economics of the business: Refurbishment and sales of refurbished IT equipment driven by cost, environmental and warranty considerations by customer	Associated costs: training, warehouse space, labor, physical infrastructure, and facility location across five continents	Policy and legislation factors supporting refurbishment such as the EU Ecodesign directive and the UK MPs inquiry into circular economy, circular economy drive in Australia and the right to repair legislation in the United States

Abbreviations: OEM = original equipment manufacturer.

the definition of remanufacturing, in which a core[8] or product is returned to performance and quality that meets or exceeds that of a new version of the product (International Resource Panel, 2018; Paterson, Ijomah, & Windmill, 2017). The CBM network effectively connects Company D, vehicle OEMs, customers (end-users), and the independent aftermarket/secondary market. Company D's remanufactured products are supplied through two CBM schemes: (1) *service exchange (independent market)* and (2) *return and remanufacture (OEMs)* (Figure 2).

Under the *service exchange scheme*, a customer pays Company D for a remanufactured product from their stock, and Company D applies a surcharge to the transaction that acts as a deposit. When the worn-out product needs to be replaced, the customer returns it to Company D and receives the surcharge credit (deposit) back, in exchange. Thus, the customer is incentivized to return the product/core, and Company D uses the old product/core to replenish their *service exchange scheme* inventory stock. The *return and remanufacture* dimension of the BM primarily applies to vehicle manufacturers who collect old parts/units from their customer/end-users and send these units in bulk to Company D. Once the remanufacturing process is complete, the company returns the remanufactured units to the manufacturers. For Company D and its stakeholders, the value manifests in economic, environmental, and social forms (Table 8). Relative to a newly manufactured version, Company D estimates that the remanufactured product is 50%–65% less expensive, consistent with remanufacturing literature (Adrian, 2010; APSRG & APMG, 2014; Lund & Mundial, 1984). Price discounting for remanufactured products creates economic value for customers, without compromising the profit margins of the remanufacturers (International Resource Panel, 2018). This is because the CBM enables a significant reduction in unit-level operating costs as a result of reduced material use and energy consumption requirements (International Resource Panel, 2018).

4.4.2 | HVM-specific CBM features

Through its HVM approach and remanufacturing CBM, which includes the maintenance of remanufactured product inventory, Company D additionally creates a time-based form of value. That is, Company D is able to significantly reduce the lead time for providing HVM replacement vehicle parts to its customers (Table 8). Further, they can reduce the amount of time required to return the same core back to the original customer. Thus, Company D's CBM incorporates an additional value-proposition grounded in minimizing the out-of-service time for fleet vehicles that complements the more conventional economic, environmental and social value creation.

4.5 | Company E Case company

Company:	Company E
Description:	Global lighting company
Company size:	32,000
Year founded:	2013
Operations:	Global

[8]A core is a previously sold, worn or nonfunctional product or module, intended for the remanufacturing process. During reverse logistics, a core is protected, handled, and identified for remanufacturing to avoid damage and to preserve its value. A core is usually not waste or scrap, and it is not intended to be reused for other purposes before comprehensive refurbishment or remanufacturing takes place (UNEP, 2018).

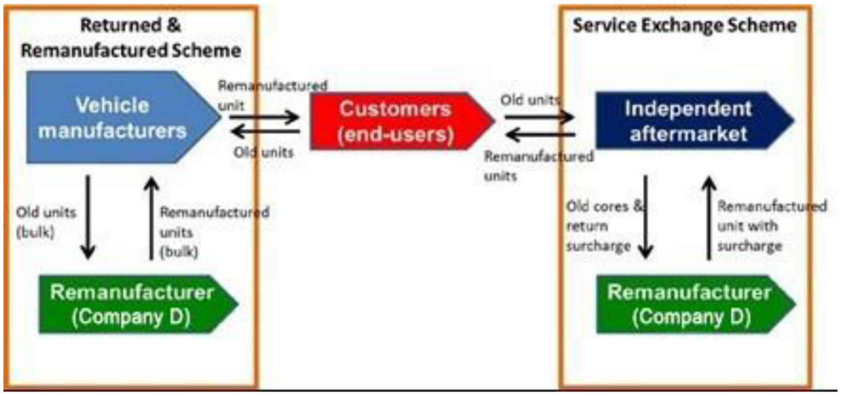

FIGURE 2 Company D business model (sourced from Company D business model case study description)

TABLE 8 Value, associated costs, and other factors influencing CBM adoption in Company D

CBM	Value prop	Value creation and delivery	Value capture	Cost components	Other factors influencing CBM adoption
Product life extension via remanufacturing consisting of "returned and remanufactured scheme" and "service exchange scheme"	Offering: remanufactured OEM steering systems, steering, hydraulics and military engineering. Target customer: OEMs, government bodies, and agencies	Value creation: economic, environmental, and social (job opportunities), customer relationship as a value. Resources and capabilities: 45 years' experience in remanufacturing, an integrated manufacturing and remanufacturing site Resources and capabilities: integrated remanufacturing and manufacturing hub Organization: Primarily B2B Position in the value network: Central	Resources sources: customers (OEMs and government departments) Economics of the business: remanufacturing primarily driven by cheaper cost of remanufactured products in comparison to newly manufactured products.	Associated costs: training, warehouse space, labor and personnel cost, and logistics cost	Policies and legislation factors supporting remanufacturing and CE transition in the United Kingdom. Policy-implementing bodies such as European Remanufacturing Network, Conseil European de remanufacture

4.5.1 | CBM/evidence of circularity

The "performance economy" model (Stahel, 2008) emphasizes the importance of selling services rather products, and inspired Company E decision to develop the bespoke "pay-per-lux" intelligent lighting system. This CBM incorporates the design of the "pay-per-lux" system to fits the requirement of the customer's space (installed location) and budget while also ensuring design for durability and ease of maintenance and repair. As a circular design strategy of the "light-as-a-service" model, Company E retains ownership and responsibility for the lighting installation, including any necessary maintenance and repair during the life of the arrangement, and the customer pays for the light that is actually used (e.g., per lumen). By enabling the optimized dimming or brightening of the lighting system in response to motion, or the presence of daylight, a combined sensor and controller system helps to keep energy consumption at a minimum. Thus, the value created, delivered, and captured in the "pay-per-lux" model is the full life-cycle management of energy-efficient lighting, including preventive maintenance and system optimization (Mendoza, Gallego-Schmid, & Azapagic, 2019). For Company E, the intentional design for longevity and recyclability into their products leads to nontraditional forms of value-creation (Schulte, 2013). Overall, this CBM enables value to manifest in environmental and economic value for the customer and for Philips (Table 9).

TABLE 9 Value, associated costs, and other factors influencing CBM adoption in Company E

CBM	Value prop	Value creation and delivery	Value capture	Cost components	Other factors influencing CBM adoption
Product as a service performance model	Offering: light as a service. Pay-per-lux, where the customer pays for the light and not the accompanying equipment. Target customer: homes, businesses	Value creation: environmental, customer, and economic. Hidden value exists, as Company E owns the product and can extract further value from it at its end of life. Resources and capabilities: manufacturing, design lab, research, and development labs. Organization: Company E, which has expertise in lighting as well as partners with expertise in design. Position in the value network: Circular value exist between Company E and customer	Resources sources: This is primarily the customer. Economics of the business: A bespoke intelligent lighting system that fits the requirement of the space where it installed at a manageable price for the customer. Company E owns the product and can manage further end-of-life strategy for the product, hence a hidden value for Company E.	Installation, service, and maintenance cost. R&D cost: labor cost.	The need to extract value from the "performance model," as developed by Walter Stahel and to maintain a contact with customer. It brings Company E closer to their customer.

4.5.2 | HVM-specific CBM features

HVMs, especially when adopting CBMs, often require major upfront financing and longer payback periods, which highlights a need and opportunity for HVM to strategically shift away from more conventional expectations regarding return on investment (ROI) and payback periods (Schulte, 2013) (Table 9). Recognizing this particular HVM-CBM challenge, Company E collaborated with a consultancy, who served as an intermediary within the system by retaining ownership of the material content (asset-base) of the lighting system and selling it back to Company E at end-of-life.

5 | ANALYSIS AND DISCUSSION

5.1 | CBMs analysis

As our industry case studies indicate, HVMs employ a range of different CBMs, including PSS, product-as-a-service (PaaS), predictive maintenance, remanufacturing, and refurbishment. This suggests the clear applicability of a variety of CBMs to HVM, specifically: *share* (focused on [i] sharing assets such as PSS and [ii] prolonging product life); *optimize* (focused on [i] increasing performance/efficiency of products via predictive maintenance practices, and [ii] leveraging big data, automation, and remote sensing; *loop* (focused on [i] enabling multiple product service lives) (Rosa, Sassanelli, & Terzi, 2019b). Further, there is evidence of CBMs tending toward "supplying service solutions rather than products," or "*service based manufacturing*," particularly in the context of HVM (MacBryde, Paton, & Clegg, 2013). Given the nature of HVM, it is reasonable to expect that "service" should be a component of the overall value proposition made to customers. Through the integration of "looping" and "optimizing" CBMs, such as remanufacturing, refurbishment, and data-driven predictive maintenance, firms can deliver value through a broadened range of activities, that offers a more balanced and complementary value proposition package (MacBryde, Paton, & Clegg, 2013; Martinez, Neely, Ren, & Smart, 2008). Although each industry case differed in terms of the product offering, size, geographic location, and industries, we noted that there were recurring themes of value considerations for CBM adoption that emerged across these HVMs.

As identified previously, the currently proposed CBM canvas options in the literature may not adequately reflect the unique opportunities for reframed value, cost, and other FOI associated with HVM. Further, the CBM canvas, as predominately evaluated in the literature may not provide sufficient insight or context to support HVM organizations as they attempt to transition from linear to circular BMs.

Given this, we integrate and model a summary of elements possible via the implementation of CBMs for HVM using a modified canvas tool, the Circular and Sustainable Business Model Canvas (CSBMC) (Figure 3). This clarifies some of the unique perspectives and forms of value and cost that may be present in a CBM for HVM, as well as the importance of different FOI, which affect each dimension of the CBM canvas in specific ways.

5.2 | Value and cost element analysis

There were observed differences between value and cost components of BMs and CBMs, across HVM industries (Tables 5–9), and these were modeled using the CSBMC (Figure 3).

5.2.1 | Value creation

In accordance with the original BM canvas (Osterwalder & Pigneur, 2010), dimensions of value creation typically include key partners and/or stakeholders, key activities, and key resources of the CBM (Bocken, Short, Rana, & Evans, 2014). Although a number of reviewed papers suggest that value creation is fully captured within these three categories, it is also clear that the collaborative and networked nature of innovation for CBMs can lead to many new concepts, value, and uncertainties that are affected by key FOI (Antikainen & Valkokari, 2016). In the context of HVM, value drivers such as commoditization, specialization, globalization, sustainability, and the use of digital technology (Martinez, Neely, Ren, & Smart, 2008) can be integrated to deliver new forms of value for stakeholders. Some value creation components identified across the CBM case studies stood-out as distinct; for example, the value created through research and development (R&D) related to a PaaS model by Company E differs meaningfully from the value that R&D creates in non-HVM models. Thus, for HVMs with CBMs, in particular, R&D is very important and can provide a competitive advantage. This aligns with the resource-based theory of the firm (RBT) in which the organization as is framed as a "bundle of value" embedded in resources (Bowman & Ambrosini, 2000; Wernerfelt, 1984). As Richardson (2008) argues, value creation and delivery describe the firm's sources competitive advantage states. In contrast to linear BMs, CBMs require a systems view of the product and product-system (Bakker et al., 2014).

5.2.2 | Value proposition

Based on the five industry case studies, we also posit that CBMs enable an expanded scope for the value proposition for HVMs, that includes the amplified value created for a broad set of stakeholders (e.g., society and the environment), in addition to the firm and its customers. Thus, the value proposition may explicitly include environmentally and socially oriented outcomes that appeal to the target customer and/or other stakeholders as a central driver of the CBM. Value proposition components of CBMs for HVMs thus include, but are not limited to the following:

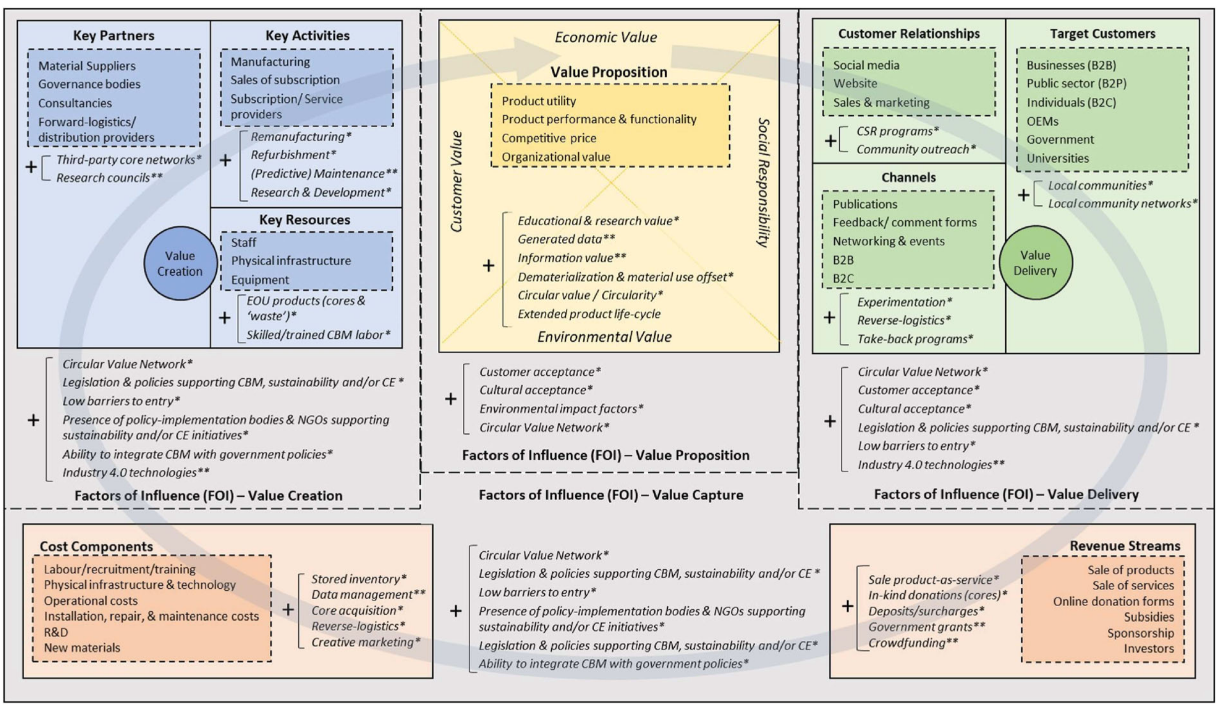

FIGURE 3 The circular business model canvas for high-value manufacturing, provides a summary of CSBMC elements of value possible via the implementation of CBMs (*) within HVM (**) organizations, above-and-beyond conventional economic, environmental, and social dimensions of business model value (Source: adapted from Osterwalder & Pigneur, 2010)

- *Economic value:* Financial, cost reduction, risk reduction, and other monetary benefits that can accrue to the company and its stakeholders (Schenkel, Caniëls, Krikke, & Van Der Laan, 2015; Subramoniam, Huisingh, & Chinnam, 2010)
- *Social responsibility value:* Pursing environmental sustainability and CE BMs, such as value retention processes (VRPs) , can enhance environmental performance and social well-being.
- *Environmental value:* The direct environmental value that can accrue by adopting CBMs (Schenkel, Caniëls, Krikke, & Van Der Laan, 2015), that is, GHG emissions reduction of between 79% and 99%, and significant material savings by adopting VRPs (UNEP, 2018).
- *Educational/research value:* HVMs can engage in collaboration with universities and research councils, enabling the advancement of qualitative and quantitative data.
- *Organizational value:* Value in the form of institutional knowledge and improving work conditions that can be gained via the process of developing and scaling CBM solutions (e.g., Company A's localized approach, and options for flexible working conditions) (Bocken, Short, Rana, & Evans, 2014).
- *Dematerialization and material-use offsets:* The inherent value, beyond cost avoidance, of the product's physical form and materials which are retained via use of VRPs, such as refurbishment and remanufacturing.
- *Generated data:* Product- and systems-level (predictive) data that can be generated via the use of digital technology within HVMs, and which can inform optimized product maintenance and end-of-life management decisions.
- *Information value:* Value of asset information and process knowledge that can be used to improve product design/quality/safety, life cycle information, and/or improved reverse supply chain (Ferrer & Whybark, 2000; Frank, 2000; Schenkel, Caniëls, Krikke, & Van Der Laan, 2015)
- *Circular value:* The value that is generated through use of a network model that accrues to the HVMs, their parts suppliers, their raw material providers, and their customers.

These industry case studies demonstrate that the scope of value proposition can be extended beyond conventional dimensions of economic, environmental, and social value through the adoption of CBMs by HVMs. This more comprehensive understanding of extended and amplified CBM value propositions can provide HVMs with strategic clarity regarding the creation/modification of circular product or service offerings (Bocken, Schuit, & Kraaijenhagen, 2018; Breuer & Lüdeke-Freund, 2017; Ries, 2011).

5.2.3 | Value delivery

Based on the industry case study insights, HVMs deliver value to a diverse and large number of beneficiaries, via interconnected global value systems (Martinez, Neely, Ren, & Smart, 2008) of communication, physical distribution and recovery, and sales channels. For certain types of CBMs, particularly those engaged in looping (e.g., Company C and Company D) and exchange (e.g., Company E), value delivery is achieved through both the physical forward distribution of products, and the physical recovery and reverse logistics systems that are maintained to manage end-of-use and end-of-life products and cores. Reverse logistics can represent a significant cost component for CBMs; however, this is typically managed effectively through pricing strategy and complementary revenue streams (e.g., Company D's core deposit). The extent, complexity, and cost of asset management, recovery, and reverse-logistics systems can vary based on whether the channels are B2B (e.g., Company D's OEM "Returned & Remanufactured" scheme) or business-to-consumer (B2C) (e.g., Company C). Some HVMs (e.g., Company D) may leverage diverse distribution channels by maintaining and managing separate B2B and B2C channels; this approach can lead to increased access to diverse market segments, while mitigating distinct associated asset management risks (EMF, 2015).

Communication channels remain an important element for HVMs wishing to engage and communicate with their customer segments about new and nonconventional value propositions enabled via the CBMs. As an example, in addition to conventional *passive* channels (e.g., publications and websites) and *active* channels (e.g., public events, networking events, and feedback forms) (Mendoza, Gallego-Schmid, & Azapagic, 2019), Company A utilizes an "experimentation" model of communication and engagement in which the public is invited to view a test trial of a product. This innovative engagement mechanism is possible largely through the integration of a CBM for HVM. Diversity in communication channels is also an important mechanism for building effective relationships with customers, enabling bidirectional feedback loops that guide the creation of novel CBM value propositions. The case studies demonstrate this diversity; that is, Company A uses social media to inform the public about product development and new launches; Company C's social media information focuses on its work in reuse and refurbishment; Company B's social media channel focuses on the sustainability agenda of the parent company; and so forth. Thus, as demonstrated, HVMs in particular have an opportunity to increasing use *active* channels to reframe opportunities for CBMs with a focus on new forms of value and new forms of delivering value to their customers.

5.2.4 | Value capture

The aggregated costs and revenues for HVMs operating under CBMs are presented in Figure 4. Fourteen (14) costs components and eight (8) revenue streams were identified from across our five HVM case studies for different customer segments and sources. Importantly, the nature and magnitude of cost components relate to the nature of the business and the type of CBM adopted, that is, where Company C experiences a relatively greater inventory warehousing cost component, Company A and Company B experience a relatively greater data

TABLE 10 Framework for connecting CBM theory to CBM practice—Example of linear-to-circular BM implementation plan for an HVM company

		Current state	Example: CBM objective	Example: transition priorities	Example: metric of measurement	Example: key strategies	Factors of influence
Value proposition to customer		Product function and utility via ownership	Function and utility via access	Reframe understanding of customer needs via two-way engagement	Asset versus liability and depreciation borne by customer; brand reputation (intangible value)	CBM narrative-building re: economic and environmental benefits	• customer acceptance; • cultural acceptance
Value creation	Key activities	Product sales	Product service system and leasing	Evaluate servitization/leasing options (by product)	Quantify material savings, cost savings, and profit margin differential	Pilot CBM with a specific product/line to explore requirements and opportunities	• access to circular value network; • low barriers to entry; • digital technologies and industry 4.0; • skilled/trained workforce; • legislation and policies supporting CBMs and CE
	Key resources	Sales team	Customer-relationship specialists and product support	Training; data collection and utilization for predictive maintenance	Maintenance frequency and scheduling	Utilize industry 4.0 and digital technology to inform relationship management	
	Key partners	Forward-logistics specialists	Circular value network, circular insurance, and circular finance	Establish preventative maintenance and reverse-logistics	Product life cycle extension/ # service lives	Offer easy and accessible circular financing plan to cover entire life-cycle management	
Value delivery	Customer relationships	Sales and marketing	Social media and community outreach	Communicate value proposition impact for potential new customers	Repeat business/longevity of relationship	Use digital, social platforms to communicate new CBM narrative	• access to circular value network; • low barriers to entry; • digital technologies and industry 4.0; • legislation and policies supporting CBMs and CE
	Key channels	Targeted B2B	Experimentation and take-back programs	Coordinate and collaborate with partners for take-back	Asset/core recovery rate and reuse rate	Leverage existing reverse-logistics specialists to get started	
	Target customers	B2B SME	B2B, B2P, and B2C	Expand scope of target customers and stakeholders and classify stakeholders	Customer/stakeholder growth rate	Conduct market analysis to identify new target segments for CBM value-proposition	
Value capture	Revenue streams	Single-transaction sale	Monthly lease/subscription payment	Explore alternative circular finance models/options	Leasing/subscriptions as % of total revenue	Partner with circular finance organizations	• access to circular value network; • legislation and policies supporting CBMs and CE; • ability to integrate CBM with government policies
	Cost components	Production, operation and R&D	Production, reverse-logistics, R&D, operations, and customer engagement	Develop cost models to account for expected cost decreases and increases from CBM	CBM profit margin (long-term) vs. current state profit margin (long-term)	Collaborate with partners to minimize/streamline reverse-logistics requirements	

management cost component. The nature and magnitude of revenue streams is also tied to the nature of the business and the type of CBM; that is, Company E's revenue streams are substantially large[9] relative to the other case studies, whereas Company A's is noted for the flexibility[10] achieved through its use of crowdfunding. As for any business, HVMs adopting CBMs must manage and balance their specific set of cost components and revenue streams, that is, Company D must manage "core deposits" as both a revenue and cost component within their unique remanufacturing CBM. A strategic approach to value capture within CBMs can enable the reduction and/or prioritizing of costs and activities, that is, the development of a corporate CE procurement strategy can reduce costs of "*maintenance, waste management, energy and carbon emission tax*" (Mendoza, Gallego-Schmid, & Azapagic, 2019).

5.3 | FOIs analysis

Numerous FOIs were identified across different dimensions of the HVM CBM case studies, including technological factors (Industry 4.0 technologies, digital technologies), policy factors (supporting legislation and government policies), and availability of resources and support (e.g., the presence of nongovernmental organizations engaged in CE). Relevant FOIs are closely tied to the extended scope of the value proposition that is enabled by CBM: For example, HVMs are often drawn to the idea of a CBM because of the inherent environmental benefits may be yielded. HVMs are also drawn toward CBMs for strategic reasons. For example, when an HVM firm already possess remanufacturing capability (e.g., product knowledge and skilled labor), the adoption of a CBM presents lower relative barriers to entry for the firm and reinforces high entry barriers for potential competitors. The presence of nongovernmental organizations engaged in CE initiatives also appears to serve as a FOI in the adoption of CBMs by HVMs: To support their decision-making and CBM transition, HVMs may look to these nongovernmental organizations for research partnerships, policy leadership, and technical advice that relates to their CBM of choice.

Our findings from CBM practice in HVM are analyzed with respect to CBM theory in an effort to further clarify areas of alignment and disparity and identify opportunities for enhanced value in HVMs interested in adopting CBMs. Using a framework to integrate CBM theory and CBM practice, per the example populated in Table 10, it is clear that a systems perspective able to account for all dimensions of the CBM, and the FOI that affect distinct elements of the CBM, is critical for any HVM organization intending to transition to a CBM.

[9]Company E recorded a net income of EUR 281 million in 2017 which represented a 51.8% increase from 2016. LED-based sales represented 65% of Company E Lighting overall sales. In 2016, this figure was 55%.

[10]Company A has recently had and closed its third crowdfunding campaign in its series of campaigns. They also have an online form where the public are allowed to invest after registering the details online.

6 | CONCLUSIONS

This work clarifies and differentiates the value, costs, and FOI associated with the adoption of CBMs by HVM organizations and extends thinking regarding the nature and form of value and cost. Using a qualitative approach, we map value creation, value proposition, value delivery, and value capture elements of the CSBMC for five industry case studies. First, we find that, irrespective of firm size, digital technologies can help in the process of value creation and capture as well as are critical enablers of FOIs, useful in the process of CBM implementation. In addition to the conventional social, economic, and environmental dimensions of value identified in CBM literature, we find that HVMs can access CBM-specific value propositions that include nonconventional forms of value that influence and motivate the adoption of CBMs: educational/research value, organizational value, generated data, customer value, and information value. Further, value capture, by means of balancing revenue and cost components, was observed to be specific to the unique nature of each HVM business and the type of CBM adopted. Thus, for HVMs to remain competitive in the adoption of a CBM, a clear understanding of the connections between required cost components, revenue opportunities, and the extended value proposition is needed. This must be clearly communicated to customers and extended value system stakeholders. Business leaders must understand what the opportunities for value creation and capture are in a CE and what is a CBM. This element must come prior to the development and adoption of potential CBMs for HVM. Future research is needed to understand the magnitude of CBM value creation versus cost, specific to HVMs, particularly the requirements for intensive upfront capital investments and financing. Given that cost reduction is a fundamental objective for HVMs, it would be important to understand the degree and influence of cost components for different types of CBMs, and how that relates to revenue potential in the same CBM context. Useful to this future research, will be a deeper investigation into measurement metrics for CBMs in HVM. This will be crucial in assessing the success or otherwise of CBMs implementation in HVM.

ACKNOWLEDGEMENTS

This research was supported by the Engineering and Physical Sciences Research Council No. EP/R032041/1. The authors acknowledge the support of the Royal Academy of Engineering (RAEng) and Airbus under the Research Chairs and Senior Research Fellowships scheme (RCSRF1718\5\41). Professor Ashutosh Tiwari is Airbus/RAEng Research Chair in Digitisation for Manufacturing at the University of Sheffield. The authors also wish to express their profound thanks to the industrial partners who provided useful data for this study.

ORCID

Okechukwu Okorie https://orcid.org/0000-0002-5210-9951

Jennifer Russell https://orcid.org/0000-0001-8881-1147

REFERENCES

Adrian, C. (2010). Remanufacturing in the UK. In *Centre for remanufacturing & reuse*.

Amit, R. H., Massa, L., & Zott, C. (2011). The business model: Recent developments and future research. *Journal of Management*.

Antikainen, M., & Valkokari, K. (2016). A framework for sustainable circular business model innovation. *Technology Innovation Management Review*, *5*(7), 1–65.

APSRG, & APMG. (2014). Triple win: The social, economic and environmental case for remanufacturing. In *Policy connect*.

Baines, T. S., Lightfoot, H. W., Evans, S., Neely, A., Greenough, R., Peppard, J., … Wilson, H. (2007). State-of-the-art in product-service systems. *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture*, *221*(10), 1543–1552. https://doi.org/10.1243/09544054JEM858

Bakker, C., Bakker, C. A., den Hollander, M., van Hinte, E., Zijlstra, Y., & Bibliotheek, T. U. Delft (2014). *Products that last: Product design for circular business models*. TU Delft Library.

Beatriz, A., De Sousa, L., Charbel, J., Chiappetta, J., Godinho, M., & David, F. (2018). Industry 4. 0 and the circular economy: A proposed research agenda and original roadmap for sustainable operations. *Annals of Operations Research*, *270*, 273–286. https://doi.org/10.1007/s10479-018-2772-8

Bech, N. M., Niero, M., McAloone, T. C., Kjaer, L. L., & Pigosso, D. C. A. (2018). Product/service-systems for a circular economy: The route to decoupling economic growth from resource consumption? *Journal of Industrial Ecology*, *23*(1), 22–35. https://doi.org/10.1111/jiec.12747

Binder, M., & Edwards, J. S. (2010). Using grounded theory method for theory building in operations management research: A study on inter-firm relationship governance. *International Journal of Operations and Production Management*, *30*(3), 232–259. https://doi.org/10.1108/01443571011024610

Bititci, U. S., Garengo, P., Ates, A., & Nudurupati, S. S. (2015). Value of maturity models in performance measurement. *International Journal of Production Research*, *53*(10), 3062–3085. https://doi.org/10.1080/00207543.2014.970709

Björkdahl, J. (2009). Technology cross-fertilization and the business model: The case of integrating ICTs in mechanical engineering products. *Research Policy*, *38*(9), 1468–1477. https://doi.org/10.1016/j.respol.2009.07.006

Blank, S. G. (2005). The four steps to the epiphany. In *Cafepress. com*. Pascadero, CA: Lulu.com.

Bocken, N., de Pauw, I., Bakker, C., & van der Grinten, B. (2016). Product design and business model strategies for a circular economy. *Journal of Industrial and Production Engineering*, *33*(5), 308–320. https://doi.org/10.1080/21681015.2016.1172124

Bocken, N., Short, S., Rana, P., & Evans, S. (2013). A value mapping tool for sustainable business modelling. *Corporate Governance (Bingley)*, *13*(5), 482–497. https://doi.org/10.1108/CG-06-2013-0078

Bocken, N. M. P., Rana, P., & Short, S. W. (2015). Value mapping for sustainable business thinking. *Journal Of Industrial and Production Engineering*, *32*(1), 67–81. https://doi.org/10.1080/21681015.2014.1000399

Bocken, N. M. P., Schuit, C. S. C., & Kraaijenhagen, C. (2018). Experimenting with a circular business model: Lessons from eight cases. *Environmental Innovation and Societal Transitions*, *28*(December 2017), 79–95. https://doi.org/10.1016/j.eist.2018.02.001

Bocken, N. M. P., Short, S. W., Rana, P., & Evans, S. (2014). A literature and practice review to develop sustainable business model archetypes. *Journal of Cleaner Production*, *65*, 42–56. https://doi.org/10.1016/j.jclepro.2013.11.039

Boons, F., Montalvo, C., Quist, J., & Wagner, M. (2013). Sustainable innovation, business models and economic performance: An overview. *Journal of Cleaner Production*, *45*, 1–8. https://doi.org/10.1016/j.jclepro.2012.08.013

Bowman, C., & Ambrosini, V. (2000). Value creation versus value capture: Towards a coherent definition of value in strategy. *British Journal of Management*, *11*(1), 1–15. https://doi.org/10.1111/1467-8551.00147

Bressanelli, G., Perona, M., & Saccani, N. (2017). Reshaping the washing machine industry through circular economy and product-service system business models. *Procedia CIRP*, *64*, 43–48. https://doi.org/10.1016/j.procir.2017.03.065

Breuer, H., & Lüdeke-Freund, F. (2017). Values-based network and business model innovation. *International Journal of Innovation Management*, *21*(3), 1750028. https://doi.org/10.1142/S1363919617500281

Chen, L. H., Hung, P., & Ma, H. w. (2020). Integrating circular business models and development tools in the circular economy transition process: A firm-level framework. *Business Strategy and the Environment*, June 2019, *29*, 1–12. https://doi.org/10.1002/bse.2477

Circle Economy (2018). *The circularity gap report*. https://www.circularity-gap.world/2020

Daniel, V., Guide, R., & Li, J. (2010). The potential for cannibalization of new products sales by remanufactured products. *Decision Sciences*, *71*(C), 547–572. https://doi.org/10.1016/S0079-6123(08)61824-5

Daou, A., Mallat, C., Chammas, G., Cerantola, N., Kayed, S., & Saliba, N. A. (2020). The Ecocanvas as a business model canvas for a circular economy. *Journal of Cleaner Production*, 120938.

de Angelis, R. (2016). *A conceptualisation of circular business models and explanation of their adoption: Evidence from four in-depth case studies [University of Exeter]*. In. Universty of Exeter. https://doi.org/10.3929/ethz-b-000238666

de Angelis, R. (2018). *Business models in the circular economy*. Palgrave Macmillan. https://doi.org/10.1007/978-3-319-75127-6

De los Ríos, I. C., & Charnley, F. J. (2015). Skills and capabilities for a sustainable and circular economy: The changing role of design. *Cleaner Production Journal*, *November* 2015, 24. https://doi.org/10.1017/CBO9781107415324.004

Eisenhardt, M. (1989). Building theories from case study research. *Academy of Management Review*, *14*(4), 532–550. https://doi.org/10.5465/amr.1989.4308385

Ellen MacArthur Foundation. (2013). Towards the circular economy. In *596/09–08*-2013.

Ellen MacArthur Foundation. (2015). *Growth within: A circular economy vision for a competitive Europe*. Ellen MacArthur Foundation. https://www.ellenmacarthurfoundation.org/publications/growth-within-a-circular-economy-vision-for-a-competitive-europe

Ferrer, G., & Whybark, D. C. (2000). From garbage to goods: Successful remanufacturing systems and skills. *Business Horizons*, *43*(6), 55–64. https://doi.org/10.1016/s0007-6813(00)80023-3

Frank, R. (2000). *Understanding smart sensors* (3rd ed.). Artech House, London.

Frishammar, J., & Parida, V. (2019). Circular business model transformation: A roadmap for incumbent firms. *California Management Review*, *61*(2), 5–29. https://doi.org/10.1177/0008125618811926

Geissdoerfer, M., Savaget, P., Bocken, N. M. P., & Hultink, E. J. (2017). The circular economy—A new sustainability paradigm? *Journal of Cleaner Production*, *143*(January), 757–768. https://doi.org/10.1016/j.jclepro.2016.12.048.CITATION

Giannetti, R., Risso, L., & Cinquini, L. (2016). Managing costs by business model: Issues emerging from the case of E-Car. *Measuring Business Excellence*, *20*(4), 28–45. https://doi.org/10.1108/MBE-08-2016-0039

Govindarajan, V., & Trimble, C. (2010). *The other side of innovation: Solving the execution challenge (Harvard business review)*. Boston, Massachusetts: Harvard Business Review Press. https://store.hbr.org/product/the-other-side-of-innovation-solving-the-execution-challenge/13219

Gustafsson, J. (2017). *Single case studies vs. multiple case studies: A comparative study* (pp. 1–15). Sweden: Academy of Business, Engineering and Science Halmstad University. January 12, 2017

Huaccho Huatuco, L., Martinez, V., Burgess, T. F., & Shaw, N. E. (2019). High value manufacturing (HVM) in the UK: Case studies and focus group insights. *Production Planning and Control*, *30*(1), 60–75. https://doi.org/10.1080/09537287.2018.1524162

Huang, X., Tan, B. L., & Ding, X. (2015). An exploratory survey of green supply chain management in Chinese manufacturing small and medium-sized enterprises pressures and drivers. *Journal of Manufacturing Technology Management*, *26*(1), 80–103. https://doi.org/10.1108/JMTM-05-2012-0053

Jackson, T. (2009). Prosperity without growth: Economics for a finite planet. In *Earthscan*, *London* (Vol. 22) (pp. 1013–1016). London, New York: Earthscan. https://doi.org/10.1260/0958-305X.22.7.1013

Jensen, J. P., Prendeville, S. M., Bocken, N. M. P., & Peck, D. (2019). Creating sustainable value through remanufacturing: Three industry cases. *Journal of Cleaner Production*, *218*, 304–314. https://doi.org/10.1016/j.jclepro.2019.01.301

Joyce, A., & Paquin, R. L. (2016). The triple layered business model canvas: A tool to design more sustainable business models. *Journal of Cleaner Production*, *135*, 1474–1486. https://doi.org/10.1016/j.jclepro.2016.06.067

Kuo, T. C., Ma, H. Y., Huang, S. H., Hu, A. H., & Huang, C. S. (2010). Barrier analysis for product service system using interpretive structural model. *International Journal of Advanced Manufacturing Technology*, *49*(1–4), 407–417. https://doi.org/10.1007/s00170-009-2399-7

Laubscher, M., & Marinelli, T. (2014). Integration of circular economy in business. Going green—Care Innovation 2014, *November*, 1–6. https://doi.org/10.13140/2.1.4864.4164

Lee, J., Suckling, J. R., Lilley, D., & Wilson, G. T. (2016). What is 'value' and how can we capture it from the product value chain? 297–313. https://doi.org/10.1007/978-981-10-0471-1_20

Lewandowski, M. (2016). Designing the business models for circular economy-towards the conceptual framework. *Sustainability (Switzerland)*, *8*(1), 1–28. https://doi.org/10.3390/su8010043

Insider Media Limited. (2018). Yorkshire entrepreneur of the month, Kevin Towers: Towers of Strength.

Linder, M., & Williander, M. (2017). Circular business model innovation: Inherent uncertainties. *Business Strategy and the Environment*, *26*(2), 182–196. https://doi.org/10.1002/bse.1906

Lindkvist, L., & Sundin, E. (2016). The role of product-service systems regarding information feedback transfer in the product life-cycle including remanufacturing. *Procedia CIRP*, *47*, 311–316. https://doi.org/10.1016/j.procir.2016.03.088

Livesey, F. (2006). *Defining high value manufacturing (issue January)*.

Lüdeke-Freund, F., & Boons, F. (2013). Business models for sustainable innovation: State-of-the-art and steps towards a research agenda. *Journal of Cleaner Production*, *45*, 9–19. https://doi.org/10.1016/j.jclepro.2012.07.007

Luiz, D., Nascimento, M., Alencastro, V., Luiz, O., Quelhas, G., Luiz, D., … Quelhas, G. (2018). Exploring industry 4.0 technologies to enable circular economy practices in a manufacturing context: A business model proposal. *Journal of Manufacturing Technology Management*, *30*(3), 607–627.

Lund, R. T., & Mundial, B. (1984). *Remanufacturing: The experience of the United States and implications for developing countries.*, *31*, 126.

MacBryde, J., Paton, S., & Clegg, B. (2013). Understanding high-value manufacturing in Scottish SMEs. *International Journal of Operations and Production Management*, *33*(11), 1579–1598. https://doi.org/10.1108/IJOPM-07-2010-0205

MacBryde, J., Paton, S., & Mendibil, K. (2011). From manufacturing to high value manufacturing: Exploring this transition. *Journal of General Management*, *37*(4), 65–79. https://doi.org/10.1177/030630701003600204

Mäkelä, M., & Turcan, R. V. (2007). Building Grounded Theory in Entrepreneurship Research. *In Handbook of Qualitative Research Methods in Entrepreneurship* (pp. 122-143). Edward Elgar Publishing.

Martinez, V., Neely, A., Ren, G., & Smart, A. (2008). High value manufacturing—Delivering on promise. In *Advanced Institute of Management Research*, London.

Mathews, J. A., & Tan, H. (2011). Progress toward a circular economy in China: The drivers (and inhibitors) of eco-industrial initiative. *Journal of Industrial Ecology*, *15*(3), 435–457. https://doi.org/10.1111/j.1530-9290.2011.00332.x

Matt, D. T., Rauch, E., & Dallasega, P. (2015). Trends towards distributed manufacturing systems and modern forms for their design. *Procedia CIRP*, *33*, 185–190. https://doi.org/10.1016/j.procir.2015.06.034

McGrath, R. G. (2010). Business models: A discovery driven approach. *Long Range Planning*, *43*(2–3), 247–261. https://doi.org/10.1016/j.lrp.2009.07.005

Meadows, D., Randers, J., & Meadows, D. (2004). *Limits to growth: The thirty-year update*. London: Routledge.

Mendoza, J. M. F., Gallego-Schmid, A., & Azapagic, A. (2019). Building a business case for implementation of a circular economy in higher education institutions. *Journal of Cleaner Production*, *220*, 553–567. https://doi.org/10.1016/j.jclepro.2019.02.045

Merli, R., Preziosi, M., & Acampora, A. (2018). How do scholars approach the circular economy? *Journal of Cleaner Production*, *178*, 703–722. https://doi.org/10.1016/j.jclepro.2017.12.112

Moreno, M., de los Rios, C., & Charnley, F. (2016). A conceptual framework for circular design. *Sustainability*, *8*, 1–13. https://doi.org/10.3390/su8090937

Moreno, M., & Charnley, F. (2014). Can re-distributed manufacturing and digital intelligence enable a regenerative economy? An integrative literature review. In R. S. R. J. H. Y. L. P. Theobald (Ed.), *Design and manufacturing* (pp. 18–22). https://doi.org/10.1007/978-3-319-32098-4

Nußholz, J. L. K. (2017). Circular business models: Defining a concept and framing an emerging research field. *Sustainability (Switzerland)*, *9*(10), 14–17. https://doi.org/10.3390/su9101810

Okorie, O., Salonitis, K., Charnley, F., Moreno, M., Turner, C., & Tiwari, A. (2018). Digitisation and the circular economy: A review of current research and future trends. *Energies*, *11*(11). https://doi.org/10.3390/en11113009

Okorie, O., Salonitis, K., Charnley, F., & Turner, C. (2018). A systems dynamics enabled real-time efficiency for fuel cell data-driven remanufacturing. *Journal of Manufacturing and Materials Processing*, *2*(4), 77. https://doi.org/10.3390/jmmp2040077

Osterwalder, A., & Pigneur, Y. (2010). *Business model generation a handbook for visionaries*, *game changers*, *and challengers* (Vol. 30) (pp. 4015–4023). Wileys. https://doi.org/10.1523/JNEUROSCI.0307-10.2010

Paterson, D. A. P., Ijomah, W. L., & Windmill, J. F. C. (2017). End-of-life decision tool with emphasis on remanufacturing. *Journal of Cleaner Production*, *148*, 653–664. https://doi.org/10.1016/j.jclepro.2017.02.011

Pieroni, M., Pigosso, D. C., & McAloone, T. C. (2018). Sustainable qualifying criteria for designing circular business models. *Procedia CIRP*, *69*(May), 799–804. https://doi.org/10.1016/j.procir.2017.11.014

Prahalad, C. (2004). In W. S. Publishing (Ed.), *The fortune at the bottom of the pyramid: Eradicating poverty through profits* (Vol. 28, Issue 4). Wharton School Publishing. https://doi.org/10.1111/j.1468-0270.2008.864_4.x

Raci, V., & Shankar, R. (2005). Analysis of interactions among the barriers of reverse logistics. *Technological Forecasting and Social Change*, *72*(8), 1011–1029. https://doi.org/10.1016/j.techfore.2004.07.002

Rajput, S., & Singh, S. P. (2019). *Industry 4.0—Challenges to implement circular economy*. Benchmarking, June. https://doi.org/10.1108/BIJ-12-2018-0430

Ranta, V., Aarikka-Stenroos, L., & Mäkinen, S. J. (2018). Creating value in the circular economy: A structured multiple-case analysis of business models. *Journal of Cleaner Production*, *201*, 988–1000. https://doi.org/10.1016/j.jclepro.2018.08.072

Richardson, J. (2008). The business model: An integrative framework for strategy execution. *Strategic Change*, *17*(5–6), 133–144. https://doi.org/10.1002/jsc.821

Ries, E. (2011). *The lean startup: How today's entrepreneurs use continuous innovation to create radically successful businesses*. New York: Crown Business.

Rockström, J., Walker, B., Hansen, J., Corell, R. W., Fabry, V. J., Karlberg, L., … Foley, J. (2009). Planetary boundaries: Exploring the safe operating space for humanity. *Ecology and Society*, *14*(2), 32.

Rosa, P., Sassanelli, C., & Terzi, S. (2019a). Circular business models versus circular benefits: An assessment in the waste from electrical and electronic equipments sector. *Journal of Cleaner Production*, *231*, 940–952. https://doi.org/10.1016/j.jclepro.2019.05.310

Rosa, P., Sassanelli, C., & Terzi, S. (2019b). Towards circular business models: A systematic literature review on classification frameworks and archetypes. *Journal of Cleaner Production*, *236*, 117696. https://doi.org/10.1016/j.jclepro.2019.117696

Sachs, J. (2015). *The age of sustainable development*. Columbia University Press. https://doi.org/10.7312/sach17314

Sarasini, S., & Linder, M. (2018). Integrating a business model perspective into transition theory: The example of new mobility services. *Environmental Innovation and Societal Transitions*, *27*(October 2017), 16–31. https://doi.org/10.1016/j.eist.2017.09.004

Sarasvathy, S. D. (2001). Causation and effectuation: Toward a theoretical shift from economic inevitability to entrepreneurial contingency authors (s): Saras D. Sarasvathy source: The academy of management review, Vol. 26, no. 2 (Apr., 2001), pp. 243-263 published by. *The Academy of Management Review*, *26*(2), 243–263. https://doi.org/10.5465/amr.2001.4378020

Saunders, M., Lewis, P., & Thornhill, A. (2012). *Research methods for business students* (6th ed.). England: Pearson Education Limited.

Schenkel, M., Caniëls, M. C. J., Krikke, H., & Van Der Laan, E. (2015). Understanding value creation in closed loop supply chains—Past findings and future directions. *Journal of Manufacturing Systems*, *37*, 729–745. https://doi.org/10.1016/j.jmsy.2015.04.009

Schenkel, M., Krikke, H., Caniëls, M. C. J., Laan, d., & van, E. (2015). Creating integral value for stakeholders in closed loop supply chains. *Journal of Purchasing and Supply Management*, *21*(3), 155–166. https://doi.org/10.1016/j.pursup.2015.04.003

Schröder, M., Falk, B., & Schmitt, R. (2015). Evaluation of cost structures of additive manufacturing processes using a new business model. *Procedia CIRP*, *30*, 311–316. https://doi.org/10.1016/j.procir.2015.02.144

Schulte, U. G. (2013). New business models for a radical change in resource efficiency. *Environmental Innovation and Societal Transitions*, *9*, 43–47. https://doi.org/10.1016/j.eist.2013.09.006

Sminia, H., Ates, A., Paton, S., & Smith, M. (2018). High value manufacturing: Capability, appropriation, and governance. *European Management Journal*, *37*(4), 516–528. https://doi.org/10.1016/j.emj.2018.11.004

Stahel, W. R. (2008). The performance economy: Business models for the functional service economy. *Handbook of Performability Engineering*, 127–138. https://doi.org/10.1007/978-1-84800-131-2_10

Stahel, W. R. (2010). The performance economy: 2nd edition. In *The performance economy: 2nd Edition*. https://doi.org/10.1057/9780230274907

Subramoniam, R., Huisingh, D., & Chinnam, R. B. (2010). Aftermarket remanufacturing strategic planning decision-making framework: Theory & practice. *Journal of Cleaner Production*, *18*(16–17), 1575–1586. https://doi.org/10.1016/j.jclepro.2010.07.022

Susarla, A., Barua, A., & Whinston, A. (2009). A transaction cost perspective of the "software as a service" business model. *Journal of Management Information Systems*, *26*(2), 205–240. https://doi.org/10.2753/MIS0742-1222260209

Teece, D. J. (2010). Business models, business strategy and innovation. *Long Range Planning*, *43*(2–3), 172–194. https://doi.org/10.1016/j.lrp.2009.07.003

UNEP. (2018). *Re-defining value: the manufacturing revolution. Remanufacturing, refurbishment, repair and direct reuse in the circular economy*. Key Insights for Business Leaders.

Upadhyay, A., Akter, S., Adams, L., Kumar, V., & Varma, N. (2019). Investigating "circular business models" in the manufacturing and service sectors. *Journal of Manufacturing Technology Management*, *30*(3), 590–606. https://doi.org/10.1108/JMTM-02-2018-0063

Urbinati, A., Chiaroni, D., & Chiesa, V. (2017). Towards a new taxonomy of circular economy business models. *Journal of Cleaner Production.*, *168*, 487–498. https://doi.org/10.1016/j.jclepro.2017.09.047

van der Velden, N. M., & Vogtländer, J. G. (2017). Monetisation of external socio-economic costs of industrial production: A social-LCA-based case of clothing production. *Journal of Cleaner Production*, *153*, 320–330. https://doi.org/10.1016/j.jclepro.2017.03.161

Van Renswoude, K., Wolde, A.T., & Joustra, D. (2015). Circular business models. Part 1: An introduction to IMSA's circular business model scan. https://doi.org/10.1787/e59f8dd6-en

Vogtlander, J., Mestre, A., Scheepens, A., & Wever, R. (2013). *Eco-efficient value creation; sustainable design and business strategies (issue January)*.

Vogtlander, J. G., Scheepens, A. E., Bocken, N. M. P., & Peck, D. (2017). Combined analyses of costs, market value and eco-costs in circular business models: Eco-efficient value creation in remanufacturing. *Journal of Remanufacturing*, *7*(1), 1–17. https://doi.org/10.1007/s13243-017-0031-9

Wernerfelt, B. (1984). A resource-based view of the firm. *Strategic Management Journal, CINCO*, *5*(2), 1–12. https://doi.org/10.1002/smj.4250050207

Yang, M., Evans, S., Vladimirova, D., & Rana, P. (2017). Value uncaptured perspective for sustainable business model innovation. *Journal of Cleaner Production*, *140*, 1794–1804. https://doi.org/10.1016/j.jclepro.2016.07.102

Yang, S., & Feng, N. (2008). A case study of industrial symbiosis: Nanning Sugar Co., Ltd. in China. *Resources, Conservation and Recycling*, *52*(5), 813–820. https://doi.org/10.1016/j.resconrec.2007.11.008

Zucchella, A., & Previtali, P. (2019). Circular business models for sustainable development: A "waste is food" restorative ecosystem. *Business Strategy and the Environment*, *28*(2), 274–285. https://doi.org/10.1002/bse.2216

How to cite this article: Okorie O, Charnley F, Russell J, Tiwari A, Moreno M. Circular business models in high value manufacturing: Five industry cases to bridge theory and practice. *Bus Strat Env*. 2021;1–23. https://doi.org/10.1002/bse.2715

APPENDIX A: Details of respondents

S/N	Role in company/institution	Industry	Number of employees in company/institution	Total work experience (years)	Educational qualification	Location
1	Founder/Chief Engineer	SME Automobile Manufacturer	21	36	MBA	UK
2	Commercial Manager	SME Automobile Manufacturer	21	15	MBA	UK
3	Head of Production Excellence at Siemens	Transport Mobility	34,200	14	Postgraduate	Germany (Global)
4	Sustainability Manager	ICT Refurbishment	146	17	BA	UK
5	CEO	Automobile parts remanufacturer	55	24	BSc	UK (Europe)
6	Senior Director Sustainability	Lighting Company	32,000	33	MBA	The Netherlands (Global)
7	Academic	University	6,600	7	PhD	UK
8	Academic	University	3,812	9	PhD	The Netherlands
9	Academic	University	4,200	16	PhD	Sweden

APPENDIX B: Semi-Interview Discussion Questions

1. Thinking about the CBM tool that we present in this paper, do you think that this could help support and deepen more sustainable initiatives or programmes in your/a business? If you think it could be helpful, do you think that the CBM tool would support full-scale change, incremental change, or both?
2. Thinking about how the CBM tool and its strategic organization of the five dimensions (value creation, value proposition, value delivery, value capture, and factors of influence), do you have any suggestions for how this tool could be improved to better support and enable your/an organisation?
3. Thinking about the use of digital technologies in your/an organization (e.g. mobile devices, Big Data, remote sensors, modelling), do you think that the combined use of digital technologies and the CMB tool could help to improve Circular Business Model adoption in your/any company?
4. If you were to use the CBM tool within your/an organization to support your adoption of Circular Business Models, do you have any suggestions for how to better integrate and connect the different components of the CBM? E.g., Could value delivery elements and value capture elements be effectively aligned, and how would you go about doing so?