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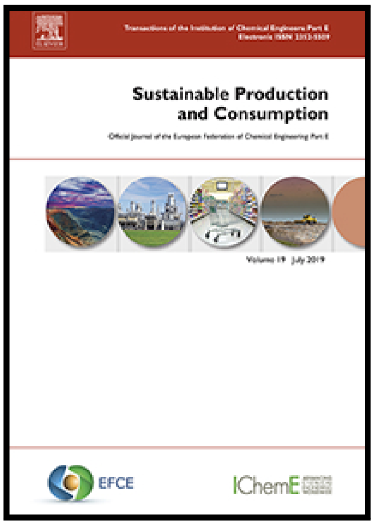

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PII: S2352-5509(21)00051-8
DOI: https://doi.org/10.1016/j.spc.2021.02.013
Reference: SPC 552

To appear in: *Sustainable Production and Consumption*

Received date: 31 August 2020
Revised date: 7 February 2021
Accepted date: 8 February 2021

Please cite this article as: Okechukwu Okorie , Martins Obi , Jennifer Russell , Fiona Charnley , Konstantinos Salonitis , A Triple Bottom Line examination of Product Cannibalisation and Remanufacturing: A Review and Research Agenda, *Sustainable Production and Consumption* (2021), doi: https://doi.org/10.1016/j.spc.2021.02.013

Sustainable Production and Consumption, Volume 27, July 2021, pp. 958-974
DOI:10.1016/j.spc.2021.02.013

A Triple Bottom Line examination of Product Cannibalisation and Remanufacturing: A Review and Research Agenda

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Abstract

Increased momentum in support of a Circular Economy (CE) has motivated the exploration of alternative production and value-retention processes that allow for the decoupling of environmental impacts from economic growth. Remanufacturing, a key value retention process, can enable significant economic, environmental and social (also known as triple-bottom line) advantages. Given their competitive value proposition, remanufactured products are often blamed by original equipment manufacturers (OEMs) for cannibalising the sale of newly manufactured products. Thus, remanufacturing is often viewed as high-risk, and potentially even a threat to conventional manufacturing activities by many OEMs, often triggering both active and passive countermeasures to protect market share. In many cases, such actions lead to reduced access to cores for remanufactures; they can also work against the uptake of remanufacturing activities that are essential for transitioning to a CE. To

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achieve a CE, remanufacturing activities must be scaled; however, without a clear understanding of the relationship between remanufacturing and product cannibalisation, OEMs may continue to avoid and/or interfere in remanufacturing systems. Further, in alignment with systems-thinking for CE, we posit that broadly-considered integration of CE dimensions is critical but lacking within the literature. To this end, this systematic review paper aims to clarify and organize the existing scientific literature about product cannibalisation and remanufacturing. We examine these contributions through an *expanded* Triple Bottom Line lens that aligns with the recognized dimensions of CE: social, environmental, economic, management, policy, and technology. A comprehensive content assessment revealed a predominant economic lens to the research, with statistical analysis, game theory, and numerical experiments as the primary methodologies employed. In addition, opportunities to more comprehensively explore social, policy, management, and technology perspectives as they relate to product cannibalisation and remanufacturing were identified. We develop and apply a new framework for considering product cannibalisation and price competition in the broader context of sustainability and the transition to CE. Finally, in addition to identifying a comprehensive range of stakeholders that need to be engaged, we recommend a future research agenda that explores the specific challenges, interactions, and relationships between product cannibalisation, remanufacturing, and the six dimensions of CE.

Keywords: remanufacturing; circular economy; cannibalisation; systematic review; triple bottom line.

1.0 Introduction

Studying the effects of product cannibalisation and its importance to Original Equipment Manufacturers (OEMs) is well established in product and service literature (Lomax, 1996; Guide and Li, 2010; Kaustov Chakraborty, Mondal and Mukherjee, 2019). Primary reasons for this includes the understanding that an assessment of the expected cannibalisation effect on new products can support decision-making regarding intervention times for new product introduction and promotions (Srinivasan, Ramakrishnan and Grasman, 2005). Furthermore, any new product entering a market is expected to take market share from all the existing players (Ehrenberg, 1991; Guide and Li, 2010). Thus, one of the critical issues associated with existing product lines is the ability to identify and understand its relationship and impact on new product entry. As concluded in several studies, predicting the effects of cannibalisation is both important and challenging for researchers and industry practitioners (Srinivasan, Ramakrishnan and Grasman, 2005; Drezner, 2011; Yeoman, 2012a). Conversely, ignoring its effects can have adverse consequences on the financial performance of a company (Harvey and Kerin, 1979; Kainuma and Disney, 2017).

A number of definitions have been used to describe product cannibalisation. They generally derive their definition from Harvey and Kerin (1979), who stated that it is the "process by which a new product gains sales by diverting sales from an existing product". Other definitions have been contextualised within areas such as marketing (Drezner, 2011), economics and closed supply chains (Drezner, 2011; Yeoman, 2012a; De Giovanni and Ramani, 2018). Within closed loop supply chains, remanufacturers have stated their concerns about product cannibalisation (Guide and Wassenhove, 2001). Remanufacturing operations involve processing used products or components, called "cores", through a sequence of standardized steps (e.g., inspection, disassembly, reconditioning, reassembly, final inspection and testing). The resulting output is a remanufactured product which meets or exceeds the quality and performance standards of a newly manufactured version of the product. Relative to the OEM's newly manufactured product, studies suggest that remanufacturing can save up to 50% of the cost, 60% of the energy, 70% of the material, and 80% of the air pollutant emission (Zhu et al., 2020; Liu et al., 2019; IRP, 2018). Remanufacturing relies on remanufacturers having access to product cores as inputs to the process; however, access to cores remains a critical supply chain challenge for remanufacturers, especially for independent (third-party) remanufacturers. Access to cores is problematic for several reasons, including the fact that cores are often geographically distributed, with their status and condition unknown. In addition to logistical challenges, OEMs are known to actively prevent the supply of these cores to remanufacturers out of concern for the risk that remanufactured products may *cannibalise* new products sales for OEMs (Atasu and Wassenhove, 2010).

Despite the importance of cannibalisation to both OEMs and remanufacturers, insights regarding the potential for, and impact of cannibalisation between new and remanufactured products is limited in literature (Atasu and Wassenhove, 2010). Given the growing prominence and relevance of remanufacturing as a key strategy with the circular economy, a clear comprehension of the risks and impacts of product cannibalization is sought by industry members and policy-makers (Atasu and Wassenhove, 2010). Much of the literature on cannibalisation in the context of remanufacturing is limited to broad themes of economics, product price determination and marketing implications (Drezner, 2011; Yeoman, 2012a; Yang and Hu, 2016). Some studies have analysed competition between OEMs and remanufacturers to better understand the effect of cannibalisation on competition (Ferguson and Toktay, 2006; Wu, 2013; Zhu et al., 2020).

Given the prevalence of concerns regarding the potential for cannibalisation of new products by remanufactured versions, the resulting supply chain interference that inhibits remanufacturer access to product cores, and the need to mitigate these challenges, we propose a triple bottom line (TBL) conceptual framework for tacking the effects of product cannibalism. The TBL is a conceptual framework that attributes firm success to attaining an equilibrium performance between business, environmental and social dimensions (Elkington, 1998) or, alternatively, profit, planet and people (3Ps)

(He *et al.*, 2019). The TBL conceptual framework has been examined across a variety of research areas including supply chain, manufacturing, waste and water management, and business models (Sénéchal, 2017; He *et al.*, 2019; Bilal *et al.*, 2020). TBL has been found to be increasingly important due to its perceived positive impact on competitiveness.

Recognizing the importance of TBL for structuring critical, fair, and accurate appraisals of business systems, researchers have also used the framework within CE literature, slightly reframed as "Circular Economy dimensions" (Geissdoerfer *et al.*, 2017) Geissdoerfer *et al.*, (2018) discuss "CE dimensions" to clarify the various sustainability paradigms that makes up the Circular Economy. Kouhizadeh, Zhu and Sarkis, (2020) address the TBL as being a part of the Ellen MacArthur Foundation's ReSOLVE framework (Ellen MacArthur Foundation, 2015b), linking TBL with blockchain technology.

A peculiarity of the CE concept is in its tendency to be discussed from a multi-dimensional perspective that links to the three pillars of sustainability: economy, environment, and society (Kerin and Pham, 2020). As studies in sustainability evolve, researchers motivated by the UN sustainable development goals have employed other relevant dimensions in the evaluation of CE, including: the role of government (policy), technology, and individuals (management) (Pomponi and Moncaster, 2017). For this study, and in alignment with Pomponi and Moncaster (2017), we adopt an "expanded TBL" framework approach that incorporates society, environment, and economy dimensions, as well as technology, policy, and management. The extant literature suggests that such an approach can result in exhausted, deeper knowledge-based solutions for studies in emerging areas (Carter and Rogers, 2008; Cheng, Yeh and Tu, 2008). In this study, these five dimensions serve as a system of categorisation for the reviewed literature and the basis on which an agenda for new research streams is proposed.

Following these observations, there are some key challenges and gaps that this study seeks to address. First, product cannibalisation remains a critical and contentious issue in the relationship between manufacturers and remanufacturers (Guide, Harrison and Van Wassenhove, 2003). Despite the uptake in studies in related areas such as remanufacturing, circular economy, digital manufacturing, research on product cannibalisation appears to have flat-lined. Secondly, there are no clear research agenda or review studies regarding the study of cannibalisation and its effects on the remanufacturing industry. We identify product cannibalisation review studies on models in maintenance systems (Fisher, 1988), and on sales cannibalisation in information technology markets (Novelli, 2013). Third, despite the common application of systems-thinking within emerging CE research, there has been little discussion regarding product cannibalisation within the context of CE. And, fourth, despite the availability of CE frameworks (e.g., ReSOLVE) and perspectives/dimensions (environment, society, economy, technology, and policy) that are capable of providing CE insights (Ellen MacArthur Foundation, 2015a), these have not been applied within remanufacturing and product cannibalisation literature.

To address these gaps, this study will use a CE perspective to systematize the extensive scientific literature that exists regarding product cannibalisation and the remanufacturing industry, specifically exploring the following questions:

(i.) What existing research related to product cannibalisation and remanufacturing has been conducted, and what methodologies were used?

(ii.) How can a CE be implemented in the remanufacturing industry, given the challenges related to the risk of product cannibalisation?

Accordingly, this study identifies, consolidates, and interprets the existing knowledge base. Using an expanded TBL approach, we then derive a research agenda and managerial implications for practitioners working in CE, remanufacturing, and product cannibalization domains.

The remainder of the paper is organised as follows. Section 2 provides the methodology used to analyse the literature. The results of the systematic literature review are described in Section 3. We outline the findings and propose a research agenda for practitioners and scholars interested in advancing the research of production cannibalisation and remanufacturing in the context of CE in Section 4. Lastly, Section 5 provides concluding remarks, managerial implications, and research limitations.

2. Methodology

2.1 Systematic Literature review

The related scientific publications have been probed using a systematic approach which follows the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines (Moher *et al.*, 2009). The PRISMA guideline follows a four-step process to ensure transparency and reproducibility. (Figure 1)

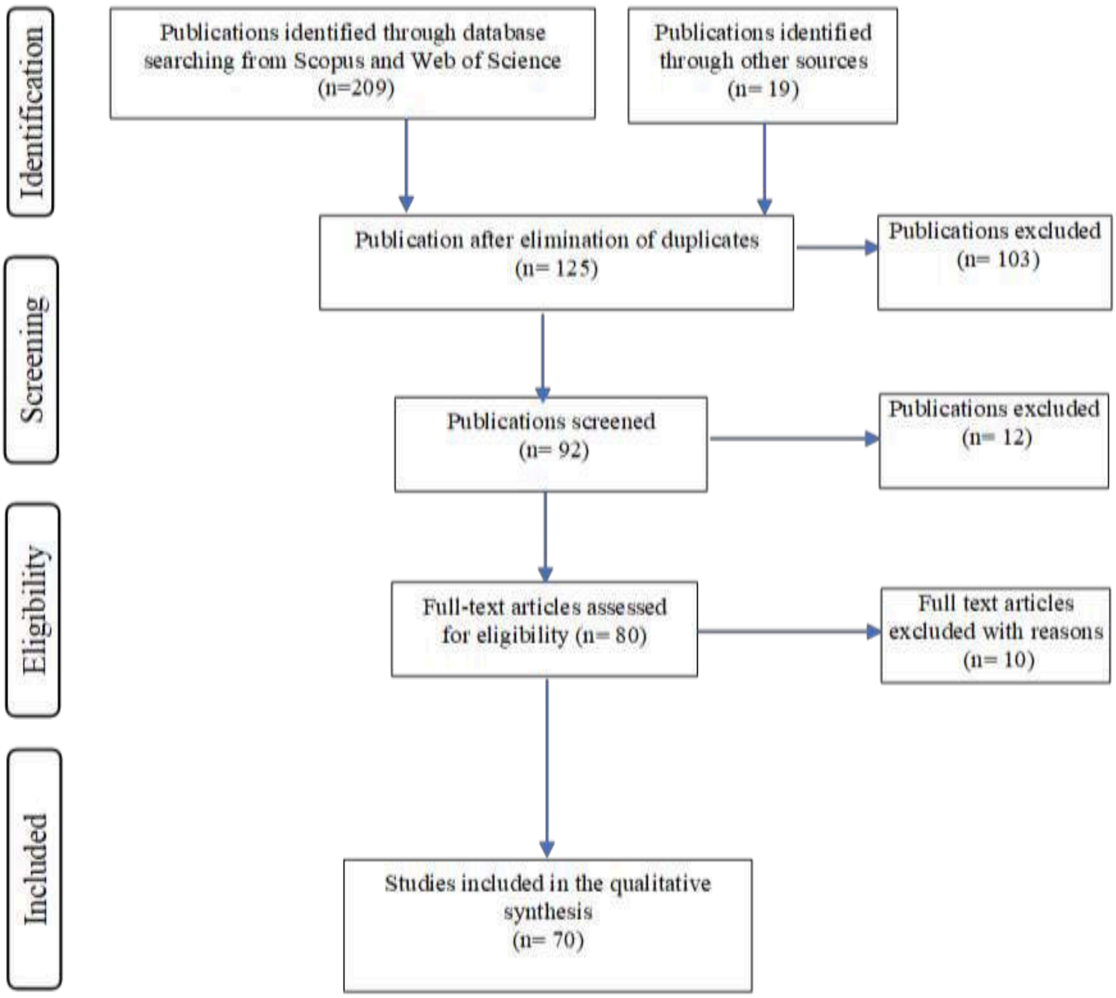

Figure 1: The review process according to PRISMA guidelines (Moher *et al.*, 2009) as has been applied in the present study.

2.1.1 *Identification*

To ensure the identification of relevant studies, keywords such as remanufacturing, cannibalisation, OEM and Circular Economy were grouped into five search entries: 1) “Remanufacturing” and “Cannibalisation”, 2) “Remanufacturing” and “Cannibal*” and “OEM”, 3) “Remanuf*” and “Cannibal*” and “Circular Economy”, 4) “Cannibal*” and “OEM” and “Circular Economy”, and 5) “Remanufacturing” and “OEM” and “Circular Economy”. A search in Scopus and Web of Science - two comprehensive abstract, and citation databases of peer-reviewed literature, scientific journals, books, and conference proceedings led to the identification of 228 publications. Scopus and Web of Science were selected because they index literature from top ranking publishers such as Elsevier, Springer, Taylor & Francis, Sage, Emerald, IEEE, and Cambridge University Press. Cross-referencing was used to complement the initial search (Bressanelli *et al.*, 2020) thus leading to the addition of 19 publications.

2.1.2 *Screening*

An elimination of duplicate publications led to 125 retained publications. To ensure the robustness of this review, only articles published in peer-reviewed journals and conference proceedings were included for screening. Thus, 103 articles were excluded, and the remaining 92 articles were screened by reading the titles and abstracts. Articles not conforming to the objective of the research were excluded (n=12).

2.1.3 *Eligibility and Inclusion*

Three eligibility criteria were used to assess the remaining 80 articles. (i.) Only studies addressing cannibalisation in remanufacturing. (ii.) Publications must include at least one of the following as a keyword, and not just as a cited expression: remanufacturing, cannibalisation, or OEM. (iii.) Research must be related to circular economy or supply chain. This step led to the exclusion of 10 articles. A final set of 70 articles were considered for the analysis.

3. Results

We used two distinct approaches to our analysis. Our initial analysis evaluated the quantitative findings regarding qualitative characteristics of the 70 eligible articles. These findings provide insight regarding the evolution of studies on cannibalisation by remanufactured products over time, in terms of yearly distribution, publication sources and type, geographical distribution, study methodology and the focus industry. Our assessment of qualitative characteristics clarified an improved understanding of how this area of research is developing, while also pinpointing areas for further investigation, and aiding in the formation of a strategy for future research. The later part of our analysis incorporated a more comprehensive document analysis to support the categorisation of the reviewed literature by the appropriate expanded TBL dimension, and by the methodology deployed in each study.

3.1 Literature yearly distribution, type and sources.

The concept of cannibalisation was introduced in the literature in the late 1970's (Harvey and Kerin, 1979), but the connection between cannibalisation and remanufacturing was not made until 2004 (Aras, Esenduran and Altinel, 2004). The number of publications on these integrated topics have shown a slow, general increase since the early 2000's, with a dramatic jump occurring between 2012 and 2013. **(Figure 2)**

The highest number of publications was recorded in 2018 (17%), followed by a decline in 2019 (16%). An increased number of publications is anticipated in 2020 because 6 publications (9%) are recorded at the time of conducting this study (June 2020).

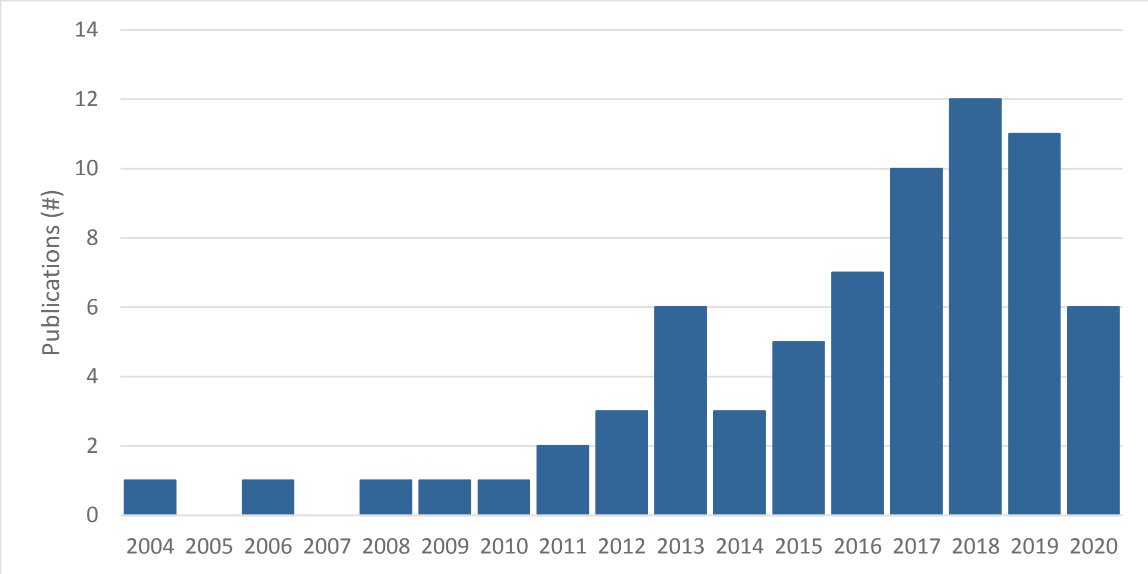

Figure 2: Distribution of reviewed literature by publication year (n=70)

Of the 70 eligible publications that were reviewed, a total of 30 publication sources were recorded, with 63.3% (19) of the sources having each published only one article. Of the sources with greater than one eligible publication, Sustainability (Switzerland) ranked 1st with 9 articles (18%) followed by the Production and Operations Management journal (16%), and the International Journal of Operation Research (14%). Procedia CIRP is the top conference source with 2 publications (4%). Figure 3 displays the quantitative ranking of sources having published more than one article (n>1).

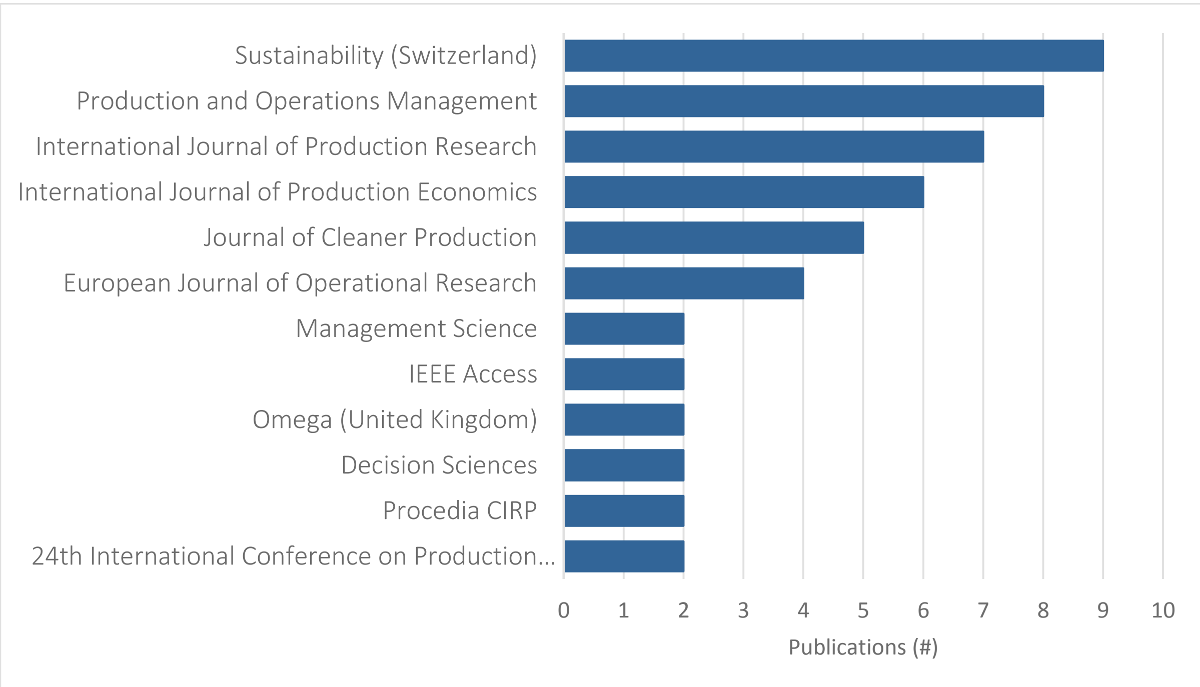

Figure 3: Quantified ranking of sources having published more than one article (n=51)

It is clear that peer-reviewed journals are the predominant publication outlet for studies exploring cannibalisation and remanufacturing (84%), and that there is currently little research output on this topic being disseminated through conference platforms (16%).

3.2 Geographical Contribution to the Literature

Geographical insights regarding the reviewed literature were obtained by analysing the countries in which the authors of these publication were based. It was found that 69 countries, based on the individual count of authors and co-authors, contributed to the literature on cannibalism and remanufacturing. Authorship of these contributions is attributed to researchers based in China (25%), the U.S. (25%), Canada (8%), India (7%), Japan (7%), U.K. (7%), and Indonesia (3%). Denmark, Israel, Korea, and Spain accounted for 2% each of the reviewed literature, and France, Germany, Hong Kong, Hungary, Pakistan, Philippines, Singapore, Sweden, Taiwan, and Turkey were each represented (1%). A map showing the geographical location of the authors of the reviewed literature is presented in Figure 5.

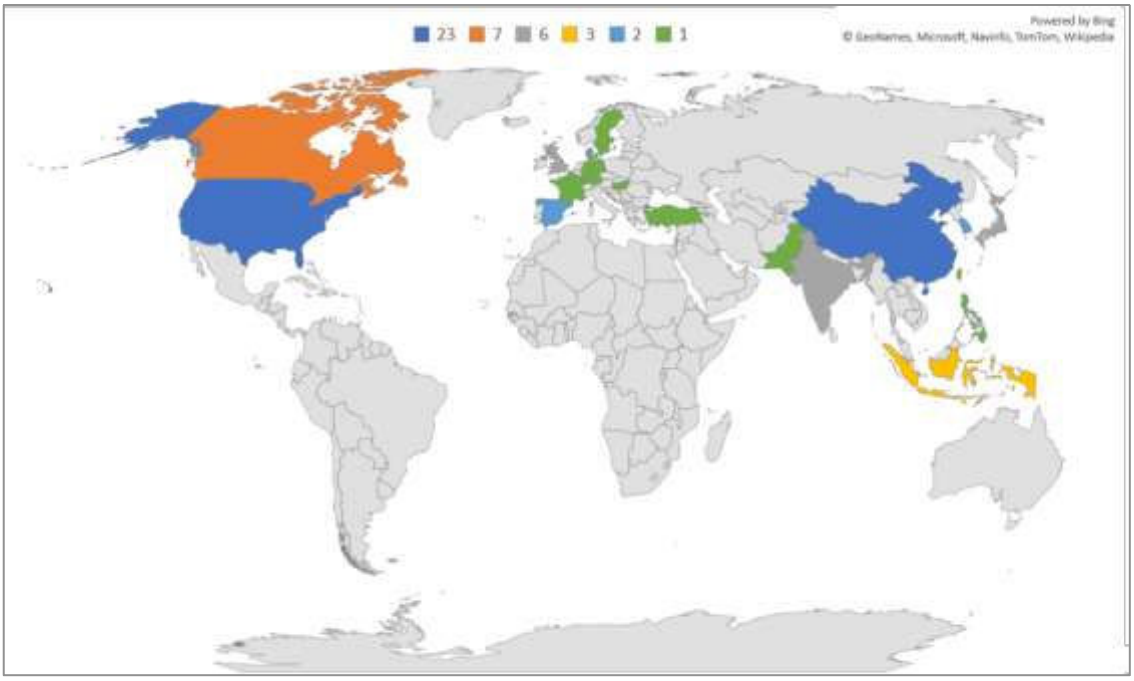

Figure 5: Frequency of publications by authors' country

3.3 Methodology and Industry

The methodologies employed within the reviewed publications were analysed (Figure 6). The result shows that statistical methods (21%) (n=70) were predominant, and these were mainly used to quantify the environmental and sustainability impacts related to product quality choices and uncertainties (He et al., 2020; Liao et al., 2018), as well as price-competition and strategy between OEMs and third-party remanufacturers (TPRs) (Wu & Zhou, 2016; Mitra, 2016), and sales incentives in remanufacturing (Kovach, Atasu and Banerjee, 2018). Game models and theories (17%) were utilised to study sustainable and environmental decisions in remanufacturing settings (Sun et al., 2018; Liu et al., 2018; Yenipazarli, 2016), pricing and taxation strategies (Meng et al., 2020; Wang & Li, 2019), and incentive policies to support remanufacturing (Wang and Li, 2019).

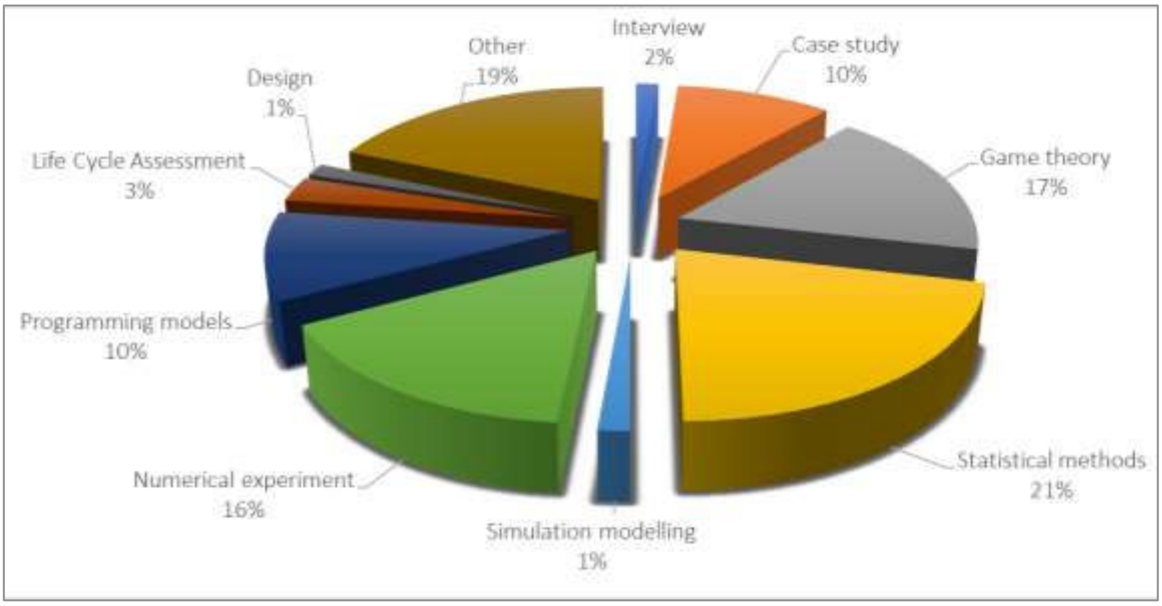

Figure 6: Categorization of study methodologies utilized in the reviewed literature (n=70).

Additional methodologies utilized in the reviewed publications include numerical experiments (16%), case studies (10%) and programming models (10%). Interviews (2%), design (1%) and simulation modelling (1%) were the least employed methodologies.

Of the reviewed literature, only 47 publications (67%) stated the industry that was the focus of their study (Figure 7). Studies show a substantial research targeted to the electronics industry (17%) (Liu *et al.*, 2018), automotive industry (13%) (Ahuja and Terkar, 2020), and product and service (11%) (Linton, 2008).

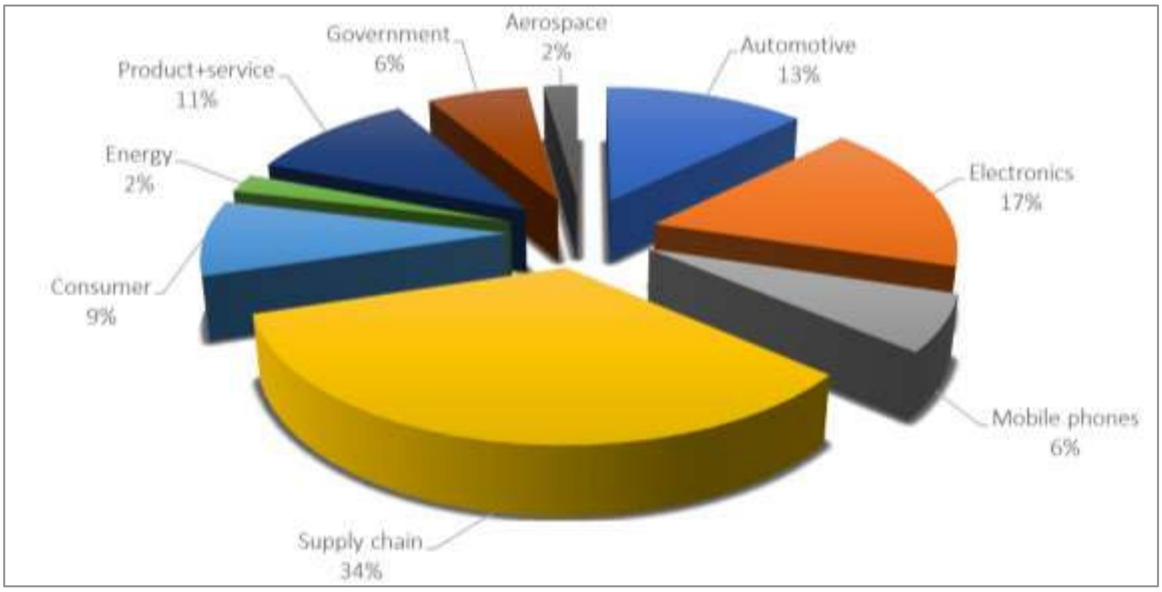

Figure 7: Representation of industry sectors in the reviewed literature (n=47)

3.4 An expanded Triple Bottom Line examination

Table 1 presents a classification of the findings of the reviewed literature using the expanded TBL approach, which include social, economic, environmental, technology, management and policy dimensions. Interpretations of the expanded TBL dimensions, as applied in this study, are described in Table 1.

Table 1: Descriptive summary of expanded TBL dimensions

Dimension	**Description of Perspective/Dimension**
Economic	Relating to the offering of remanufacturing-related products and services in remanufacturing context with an expectation of economic margin to ensure profit (Davlembayeva, Papagiannidis and Alamanos, 2019).
Social	Relating to the maximisation of product and service value as they contribute to social well-being. This includes the social dimension of TBL, the ‘sharing economy’ opportunities of the CE (Zhu *et al.*, 2018)

Environmental	Relating to the reduced environmental burden enabled the partial offset of natural resource consumption, and the pursuit of more environmentally-friendly production activities (Geissdoerfer et al., 2018).
Technology	Relating to the management of demand and supply, storage, and processing of big data that is required for efficient and effective remanufacturing (Pomponi and Moncaster, 2017).
Management	Relating to the coordination and value creation across other dimensions and elements of TBL and CE (Ünal and Shao, 2019). May be viewed and addressed as competitive capabilities within some of the literature (Linton, 2008).
Policy	Relating to the participation of government in ensuring favourable policies for remanufacturers and the impact of policy upon cannibalisation in the context of CE (Wahjudi et al., 2019).

The reviewed literature was classified using the expanded TBL approach to clarify the lenses that researchers have brought to the study of cannibalisation in the context of remanufacturing. Per Figure 8, 59% of the reviewed publications (n=70) study cannibalisation and remanufacturing using an economic perspective, and this is followed by the application of an environmental perspective (19%). The other CE dimensions are represented, but to a lesser degree: social (8%), management (7%), policy (6%) and technology (1%).

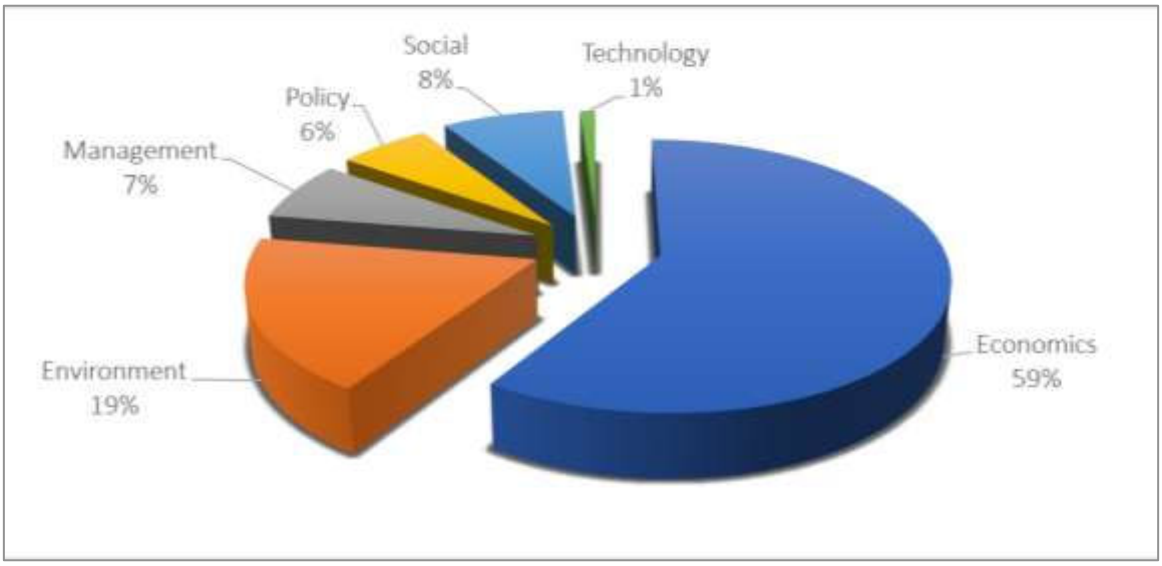

Figure 8: Primary CE dimensions (expanded TBL approaches) applied in the reviewed literature (n=70)

In general, the quantitative analysis of qualitative aspects of the reviewed literature show that product cannibalisation is still discussed within the context of remanufacturing by researchers and practitioners, however discussion tends towards the challenge of product cannibalisation as it relates to other remanufacturing system challenges, such as the *"lack of cores"* and *"availability of cores"* and not the specific concern of product cannibalisation. Generally, research interest in remanufacturing and cannibalisation has been on a constant but modest increase from 2014 till date (Figure 2). The vast majority of these studies assume an economic or environmental lens (Figure 8), with the electronics and supply chain sectors representing the majority of studies that had an industry focus (Figure 7). While statistical methods represent the majority of methodologies used to study cannibalisation in the context of remanufacturing and CE, game theory and numerical experiments are also common (Figure 6). The majority of these papers have been published within *Sustainability* journal, *Production and Operations Management, International Journal of Production Research* and *International Journal of Production Economics,* thus strongly suggesting a recognized alignment of these topics within sustainable production and operations research.

Table 1 summarizes the relationship between the methodologies used in the reviewed literature, and the CE dimension that is the focus of the study. From this summary it becomes clear that there is a lack of research that adopts technology, policy, social and management dimensions, and thus, many of the impacts of product cannibalisation upon these CE dimensions for remanufacturing remain unclear. Similar gaps relating to CE dimensions were identified in the literature review paper exploring CE in the WEEE industry (Bressanelli *et al.*, 2020). The next section examines the identified literature.

Table 2

Summary of methodological approach by Circular Economy dimension

		Circular Economy dimensions					
		Economics	**Environment**	**Management**	**Policy**	**Social**	**Technology**
Methodology	**Programming models**	(Kwak, Koritz and Kim, 2013) (Okuda *et al.*, 2018) (Kwak, 2018) (Hashemi, Chen and Fang, 2014) (Aras, Esenduran and Altinel, 2004) (Wang *et al.*, 2018) (Zhou *et al.*, 2013)	(Wang *et al.*, 2018)	(Zhu and Wang, 2016) (Zhou *et al.*, 2013)	--	(Wu and Zhou, 2016)	--
	Environmental life cycle	(Östlin, Sundin and Björkman, 2009)	(Agrawal *et al.*, 2012) (Östlin, Sundin and Björkman, 2009)	--	--	--	--
	Numerical experiment	(Ovchinnikov, Blass and Raz, 2014) (Kainuma, 2019) (Yamzon *et al.*, 2016) (W. Zhang and He, 2019) (Gan *et al.*, 2017) (Nanasawa and Kainuma, 2017) (H. Liu *et al.*, 2018) (Oraiopoulos, Ferguson and Toktay, 2012) (A. Ovchinnikov, 2011)	(Yang *et al.*, 2018) (Ovchinnikov, Blass and Raz, 2014)	(S. Mitra, 2018) (Liu, Chen and Diallo, 2018)	--	(Yang *et al.*, 2018)	--
	Simulation modelling	(Guleryuz, Kocabas and Ozturk, 2014)	--	--	--	--	--
	Statistical methods	(Liao *et al.*, 2018) (Wang *et al.*, 2019) (Reddy and Kumar, 2020) (K.	(Liao *et al.*, 2018) (Wang *et al.*, 2019)	--	--	--	--

		Chakraborty, Mondal and Mukherjee, 2019) (He, Liang and Wang, 2020) (Raz, Ovchinnikov and Blass, 2017) (Atasu and Souza, 2013) (Mitra, 2016) (Liu, Chen and Diallo, 2018) (Bellos, Ferguson and Toktay, 2017) (Abbey *et al.*, 2017) (Zhou and Gupta, 2020) (Li *et al.*, 2019)	(He, Liang and Wang, 2020) (Raz, Ovchinnikov and Blass, 2017) (Zheng *et al.*, 2019) (Atasu and Souza, 2013)				
	Game Theories	(Wang, Zhang and Yan, 2019) (Mitra, 2018) (Liu *et al.*, 2017) (Chen, Gilbert and Xia, 2016) (Y. Liu *et al.*, 2018) (Sun, Zhang and Li, 2018) (Wen Zhang and He, 2019) (Chen, Venkatadri and Diallo, 2019)	(Wang, Zhang and Yan, 2019) (Yenipazarli, 2016) (Y. Liu *et al.*, 2018) (Sun, Zhang and Li, 2018) (Wang and Li, 2019)	(Zhou, Meng and Yuen, 2020)	(Zhu *et al.*, 2017) (Yenipazarli, 2016) (Meng *et al.*, 2020)	(Wang, Zhang and Yan, 2019) (Li *et al.*, 2018) (Wang and Li, 2019)	(Chen, Gilbert and Xia, 2016)
Methodology	**Case studies**	(Matsumoto and Umeda, 2011) (Hameed *et al.*, 2013) (Linton, 2008) (V. Ahuja and Terkar, 2020) (Loomba and Nakashima, 2012) (Pang *et al.*, 2015) (Chen *et al.*, 2015)	(Matsumoto and Umeda, 2011)	(Linton, 2008)	(V. Ahuja and Terkar, 2020)	--	--
	Interviews	(Wahjudi *et al.*, 2019)	--	--	(Wahjudi *et al.*, 2019)	(Wahjudi *et al.*, 2019)	--
	Design	--	--	--	-	(Naik and Terkar, 2017)	
	Other	(Lacourbe, 2016) (Qian *et al.*, 2019) (Wu, 2013) (Abbey, Blackburn and Guide,	(Qian *et al.*, 2019)	(V.D.R. Guide and Li, 2010)	(Lacourbe, 2016)	(Raz, Ovchinnikov	--

	2015) (Zhu and Wang, 2016) (Zhou *et al.*, 2017) (Steeneck and Sarin, 2018) (Subramanian, Ferguson and Beril Toktay, 2013) (Kovach, Atasu and Banerjee, 2018) (V.D.R. Guide and Li, 2010)		and Blass, 2017)

3.5 Remanufacturing and product cannibalisation as explored through an expanded Triple Bottom Line approach

The relationship between product cannibalisation, remanufacturing, and the transition to a CE is complex, but fundamentally driven by relative prices of an OEM new product, and the remanufactured version (Figure 9). However, the literature reveals additional factors and influences at work within this system that clarify the challenge that product cannibalism can pose for the long-term adoption of remanufacturing as part of a circular economy.

Figure 9 summarizes some of the relationships and underlying causality (direct and indirect) between core themes and factors that were explored and/or revealed by the literature. Arrows connect different factors that are relevant to and/or influence product cannibalism, remanufacturing, and the adoption of circular economy practices. These arrows indicate the presence and directionality of the relationship between various factors; the polarity of the influence is also included to clarify the dynamics (balancing or reinforcing) of this system. The presence of clear economic, social and environmental factors within the system demonstrates the connection between these TBL dimensions, and thus the logic for applying a TBL approach to this analysis. Some of the dynamics of this system are described in the following sections, along with supporting references from the literature. Figure 9 can be used to explain these interconnections and dynamics, and to understand how different system stakeholders may intervene to achieve desired outcomes.

Since the value proposition of remanufactured products is that they meet, or even exceed, the performance of the new version of the product, remanufactured products can be positioned by TPRs in the market as substitutes for new products (Atasu and Wassenhove, 2010; Ferrer and Swaminathan, 2010).

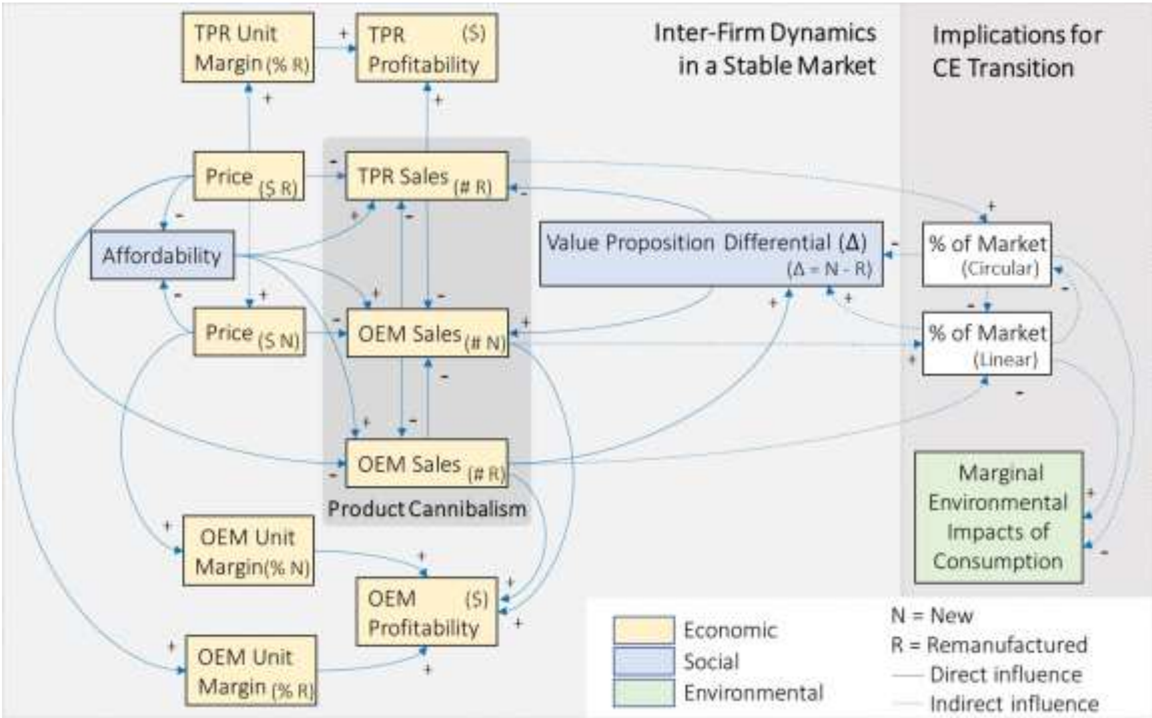

Figure 9: Causal loop diagram of the directional influences between relative prices of remanufactured vs. new products, as they relate to and determine other economic, social, and environmental implications. Note: *[+] indicates the polarity of the relationship, such that an increase in one variable results in a relative increase to the other; [-] indicates that an increase in one variable results in a relative decrease to the other.*

This dynamic between the number of new vs. remanufactured products sold is compounded by the fact that remanufactured products can be produced at a lower cost, and thus TPRs are able to offer significant price discounts while maintaining the required unit margin (Atasu, Sarvary and Van Wassenhove, 2008; International Resource Panel, 2018). OEMs that produce only new products do not have this flexibility, while OEMs that also engage in remanufacturing may be able to pursue a viable price discounting strategy for their remanufactured products (Atasu, Sarvary and Van Wassenhove, 2008; Hong *et al.*, 2020). However, 'who' performs the remanufacturing is an important consideration, as studies suggest that remanufacturing by a TPR serves to improve the perceived quality of the OEM's new product, whereas if the OEM remanufactures, this can undermine quality perceptions regarding the quality of the OEM's new product (Agrawal, Atasu and Van Ittersum, 2015).

Within a hypothetical stable marketplace, in which demand is established and constant (e.g., a set number of customers choose between a remanufactured or new product), product cannibalism may occur because the price discount offered on otherwise 'equal' remanufactured product creates a rational economic argument for the consumer to choose the remanufactured product instead of the new version. In the minds of consumers, the more 'similar' the remanufactured and new products are (e.g., a smaller value proposition differential), the more impactful the price discount offered on the remanufactured product can become (Zhou, Xiong and Jin, 2020). Framed as a decision of "remanufactured vs. new", the product cannibalism risk to the OEM's sales and profitability interests can be understood (Agrawal, Atasu and Van Ittersum, 2015). However, there are other factors to consider: First, other factors besides price can influence perceptions of value proposition (Atasu, Sarvary and Van Wassenhove, 2008; International Resource Panel, 2018); second, having a relatively preferable value proposition does not necessarily equate to a product sale unless the price is also affordable for the customer; and third, in reality, markets are never stable or established, but instead are dynamic with new customers entering and existing customers leaving, consistently (Atasu, Sarvary and Van Wassenhove, 2008; Debo, Toktay and Wassenhove, 2009).

While environmental considerations do not typically and singularly drive the purchase decision for remanufactured products (Atasu, Sarvary and Van Wassenhove, 2008), the environmental advantages, including the relatively lesser carbon- and materials-footprint, and the effective 'life-extension' of the product, presents TPRs with an additional value proposition advantage (International Resource Panel, 2018; Kabel *et al.*, 2020; Reis *et al.*, 2020). When combined with equal or better functionality and lower price, the relative attractiveness of the remanufactured product can be emphasised. In contrast, many OEMs may choose to leverage their brand and reputation, emphasising value proposition arguments grounded in product quality, warranty, and customer service support advantages to clearly differentiate from the TPR (Sun *et al.*, 2020). In this way, OEMs may try to increase the value proposition differential by suggesting that remanufactured products have inherent quality and performance risks that should overwhelm any advantages of price discounts or better environmental performance offered by remanufacturing. Interestingly, consumers seem to differentiate remanufactured vs. new products as part of their evaluation process, in terms of their sensitivity to different factors. As noted by Sun et al. (2020), consumers who are mainly interested in acquiring a new product tend to be more sensitive to price, while consumers who are interested in acquiring a remanufactured product tend to also be sensitive to perceived quality and reliability. Thus, the methods and emphasis of the OEM and TPR differentiation strategy are important to consider in the context of potential cannibalisation.

Regardless of other factors, the often-significant price discount on remanufactured products, made possible by lower marginal costs, contributes to a very dynamic market place. At lower prices, new consumers are able to afford, and therefore engage in the market (e.g., purchase the remanufactured product) when they otherwise would not be able to (Giuntini and Gaudette, 2003). This suggests that some sales of remanufactured products may not necessarily 'cannibalise' the sale of new products, and that instead the market base may actually be expanded by the presence of remanufactured options.

Fundamentally, these issues are tied to the transition to a CE because of the balance between new and remanufactured products that are present in the marketplace, and thus the portion of the industry sector that is engaging in remanufacturing activities (Figure 9). As the number of remanufactured product sales increases, and provided that the remanufacturing sales rate exceeds the sales rate of the new products, there can be a shift of the production balance towards a circular (vs. linear) economy. As an extension of this shift, and acknowledging the marginal environmental benefits of remanufactured vs. new products, the greater the share of the market that is 'circular', the relatively lesser environmental impacts associated with aggregate production and consumption.

Thus, although not directly connected, the response that OEMs and TPRs have to concerns about, and realities of product cannibalism and remanufacturing can ultimately influence the potential for the transition to the CE, and the mitigation of environmental impacts associated with consumption-production systems.

Accordingly, the reviewed literature was classified into the expanded TBL approach, as identified in Section 1, to unravel how research has attempted to study the effect of cannibalisation in the context of remanufacturing. Figure 8 shows that the majority of the publications (n=70) study cannibalisation and remanufacturing from the economic perspective (59%), and the environmental perspective (19%). While there are publications on the other CE dimensions, these represent a lesser share of the research: social (8%), management (7%), policy (6%) and technology (1%). The following analysis examines the literature in greater detail, assessing the economic and environment dimensions individually, and grouping the literature into a technology/management dimensions cluster, and a social/policy dimensions cluster

3.6.1 Economic Dimension

Pricing and its impact on remanufacturing have been predominantly studied (Anton Ovchinnikov, 2011; Zhu and Wang, 2018; Meng *et al.*, 2020) because it is a key enabler of cannibalisation. For OEMs and TPRs, there are several factors that influence price differentials between *used* and *remanufactured* products, including but not limited to seller reputation, warranty duration, proxies of demand and supply of remanufactured products, and the duration and availability of a return policy (Pang *et al.*, 2015). Studies report a mixed result in the pricing strategy of both new and remanufactured products. While some studies suggest that the price of new products should decrease or be stable when competitive remanufactured products enter the market (Ovchinnikov et al., 2014), the findings from Abbey, Blackburn, et al., (2015) report that the optimal price of new products should increase with the inflow of remanufactured products. Liu et al., (2018) corroborates these findings by developing a model that considers the price of the new and remanufactured products at different periods; results indicate that the optimal pricing strategy is to set the price of the remanufactured product lower than the price of the new product at all times. The potential threat of cannibalisation posed by remanufactured products has led some OEMs to explore how the inclusion of remanufactured products in their portfolios, to ascertain their profitability (Wu, 2013). Linton, (2008) affirms that OEMs will earn greater overall profit by offering both new and remanufactured versions of their products. The uptake of remanufacturing by OEMs is likely to increase economic competition between new and remanufactured products (Debo, Toktay and Wassenhove, 2009) and by extention, the competiton between OEMs and TPRs for both resources (e.g., cores) and customers (Atasu, Sarvary and Van Wassenhove, 2008; Agrawal, Atasu and Van Ittersum, 2015).

It is also worth noting that an increase in consumer demand for remanufactured products may also contribute to OEM motivation to adopt remanufacturing activities, or to interfere in the supply of cores available to TPRs. Given the demonstrated practice of substantial price discounts, the provision of competitive warranties, and the potential environmental benefit, the value proposition of remanufactured products is increasingly competitive, relative to the OEM's new version of the product (International Resource Panel, 2018).

Several studies have investigated OEM competition strategy in the context of remanufacturing. Ferrer & Swaminathan, (2010) investigated the competition between OEMs and TPRs and found that OEMs tend to decide to remanufacture recovered products/cores when competition intensifies. Findings from Bulmus et al., (2014) indicate that OEMs may opt to manufacture fewer new products if the cost-benefit of remanufacturing diminishes and if remanufacturer demand for cores increases. OEMs may choose not to remanufacture their products or develop a recovery strategy for their products/cores out of concern that it may lead to the cannibalisation of higher-margin new products. However, as identified by Feruson and Toktay (2006b), this may result in a boomerang-effect. While some OEMs such as Dell and IBM offer free take-back programs for used products (computers) to support their parallel remanufacturing ventures/divisions, other firms such as

Bosch and Lexmark offer incentives to customers to motivate a higher return-rate for those used products (Valenta 2004). Consumers' preferences affect the market share of remanufactured products from either OEMs or TPRs, hence, authorisation becomes petinent (Liu et al., 2018). Moreover, consumers expect quality remanufactured products with a warranty, at very low prices (Wang & Hazen, 2016). Regardless of the actual price, consumers prefer OEM's product or OEM's authorised remanufactured products than the non-authorised ones (Liu et al., 2018).

The reviewed literature in the economic context has shown that cannibalisation in remanufacturing has been examined from the pricing perspective, pointing to the factors that determine pricing strategies for both new and remanufactured products; further, consideration of cannibalism can inform how OEMs reach optimum pricing points for their new products. The implications of pricing, and indirectly, the risk of product cannibalism, are also discussed in the context and conditions of competition between OEMs and TPRs. Furthermore, consumer preferences and their effect on pricing strategies and positioning of remanufactured products have been captured within the existing literature. Despite the substantial research into product cannibalisation and remanufacturing from the economic perspective, we posit that there is still room to explore and expand exisiting and emerging research themes of cannibalisation and remanufacturing in the areas of business models, and business and economic metrics.

3.6.2 Environmental Dimension

Remanufacturing offers relative environmental advantages when compared to the impacts associated with conventional manufacturing. However, it is a complicated system with mixed findings especially in the cannibalisation context (Liao *et al.*, 2018). Various studies have attempted to study cannibalisation and remanufacturing within the environmental dimension. Liao et al., (2018) evaluated the environmental benefits of remanufacturing under quality uncertainty by comparatively analysing the carbon emissions between different remanufacturing scenarios. Wang et al., (2019) presented an optimisation model for remanufactured product planning that accounds for the total GHG emission from production. Yenipazarli, (2016) points out that the introduction of heavy charges/taxes on carbon emissions can lead to the internalisation of environmental costs, and can help to drive remanufacturing investments. However, there is the risk of a higher degree of product cannibalisation in the product line where new and manufactured products coexist.

Studies have shown that cannibalisation can lead to positive outcomes while also maximising the environmental impacts of remanufacturing. A relationship between a firm's environmental impact and cannibalisation by remanufactured products was established by Ovchinnikov et al., (2014). Using an analytical model and behavioural study, the authors demonstrate that the introduction of remanufactured products can result in cannibalisation that subsequntly leads to a decrease in environmental impact, without impacting the price of new products. More recently, He et al., (2020) developed models to analyse the environmental implications of the desired product quality level under outsourced remanufacturing conditions. Their work revealed that above the threashold for environmental impact, integrated remanufacturing activities can be beneficial for OEMs; however, for TPRs, outsourcing the remanufacturing process is often equally or more environmentally beneficial. Depending on the conditions of the recovery and remanufacturing system, unintended consequences can stem from the increase in remanufacturing. As presented by Atasu & Souza, (2013), if reused cores or components are not of high-quality, enabling higher profitability, then overall consumption may increase, generating greater negative environmental impacts. Similarly, in a study by Zheng et al., (2019) to ascertain the impacts of Design for Environment (DfE) on a firms' production-quantity decision,the authors suggest that under certain conditions, high levels of DfE could negatively impact the environment, as a result of increased total sales of remanufactured products. Thus, cannibalisation by remanufactured products may lead to marginal decreases in environmental impact; however, as alluded by Zink and Geyer (2017), these environmental gains may be offset if the production system and sales strategy leads to an overall increase in consumption.

Competition and collaboration between OEMs and/or TPRs can also impact the environment. Raz et al., (2017) showed that competition between firms may worsen total environmental impact as a result of market expansion caused by the introduction of remanufacturing. Similarly, a more recent finding from Wang et al., (2019) shows that OEMs with options to remanufacture can actually *increase* environmental impacts if they choose to collaborate with TPRs to do so. Thus, in spite of the potential operational benefits, collaboration may not generate environmental benefits.

There are diverse views regarding the impact of cannibalisation by remanufactured products upon the environment, and additional considerations including competition, product recovery, and outsourcing have been incorporated into many of these studies to assertain the associated environmental consequences. Despite the expanding base of knowledge regarding the environmental implications of cannibalisation and remanufacturing, there remains opportunity to explore additional CE dimensions including the role of "green consumers", and the broader life-cycle considerations associated with cannibalisation at the systems-level.

3.6.3 Social and Policy Dimensions.

The next stream of literature assesses the social and policy dimensions of the research on cannibalisation and remanufacturing. Very few studies have considered the social perspective. Raz et al., (2017) asserts that the price reduction and market expansion create additional consumer surplus; further, lower price points may enable economic access for those who otherwise would not be able to pariticpate in the marketplace (International Resource Panel, 2018). Yang et al., (2018) considered the retailers' differentiated response strategies and how they affect the welfare issues related to our society. By considering the consumers' willingness to pay for both new and remanufactured products, the authors pointed out that an increased social welfare is achieved if the level of eco-centrism is not too pronounced.

Contratry to popular assertions, Wahjudi et al., (2019) identified prestige concerns as a form of social barrier to the acceptance of remanufactured products, and social expectation in terms of the positive societal image and more job opportunities, as drivers of increased remanufacturing. Social expectations of remanufacturing (e.g., adopting a charitable donations perspective) was studied by Li et al., (2018). The price of remanufactured products is typically 30 ~40% lower than that of new products and the unit-cost is typically 40~65% of the cost of new products (Giuntini and Gaudette, 2003), hence, remanufactured products may be perceived as more suitable for donations and the promotion of Corporate Social Responsibilities. Similarly, from the social welfare perspective, Yue Wang & Li, (2019) evaluated the optimal price level for remanufactured products, and identified situations where incorporating tax on remanufactured products could worsen societal welfare.

Government interventions and legislation play an essential role in dealing with cannibalisation and remanufacturing. In durable goods industries, managing cannibalisation can pose a huge challenge. Some OEMs opt to destroy unsold/unused products in order to avoid cannibalisation, and may cause huge losses to themselves and the society at large, in addition to environmental impacts. Lacourbe, (2016) suggests that exporting used products to a physically separate market can reduce the level of cannibalisation within the domestic market. Moreover, government policies can help facilitate this by imposing restrictions or penalties on used/remanufactured products, which tends to push them out of the market and stimulates export (International Resource Panel, 2018). Subsidy policies can help to weaken cannibalisation of new product sales, as noted by Zhu et al. (2017), who compared a policy that subsidised the *donation* of remanufactured products against the prevailing policy in which the *resale* of remanufactured products by government was subsidized. Meng et al., (2020) recently investigated the optimal government consumption subsidy policy in which OEMs manufacture new products and TPRs remanufacture used products from consumers. Using a game model, and contrary to earlier findings on government policies, the authors concluded that the offer of a consumption-based subsidy can cannibalise demand for new product while boosting demand for remanufactured products. Other studies on policy allude to the use of carbon emission taxes in order to realise the inherent triple bottom line opportunities of remanufacturing (economics, environmental, and social benefits) (Yenipazarli, 2016), as well as the implications of government intervention to permit the free trade of remanufactured products (Vinay Ahuja and Terkar, 2020).

3.6.4 Management and Technology Dimensions.

Management professionals are often critical of whether to engage in remanufacturing, and firms approach the decision from various perspectives. Managers in many manufacturing firms believe that new product sales are cannibalised by the sale of remanufactured products; because corporate profitability is often strongly linked to the volume of new product sales, managers may consider remanufacturing to be counterproductive (Mitra, 2018) as a rational economic option (Linton, 2008). An HP sales manager in Germany shared the same perspective during a project aimed at recovering greater value from product return (Guide et al., 2005). A contrary view was expressed by managers in firms that specialise in capital goods that are more commonly remanufactured (e.g., imaging equipment). They showed little or no concerns for cannibalisation, and agree that although some cannibalisation may occur, the sales of remanufactured products tends to increase market shares (Guide and Li, 2010).

Some specific studies have provided managerial insights on remanufacturing decisions, the sales of new and remanufactured products, and remanufacturing authorisation. Zhou et al., (2013) provided managerial insights by considering a decentralised closed-loop supply chain where OEMs purchased new components from one supplier to produce new products, and collected used products from consumers to be used for remanufacturing. Insights from this study were summarised in a conceptual framework that suggests OEMs may engage in remanufacturing without considering the trade-off between the cost saving of remanufacturing and cannibalisation of new product sales. Zhu & Wang, (2016) studied the effectiveness of adopting a trade-in program in selling new and remanufactured products on both primary and replacement segments of their product lines. A more recent study by Zhou et al., (2020) utlised a Stackelberg game to explore the decision making processes of OEMs and TPRs regarding the implementation of remanufacturing authorisation. The authors advise that managers should consider affordable and profitable authorisation fees because it leads to a win-win situation for OEMs and TPRs.

Studies of the impact of technology upon cannibalisation or remanufacturing are limited, and research regarding the integration of these topics has received even less attention. A significant work was performed by Chen et al., (2016) regarding how OEMs can induce suppliers to offer more favourable prices to downstream buyers. Their findings reveal that by committing to offer a "lowest available" wholesale price, technology-sharing by the incumbent OEM is imperative, and thus the supplier, the incumbent OEM, and the rival become better positioned.

3.7 Summary of findings

Remanufacturing is understood to be a key contributor to sustainable development, owing to the social, economic and environmental benefits that are possible through circular business models (Linton, 2008; Rathore, Kota and Chakrabarti, 2011; UNEP, 2018). We expand these dimensions to include management, technology, and policy lenses, thus capturing an expanded TBL approach. This review examines the CE implications of remanufacturing and product cannibalization through a review of the literature, as described in the review protocol (Section 2.0). Overall, we find support for this approach, first, in the clarification of whether and how economic, environmental, social, management, technology and policy dimensions are currently incorporated into to the literature, and second, by synthesising a research agenda to more comprehensively explore the relationships and influences between product cannibalisation and remanufacturing. Findings suggest that the economic and environmental perspectives are relatively clear and understood. Compared to the volume of publications that adopt economic and environmental perspectives, the existing literature does little to advance understanding across technology, social, management and policy dimensions. To move towards a CE through better understanding of the implications of product cannibalisation and remanufacturing, the social, policy, technology and management implications need to be further explored.

4.0 Discussion

This study synthesises existing literature regarding product cannibalisation and remanufacturing within the context of a circular economy. While remanufacturing and product cannibalisation exist as individual and integrated studies, there are no studies that examine these areas as they influence the transition to a CE. In order to investigate the existing work in this area and to develop a meaningful research agenda, a systematic literature review was conducted. This section discusses the results of the review and the various CE perspectives as identified. From this a research agenda is proposed.

4.1 Product cannibalisation and remanufacturing: State of research.

We discovered that, while there has been an increase in the papers examining both topics between 2004 and 2020, none of these examines product cannibalisation through the sustainability lens, or using a TBL approach. We also observe that studies on product cannibalisation have not continued to increase in recent years, despite the fact that product cannibalisation has remained a very contentious issue for both OEMs and remanufacturers. For example, in response to the challenge faced by TPRs trying to access cores, OEMs have largely blamed the situation on product cannibalisation (Kurilova-Palisaitiene, Sundin and Poksinska, 2018; Okechukwu Okorie, Salonitis, Charnley and Turner, 2018). Our findings show that over 59% of the papers focused on topics within the larger set of economics. This is consistent with the citation network analysis by Lee and Kwak (Lee and Kwak, 2018), which found that out of 7,300 articles, the main research topics associated with remanufacturing focused on topics of cost and profit in the market, business models, and price optimisation models. Much of what we have discovered is aligned with scholarly findings related to remanufacturing research. A number of studies have attempted to broadly compartmentalise integrated research areas of the circular economy into the areas of environmental, economic, social, policy and technology. These include circular economy and manufacturing (Lieder and Rashid, 2016), circular economy and Industry 4.0 (Okechukwu Okorie, Salonitis, Charnley, Moreno, *et al.*, 2018), remanufacturing and Industry 4.0 (Kerin and Pham, 2020), and blockchain and circular economy (Liu and Liu, 2013; Stenmarck, Quested and Moates, 2016; Farooque, Zhang and Liu, 2019). A key insight from our analysis is that there is only very limited research into the technology, social, policy and management dimensions, and that the environmental dimension tends to be overlooked in comparison to the economic dimension. This presents several challenges and opportunities for remanufacturing and cannibalisation research within the context of the circular economy.

As observed, the research has employed a varied mix of methodologies that are common to the CE literature (Geissdoerfer *et al.*, 2017; Beatriz *et al.*, 2018; Goyal, Esposito and Kapoor, 2018). These include, programming models, (environmental) life cycle analysis, simulation modelling, statistical methods, game theories, case studies and interviews, amongst others. As the current integrated remanufacturing and product cannibalization research also tends towards a heavy focus on qualitative studies, there is an opportunity to apply new streams of quantitative methodologies (e.g., agent-based modelling, multi-criteria decision analysis, multi-method modelling) to support or critique existing theory and qualitative research. There is also additional opportunity to support expanded research work in this space using surveys and industry case studies (Charter and Gray, 2008).

4.2 Product cannibalisation and remanufacturing: Geography of research.

Most of published research on this integrated topic emanates from the U.S. (25%) and China (25%), of the reviewed literature (n=70). We argue that this is primarily because the U.S. was among the first nations to have identified the environmental and social benefits of remanufacturing (Hauser and Lund, 2003; Hauser, W., 2003) and have continued to see remanufacturing as an economic driver (Hauser, W., 2008). In contrast, uptake in remanufacturing in China has been largely driven through policy and legislation that are fundamentally oriented towards CE (Yuan Zengwei, Bi Jun, 2006; Geng and Doberstein, 2008; Mathews and Tan, 2016).

Europe has seen an uptake of research in the CE in recent years. In their paper examining a worldwide research on the CE and environment, Ruiz-real et al.(Ruiz-real *et al.*, 2018) found out that out of 25 countries, ranked in terms of the number of articles, citations, and h-index in this subject area, 17 were from Europe.

The industrialized status, and well-established manufacturing sectors in these countries have also enabled data collection, research, and analysis to explore the interactions between product cannibalisation and remanufacturing. It is important to note that calls have been made to ensure that industrializing and non-industrialized economies have access to CE technologies, such as remanufacturing. Thus, highlighting the absence of research contributions, and therefore the opportunity for future focus, technology transfer, and increased capacity in these economies is an important consideration for the transition to CE (International Resource Panel, 2018).

4.3 Product cannibalisation and remanufacturing: Expanded triple bottom line research focus.

The majority of the reviewed literature focuses on the economic dimension, where 59% of research investigated aspects such as product pricing, secondary market competition, sales, and inventory planning, as they relate to the relative profitability of remanufacturing operations. Indirectly related to these economic elements, particularly product pricing, is a systemic lack of access and supply or cores, which has been identified by remanufacturers as one of their key challenges (Ijomah, 2009; Casper and Sundin, 2018; Kurilova-Palisaitiene, Sundin and Poksinska, 2018). However, it is important to note that while substantial economic modelling research has been performed to enhance demand forecasting, price optimisation, and price elasticity in the context of remanufactured products, these studies have typically ignored the effect of product cannibalism (Yeoman, 2012b). This may be due to the difficulty in measuring the effects of cannibalisation, as well as the difficulty in capturing all related variables within an optimisation algorithm (Yeoman, 2012b). Given this oversight, we suggest that an answer to challenges of product cannibalisation and remanufacturing may be revealed through a broad, robust focus on the social, policy, technology aspects of the expanded TBL.

Of the 47 papers that revealed an industry sector focus, the representation of industry sectors within the research was observed to be relatively balanced. The supply chain industry accounted for the most substantial share (34%), while the smallest shares were held by aerospace and energy sectors (2%, respectively); however, we note that these industries are actually quite interconnected, and hence, argue that the industry focus is fairly balanced. However, when paralleled with the key sectors that are known to engage in remanufacturing (Adrian, 2010), several sectors do not appear: construction, office furniture, pumps and compressors, ink and toner cartridges and clothing. We argue that research studies designed to include a broader selection of industry sectors can offer cross-sector insights, and therefore may lead to more meaningful CE research and opportunities. For example, clothing and fashion have been common case study sectors in a number of CE-related publications, but these studies do not yet address issues of product cannibalisation and other remanufacturing themes (Setterwall Rydberg, 2016; Sandvik and Stubbs, 2017; Alcayaga and Hansen, 2019).

4.4 *Circular economy implementation in remanufacturing industry in the context of product cannibalisation: A research agenda.*

As product differentiation between new and remanufactured products becomes increasingly prevalent as a result of manual tagging, RFID, and other technologies, cannibalisation remains a concern for OEMs (Atasu and Wassenhove, 2010). The cost advantages enabled via remanufacturing allows the remanufacturer to provide significant price discounts (Kurilova-Palisaitiene and Sundin, 2014) in order to compete against the new version of the same product from the OEM (Ijomah *et al.*, 2007; Atasu and Wassenhove, 2010; De Giovanni and Ramani, 2018). The discounted pricing strategy utilized by a remanufacturer may trigger the OEM to reduce the sale price of the new product; alternately, it may spur the OEM to seek differentiation through marketing strategies, i.e., emphasising the quality, value, performance, and brand associated with the new product, as justification of the price premium. In some cases, OEMs may attempt to counterbalance the effect of cannibalisation by undertaking their own remanufacturing operations (hence called Original Equipment Remanufacturers or OERs).

Using examples from the various papers reviewed as well as the authors' experience in developing research agenda from review studies (O. Okorie *et al.*, 2018), we propose a research agenda (Table 3). This agenda captures the expanded TBL elements, a brief definition, stakeholders and the research agenda which combines the perspectives, definition and stakeholders. Similar research agenda-setting has been employed in several literature (Bocken, Rana and Short, 2015; Murray, Skene and Haynes, 2017; Centobelli *et al.*, 2020; Kerin and Pham, 2020). Key *stakeholders* are identified and designed into the research agenda in order to ensure an appreciation for managerial implications. We envision that these stakeholders, as identified in several CE studies (Leipold and Petit-Boix, 2018; Okechukwu Okorie, Salonitis, Charnley, Moreno, *et al.*, 2018; Bertassini *et al.*, 2021), will engage in helping to set and guide this research agenda, especially as this area is emergent. For industry-based researchers and practitioners, the research agenda can help to enable the transition to a circular economy while providing new insights regarding the potential for product cannibalisation. For academic researchers, the research agenda proposes statements which can generate research questions, extend the research on remanufacturing, and re-emphasise remanufacturing role in the circular economy.

Table 3: Research agenda for remanufacturing and OEM product cannibalisation

CE Dimension	Description	Stakeholder(s)	Emerging research agenda
Economic	Relating to the offering of remanufacturing-related products and services in remanufacturing context with an expectation of economic margin to ensure profit.	Academia, government policymakers, remanufacturing business/ economic units	1. Investigate price volatility for remanufacturers to understand effect of product cannibalisation. 2. Develop business models to capture value for remanufactured goods with reduced cores supply. 3. Identify key remanufacturing business metrics to support circular business models while managing the downside of cannibalisation. 4. Modelling techniques needed to capture economic metrics for remanufacturing, product cannibalisation and circular value for remanufacturers.
Technology	Relating to the management of demand and supply, storage, and processing of big data that is required for efficient and effective remanufacturing (Pomponi and Moncaster, 2017).	Reman customers, reman mid-level managers, OEMs	1. Investigate price volatility for remanufacturers to understand effect of product cannibalisation. 2. Digital technologies to support quality assessment of remanufactured products and their implications for CE transition. 3. Identify data requirements needed for simulation modelling, survey and experiment methodology needed to understand the impact/value of technology on managing product cannibalisation.
Environmental	Relating to the reduced environmental burden enabled the partial offset of natural resource consumption, and the pursuit of more environmentally-friendly production activities (Geissdoerfer et al., 2018).	Government, non-governmental policymakers, remanufacturing sustainability units.	1. Understanding of green consumers and their impact on cannibalisation. 2. Understanding the impact of cannibalisation on OERs and the environment. 3. Explore how product cannibalisation affects the broader biological cycles within a circular economy.

Policy	Relating to the participation of government in ensuring favourable policies for remanufacturers and the impact of policy upon cannibalisation in the context of CE (Wahjudi et al., 2019).	Top-level reman managers, policymakers, academia.	1. Examine relationship between taxation and cannibalisation and develop policy from study. 2. Product take back legislation Vs voluntary take back for product recovery. How does it affect quality choices and influence policy? 3. Develop policy focused on incentivising OEM and remanufacturer in order to limit cannibalisation and/or optimise/create symbiosis between OEM and remanufacturer. Map this policy to CE transition principles
Social	Relating to the maximisation of product and service value as they contribute to social well-being. This includes the social dimension of TBL, the 'sharing economy' opportunities of the CE.	Academia/research institutes, policymakers, remanufacturers.	1. Identity and prioritise who should remanufacture (OERs, IRs or TPRs), within existing social context for the CE? 2. Identification of enabling stakeholders for remanufacturing and OEM product cannibalism. 3. Build collaboration between OEM and remanufacturers by identifying where both needs intersect in the context of managing product cannibalisation for a CE. 4. Investigate the skillsets of workers.
Management	Relating to the coordination and value creation across other dimensions and elements of TBL and CE (Ünal and Shao, 2019). May be viewed and addressed as competitive capabilities within some of the literature (Linton, 2008).	Top and middle level managers.	1. Identify the "soft" metrics for capturing and measuring value needed to commit management in prioritising product cannibalisation challenges for remanufacturers. 2. Explore how decision-making within remanufacturing influences product cannibalisation and identify key stakeholders.

5.0 Conclusions

There is an increasing focus on EOL strategies by academic, government, non-governmental and industrial stakeholders as environmental, financial and regulatory pressures compel businesses to examine new and improved methods for increasing material- and process efficiency, and reducing waste (Goodall, Rosamond and Harding, 2014). As remanufacturing is more energy efficient in comparison to traditional manufacturing and has clear social, economic and environmental benefits, this EOL strategy has seen an uptake in research and policy discussions. For remanufacturing to be truly sustainable and viable business model, the challenge of ensuring access to cores by both TPRs and OEMs must be addressed. The current view that remanufactured products cannibalise the sales of new products acts as a disincentive for OEMs to engage in remanufacturing activities, and an incentive for OEMs to restrict the supply of product cores and spare parts that are critical inputs for TPRs. Thus, the lack of clear understanding regarding the interactions and influence of remanufacturing and product cannibalisation, pose a major challenge to the uptake of remanufacturing, and the CE in general.

This study aimed to breathe life into the areas of remanufacturing and product cannibalisation research by clarifying the known relationships and influences, and applying an expanded TBL lens to a review of the literature. The contribution of this study is three-fold. As the first of its kind, it presents the findings of a systematic review of the published review on the integrated area of remanufacturing and product cannibalisation with respect to an expanded version of the TBL approach. Secondly, it provides a clear framework grounded in CE dimensions that allows for a systematic and comprehensive consideration of the existing literature on remanufacturing and product cannibalisation. Thirdly, as an extension of the gaps revealed by this analysis, a clear research agenda is organized and presented, with the objective of clarifying how continued research into the relationship between product cannibalisation and remanufacturing can support not only the remanufacturing industry and the OEMs and TPRs that operate in across diverse sectors, but can also support improved strategies for the transition to a CE.

We have clarified the most commonly-used methodologies and case study sectors, as well as clear knowledge gaps and opportunities for future research. Future research can also support the CE transition by exploring and quantifying opportunities for the mutual benefit of remanufacturers and OEMs, and whether remanufacturers and OEMs can find a common ground with regard to the challenge of product cannibalisation. Reconciling the tension between the sale of new vs. remanufactured products will be important if we are to realize the potential of remanufacturing as an important tool for sustainable development.

Declaration of Competing Interest
None

ACKNOWLEDGMENT

Okorie is grateful to the UK Engineering and Physical Sciences Research Council No. EP/R032041/1 who allowed him to work on this study. This study developed from Okorie's time as a Visiting Research Fellow at Golisano Institute of Sustainability, Rochester Institute of Technology, New York. Their support during the period of his fellowship is acknowledged.

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2021-02-10

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Okorie O, Obi M, Russell J, et al., (2021) A triple bottom line examination of product cannibalisation and remanufacturing: a review and research agenda. Sustainable Production and Consumption, Volume 27, July 2021, pp. 958-974

https://doi.org/10.1016/j.spc.2021.02.013