Proceedings of the IS4CE2020 Conference of the
International Society for the Circular Economy
6 – 7 July 2020, University of Exeter, Exeter
https://www.is4ce.org

The reuse economy for digital technologies: A rapid review

***Okechukwu Okorie[1], Jennifer D. Russell[2] and Fiona Charnley[1].**

[1]Exeter Centre for the Circular Economy, University of Exeter, Rennes Drive, Exeter, EX4 4PU, UK
[2]Dept. of Sustainable Biomaterials, Virginia Tech, 1650 Research Centre Dr., Blacksburg VA 24601 USA

*o.s.okorie@exeter.ac.uk.

Abstract
This study outlines the research undertaken to evaluate the reuse economy for digital technologies. While the direct reuse of products offer the lowest economic and environmental impact, the reuse economy for ubiquitous products such as digital technologies is still lacking in research. Furthermore, there is still lack of clarity on what digital technologies means with regard to identifying a research agenda within the context of the circular economy. Using a rapid review of evidence, we identify and empirically examine 47 papers from the literature relating to reuse economy, circular economy and digital technologies. Overall, the paper shows that there is a relative research emphasis on technological, socio-cultural, and environmental aspects of reuse. Economy and policy aspects of the reuse economy, important for advancing circular economy research and understanding value within this reuse economy, remains latent. As a resource efficient circular economy includes maximising value for economic benefits, advancing this area of research will be important especially for the informal sector of developing economies. We also observe that product and process scales of these digital technologies do not largely contribute to the current investigation on reuse economy. We link this slow uptake in research to the lack of clarity experienced in understanding what constitutes digital technologies within the context of reuse economy. Finally, we develop a research agenda across the five dimensions of sustainability, highlighting reuse economy research emphasis for the economy and policy aspect of the circular economy.

Keywords: *direct reuse; circular economy; digital technologies; literature review; methods*

Introduction
High-profile discussions regarding the transition to a Circular Economy (CE) extort the environmental and economic opportunities enabled by the adoption of advanced technologies, product design and business model innovation, and the overhaul of existing infrastructure and policy (Ellen MacArthur Foundation, 2015; International Resource Panel, 2018). However, when combined with the general absence of a social dimension to CE (Murray et al., 2017), such emphasis on technology and innovation poses the risk of creating further disparity in CE participation, making CE less accessible for both individuals and economies as a result of social and/or economic conditions (International Resource Panel, 2018). The high-tech emphasis of CE discourse and research may have facilitated a potential 'blind spot' in CE research into which lower-tech solutions grounded in socio-cultural contexts, such as reuse and repair, are ignored. Ironically, of all the proposed CE activities, reuse and repair are among those that have been practiced the longest by human communities (Strasser, 2000).

Reuse and direct reuse, arguably, offer the lowest economic and environmental impacts within the CE portfolio of activities; this is due to the fact that direct reuse retains the inherent form of the product or component, and requires little-to-no additional resource inputs to enable another service life (IRP 2018). As long as the reuse activity displaces the production and use of a 'new' product, significant environmental and economic impacts associated with primary production can be avoided (Cooper & Gutowski, 2017).

Digital technologies have been identified as critical tools in the transition to CE, as part of the fourth industrial revolution (Industry 4.0) that consists of 3D printing, the Internet of Things (IoT), and Big Data and Analysis (Bressanelli et al., 2018). At the same time, digital technology hardware (e.g. laptops, tablets, smart phones) must also be physically managed within CE systems. Given the potential for reuse to serve as an accessible, low-impact CE solution, and as a mechanism to address the increasing role of digital

technologies in industry and in the waste stream, this study has as its main goal to clarify and describe the literature on the reuse economy for digital technologies.

Method

This study employed a "rapid review" (RR) approach. According to (Ganann et al., 2010) RR's are defined as, *"reviews that use methods to accelerate or streamline traditional systematic review processes".* Others, such as (Wright & Bragge, 2018) argue that RR is needed when an overview of evidence is required in a short time. While there is no singular definition for RR in the literature, there are several characteristics of RR that differentiates it from other review types, such as systematic literature review or scoping review. They focus on already synthesised research evidence (Khangura et al., 2012), generally take a shorter time to develop (Borg et al., 2019; Temple University Libraries, 2020; Watt et al., 2008b) and provide an overview of the assessed field in a short time frame (Rasmussen et al., 2018; Watt et al., 2008a). It follows the systematic review protocol in identifying a search strategy and keywords, identifying the research database, setting inclusion and exclusion criteria for literature screening and selection, data extraction and evaluation. A synthesising of findings follows the data evaluation.

The short timeframe advantage (≤ 5 weeks) which rapid review offers is the main rationale for its choice in this study. It is employed in science and humanities research and enables the industry, practice and policy bodies to be informed by research evidence sooner (Borg et al., 2019). This study contributes to the broader area of circular economy, sustainability and climate change research. The urgency of these areas enables elucidation of a broad range of behavioural interventions, frequently required by researchers and policy makers (Watt et al., 2008b). For clarity and transparency reasons we used the PRISMA statement to direct our data collection process (Moher et al., 2009).

We undertake a comprehensive search of peer-reviewed articles as identified from multiple search databases of SCOPUS, Web of Science and Google Scholar. This search was performed on the 28th of May 2020 as stated in the literature review protocol in Table 1 below.

Table 1: Literature Review Protocol

Item	Description/ Criteria	Rationale
Time Period	2000- 2020	As this "reuse economy" review is the first of its kind, there are no reference reviews to limit how far back we can go. Also, key scoping terms (Sustainability and Circular Economy) only became mainstream after 2000
Boolean Operators	AND between keywords; OR between Database search fields	This is common in literature review studies (Temple University Libraries, 2020)
Language	English	This is the language of the researchers
Article Type	Original studies only	Exclude reviews, letters and editorials. This is consistent with systematic reviews
Geography	Global but with regional focus identified	This is important ensuring we do not exclude relevant studies, insights and methodologies and/or themes that are emerging due to diverse global approaches to sustainability and CE research and policy
Types of research outputs	Case studies, action-based research, descriptive research e.g models, analytical research (e.g. quantitative measurement and/or models)	This is consistent with the need to focus on the context of reuse and the reuse economy, as substantiated by case studies and action-based research. This is also important in enabling the development of a research agenda for reuse economy (motivated by descriptive research insights, e.g models).

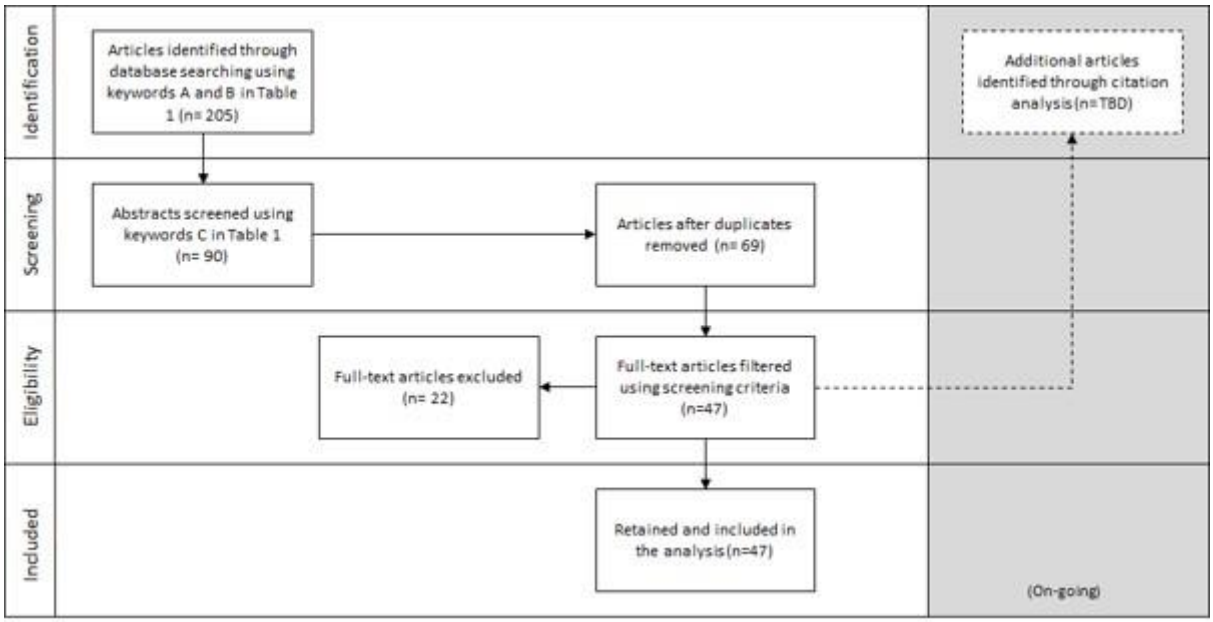
We identify the key term of the research to be "direct reuse". This refers to the redistribution of a product at its end-of-use (EoU), for an additional service life performing its original intended use, and for which minimal-to-no repairs or modifications are required. Direct Reuse may occur between consumers (C2C), business-to-consumer (B2C), or business-to-business (B2B) transactions. Direct Reuse channels may include exchange (e.g. non-monetary transaction), donation (e.g. charity), commercial (e.g. for monetary payment), and end-of-use/end-of-life management (e.g. product take-back).

The rationale for this is predicated on the understanding that the term "reuse" is too broad and implies any form of redistribution, repurposing, etc. of a product and/or its components (International Resource Panel, 2018). Interest of this study is on the redistribution of products (maintained in their inherent form), for their original intended purpose (e.g. a mobile phone to be reused as a mobile phone), and requiring minimal-to-no repairs or modifications prior to redistribution.

The context for direct reuse must be embedded in the concept of sustainability for society and/or environment, and/or embedded in the concept of circular economy. The research lens may include social and/or environmental and/or economic perspectives and interests. The rationale for the research scope is predicated on the understanding that Direct Reuse is identified as a key component of the waste management hierarchy (Reduce, Reuse, Recycle) and within the Circular Economy. Thus, it is explored in the context of retaining material and product value within economic systems (as opposed to cultural and/or social contexts)

As the terminology used to describe a systematic review and meta-analysis has evolved over time, the need to encompass both systematic review (which includes rapid review employed in this study) and meta-analyses has increased. The PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) was developed by medical researchers in 2009 (Moher et al., 2009) and employed in this study, for data collection. This is captured in a flow chart in Figure 1.

Figure 1: PRISMA flow diagram of the data collection process.



We run our search using three identified databases: SCOPUS, Web of Science and Google Scholar. All three databases are frequently used in review studies across sciences and humanities research (Borg et al., 2019; Okorie et al., 2018; Webster et al., 2020) (Table 2).

Table 2: Keywords used in database searching

Code	Keywords	Web of Science	SCOPUS	Google Scholar	Total
A	(circular economy OR reuse economy) AND (consumer product reuse OR second hand reuse) NOT (textile* OR apparel OR cloth* OR fashion)	107	64	--	171
B	"Direct Reuse Economy" OR "Reuse Economy Products" OR "Direct secondary reuse products" OR "Consumer-to-Consumer product reuse" OR "Circular Economy Direct Reuse"	--	--	34	34
C	"ICT" OR "consumer product*" OR "consumer electronic*" OR "EEE" OR "WEEE" OR "digital technolog*"	--	--	--	25

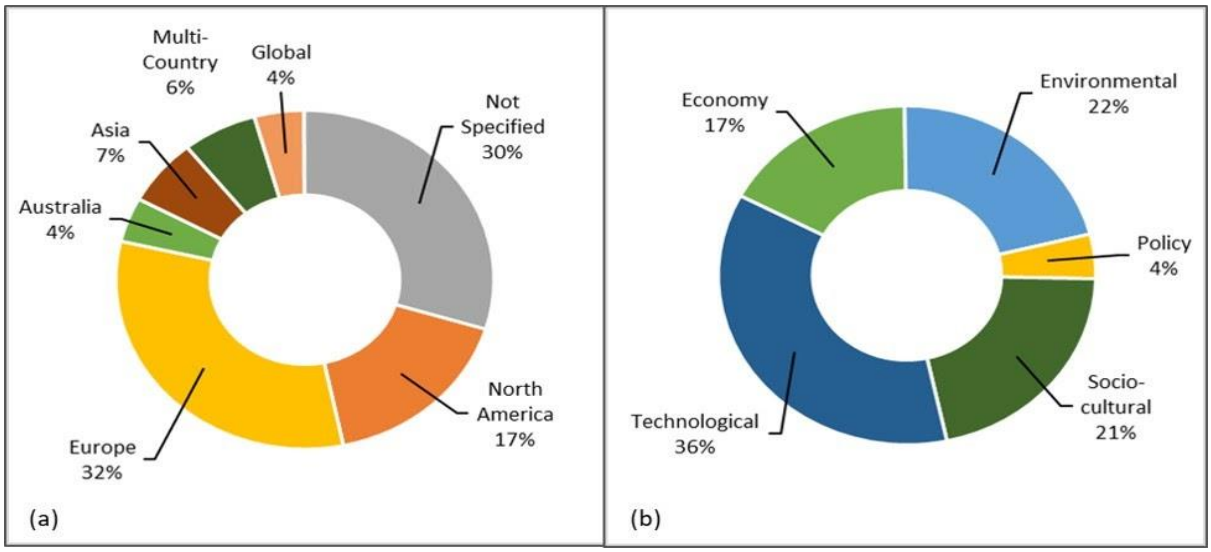
We apply the inclusion and exclusion criteria as indicated in Table 1 and analyse the articles based on the key terms and the research scope. After these were applied we obtained the following results; Web of Science: 37 articles were found to be applicable for our research, 19 articles were found to be applicable to our research in SCOPUS and 34 articles were found to be applicable to our research in Google Scholar. Thereafter duplicates were removed from the returned articles and 69 articles were returned. Finally, full-text articles were excluded from the search and a final outcome of 47 articles retained for analysis. The next section captures the analysis of these articles their and results.

RESULTS

The geographic representation of the included articles was assessed (Figure 2(a)), and a deductive analysis was conducted across three thematic areas. First, included articles were organized by the five domains of sustainability to clarify the primary lens with which the research study was conducted, as well as the targeted research contribution (Figure 2(b)); included articles were then organized by the scale at which the research was conducted, to clarify the current representation of micro-, meso-, and macro-perspectives regarding reuse activities (Figure 3(a)); and finally, included articles were organized by the product-focus of the research (if any), to delineate the presence of digital technology-specific research and insights - the primary interest of this study - relative to general EEE, other products, and non-product-related reuse studies (Figure 3(b)).

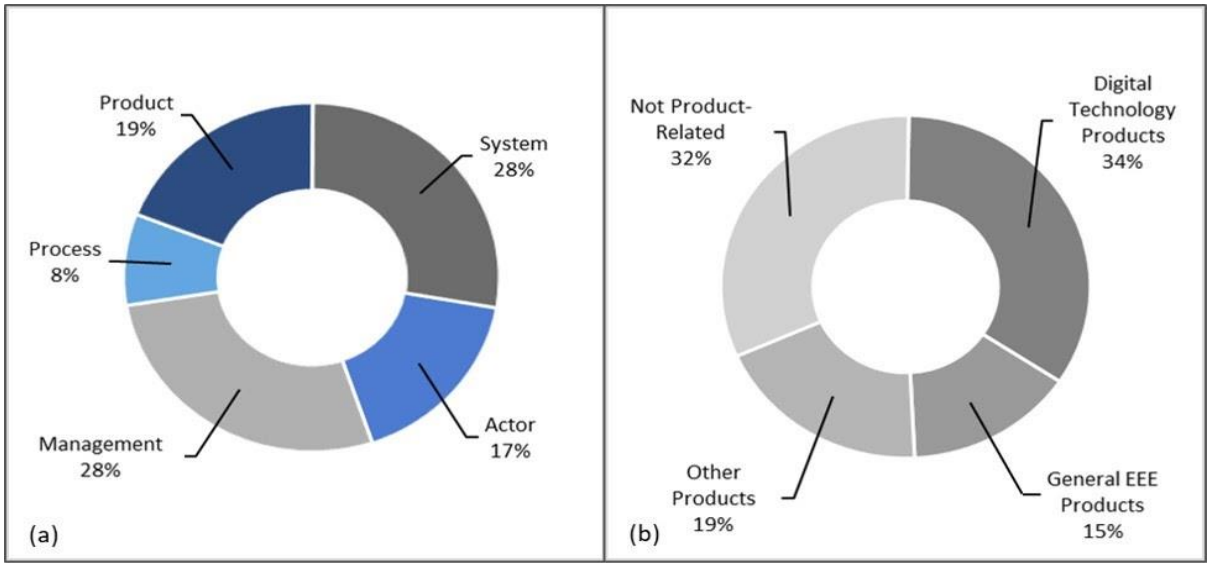
As shown in Figure 2(b), despite the desire for balance across the dimensions of sustainability, there is a relative research emphasis on technological, socio-cultural, and environmental aspects of reuse; this unsurprisingly reflects the mechanisms (technological), conventional sustainability motivation (environmental), and actors and networks (socio-cultural), associated with reuse activities.

Figure 2: Included articles, organized by (a) geography, and (b) the five domains of sustainability (n=47)



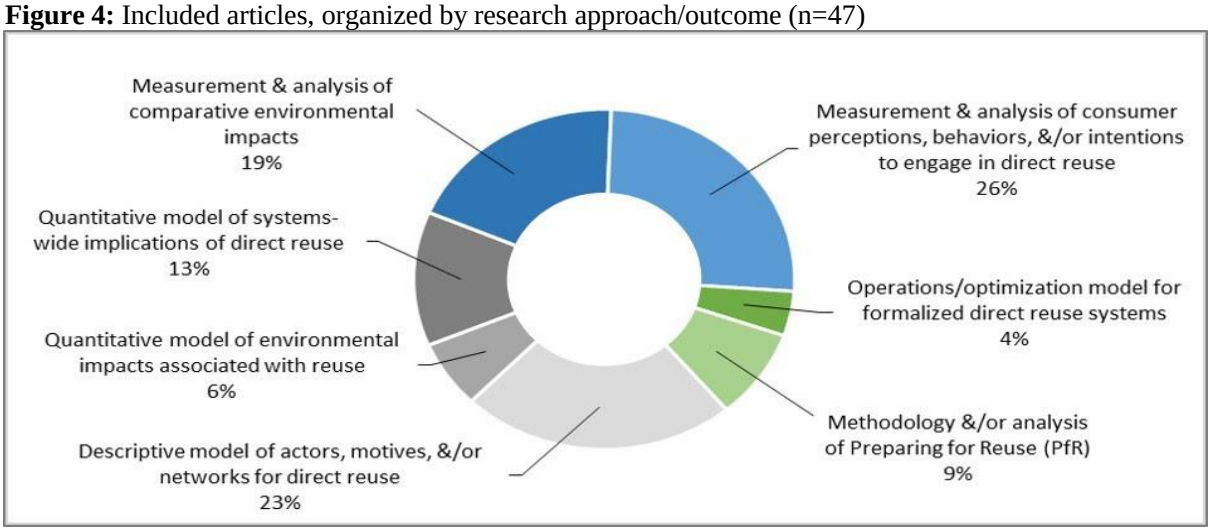
As shown in Figure 3 (a), system- and management-scales accounted for the majority (56%) of the reviewed literature, with product- and process-scales, largely represented by applied case studies, as a secondary emphasis (27%). Actor-focused research, predominated by consumer surveys, was also a clearly identifiable theme (17%). Finally, despite the search emphasis on digital technologies (and variations, i.e., consumer electronics), only 34% of included articles specifically addressed the reuse of products that could be classified as "digital technology" (Figure 3(b)). Often, these products were rolled into studies of general electrical and electronic equipment (EEE), including home appliances. Almost one-third (32%) of the relevant literature on reuse economy was not product-related.

Figure 3: Included articles, organized by (a) scale of the research focus, and (b) product-focus (n=47)



To support the development of a research agenda regarding a reuse economy for digital technology, an inductive analysis of full-text articles was conducted to identify emerging themes and patterns regarding the focus, approach, and outputs of the current literature (Figure 4). This analysis revealed three primary themes: Qualitative and quantitative models to describe the interrelationships between direct reuse, environmental impacts, social motivations and networks, and economic factors (42%); comparative measurement studies to quantify environmental and/or economic impacts of reuse activities vs. replacement and other CE options (45%); and models and/or methodologies to optimize operations and logistics within formal reuse systems (13%).

Figure 4: Included articles, organized by research approach/outcome (n=47)



Discussion

This study aimed to investigate the state of the art of the reuse economy for digital technologies using a rapid review methodological protocol. This rapid review of evidence suggests that there is lack of clarity into what constitutes "digital technologies" concerning the reuse economy and that this may have an impact in a balanced diffusion of reuse across all dimension of sustainability. As described in Figure 3b, at least 32% of included literature captured non-digital technology products, and an additional 32% were not product-focused at all; the generalization of reuse economy research and insights may fail to meaningfully support the pursuit of a reuse economy specific to the high-value and unique nature of digital technologies, and also fails to incorporate key CE research learnings, namely that implementation requires product-specific and local focus and solutions (André et al., 2019; International Resource Panel, 2018). Further, this review highlighted that the classification of digital technologies alongside other EEE) may be problematic: Despite the fact that consumer perceptions of value, reuse logistics and PfR methodologies, and economic models differ significantly between household appliances (e.g. microwaves, VCRs) and digital technologies (e.g. laptops, smart phones) (Simpson et al., 2019; Van Loon et al., 2018), however, all are captured similarly within WEEE policy and programming around the world.

When paralleled by research drawn from other fields (Okorie et al., 2018), the findings show that research emphasis on reuse is firmly focused on the technological, environmental and sociocultural aspects of the reuse economy. Successful implementation of CE requires compatible promotion of sustainable economic development (Qiao & Qiao, 2013) effective policy (Hopkinson et al., 2018); however, as described in Table 3, policy-focused research into the reuse economy is lacking, alongside other important themes including decision-support tools for various actors within reuse economy, as well as quantitative assessments of integrated environmental and economic impacts of reuse (vs. one or the other).

Table 3: Clarification of reuse research emphasis across dimensions of sustainability, to highlight future research needs and opportunities

Reuse Research Emphasis	**Dimensions of Sustainability**					
	Economy	**Env.**	**Policy**	**Socio-cultural**	**Technological**	**Total**
Actors, interactions, &/or transactions within reuse systems	3			1		**4**
Barriers to &/or opportunities for reuse			1		4	**5**
Consumer perceptions & behaviours	1			8	3	**12**
Decision-support for actors in reuse systems					2	**2**
Economic impacts	3			1		**4**
Efficient/optimized reuse operations		2			7	**9**
Environmental & economic impacts	1	2				**3**
Environmental impacts		6	1		1	**8**
Total	**8**	**10**	**2**	**10**	**17**	**47**

Addressing these gaps is a critical part of future research into the reuse economy, particularly for digital technologies. The urgency of this need is emphasised by the increasing ubiquitous nature of these digital technologies. For instance, more than a billion computers are estimated to be in use worldwide and over 5

billion units of mobile phones are currently in use (Neto & Bloemhof-Ruwaard, 2012; Pew Research, 2019). Extending the service lives of mobile phones through direct reuse is considered to be one of the most effective measures to close loops and increase loop efficiency (Sinha et al., 2016). This is despite much of the literature in CE focusing on the "outer material flows" of recycling, remanufacturing and refurbishing (Wieser & Tröger, 2016). Advancing this argument towards the reuse economy and digital technologies, it becomes imperative to capture all sustainability dimensions for digital technologies.

Conclusion

Reuse economies are an essential component of CE, particularly for ensuring accessibility and participation of individuals, communities and economies across a wide-range socio-economic spectrum. Given increasing volumes and pervasive nature of digital technologies – as enablers of CE, and as physical materials that must be managed within the CE – an intentional and considered approach to future research and exploration of the requirements of a reuse economy for digital technologies will be critical. Particularly, within such a research agenda, the balanced inquiry into the role and attributes of effective policy, as well as the requirements of product-specific and local perspectives, will be important.

Acknowledgements

The UK Engineering and Physical Sciences Research Council No. EP/R032041/1 supported this research. The authors are grateful for their support.

References

André, H., Ljunggren Söderman, M., & Nordelöf, A. (2019). Resource and environmental impacts of using second-hand laptop computers: A case study of commercial reuse. *Waste Management*, *88*, 268–279. https://doi.org/10.1016/j.wasman.2019.03.050

Borg, K., Boulet, M., Smith, L., & Bragge, P. (2019). Digital Inclusion & Health Communication: A Rapid Review of Literature. *Health Communication*, *34*(11), 1320–1328. https://doi.org/10.1080/10410236.2018.1485077

Bressanelli, G., Adrodegari, F., Perona, M., & Saccani, N. (2018). The role of digital technologies to overcome Circular Economy challenges in PSS Business Models: an exploratory case study. *Procedia CIRP*, *73*(2018), 216–221.

Cooper, D. R., & Gutowski, T. G. (2017). The environmental impacts of reuse: a review. *Journal of Industrial Ecology*, *21*(1), 38–56.

Ellen MacArthur Foundation. (2015). *Growth within: a circular economy vision for a competitive Europe*. Ellen MacArthur Foundation.

Ganann, R., Ciliska, D., & Thomas, H. (2010). *Implementation Science Open Access METHODOLOGY Expediting systematic reviews: methods and implications of rapid reviews*. 1–10. https://doi.org/10.1186/1748-5908-5-56

Hopkinson, P., Zils, M., Hawkins, P., & Roper, S. (2018). Managing a Complex Global Circular Economy Business Model: Opportunities and Challenges. *California Management Review*, *60*(3), 71–94. https://doi.org/10.1177/0008125618764692

International Resource Panel. (2018). *Re-Defining Value - The Manufacturing Revolution: Remanufacturing, Refurbishment, Repair and Direct Reuse in the Circular Economy.* (N. Nasr, J. Russell, S. Bringezu, S. Hellweg, B. Hilton, C. Kreiss, & N. von Gries (eds.)). United Nations Environment Programme.

Khangura, S., Konnyu, K., Cushman, R., Grimshaw, J., & Moher, D. (2012). Evidence summaries: The evolution of a rapid review approach. *Systematic Reviews*, *1*(1), 1–9. https://doi.org/10.1186/2046-4053-1-10

Moher, D., Liberati, A., Tetzlaff, J., & Altman, D. G. (2009). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *BMJ (Online)*, *339*(7716), 332–336. https://doi.org/10.1136/bmj.b2535

Murray, A., Skene, K., & Haynes, K. (2017). The circular economy: an interdisciplinary exploration of the concept and application in a global context. *Journal of Business Ethics*, *140*(3), 369–380.

Neto, J. Q. F., & Bloemhof-Ruwaard, J. M. (2012). An Analysis of the Eco-Efficiency of Personal Computers and Mobile Phones. *Production and Operations Management*, *21*(1), 101–114.

https://doi.org/10.1111/j.1937-5956.2011.01234.x
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), 3009. https://doi.org/10.3390/en11113009
Pew Research. (2019). *Smartphone Ownership Is Growing Rapidly Around the World, but Not Always Equally*. Pew Research Centre, Global Attitudes & Trends.
Qiao, F. ., & Qiao, N. . (2013). Circular economy: An ethical and sustainable economic development model. *Prakseologia*, *154*, 253–272.
Rasmussen, C. D. N., Højberg, H., Bengtsen, E., & Jørgensen, M. B. (2018). Identifying knowledge gaps between practice and research for implementation components of sustainable interventions to improve the working environment – A rapid review. *Applied Ergonomics*, *67*, 178–192. https://doi.org/10.1016/j.apergo.2017.09.014
Simpson, D., Power, D., Riach, K., & Tsarenko, Y. (2019). Consumer motivation for product disposal and its role in acquiring products for reuse. *Journal of Operations Management*, *65*(7), 612–635.
Sinha, R., Laurenti, R., Singh, J., Malmström, M. E., & Frostell, B. (2016). Identifying ways of closing the metal flow loop in the global mobile phone product system: A system dynamics modeling approach. *Resources, Conservation and Recycling*, *113*, 65–76. https://doi.org/10.1016/j.resconrec.2016.05.010
Strasser, S. (2000). *Waste and want: A social history of trash*. Macmillan.
Tam, E., Soulliere, K., & Sawyer-Beaulieu, S. (2019). Managing complex products to support the circular economy. *Resources, Conservation and Recycling*, *145*, 124–125. https://doi.org/10.1016/j.resconrec.2018.12.030
Temple University Libraries. (2020). *Systematic Reviews & Other Review Types*. Temple University Libraries. https://doi.org/10.1108/eb026408
Van Loon, P., Delagarde, C., & Van Wassenhove, L. N. (2018). The role of second-hand markets in circular business: a simple model for leasing versus selling consumer products. *International Journal of Production Research*, *56*(1–2), 960–973.
Watt, A., Cameron, A., Sturm, L., Lathlean, T., Babidge, W., Blamey, S., Facey, K., Hailey, D., Norderhaug, I., & Maddern, G. (2008a). Rapid reviews versus full systematic reviews: An inventory of current methods and practice in health technology assessment. *International Journal of Technology Assessment in Health Care*, *24*(2), 133–139. https://doi.org/10.1017/S0266462308080185
Watt, A., Cameron, A., Sturm, L., Lathlean, T., Babidge, W., Blamey, S., Facey, K., Hailey, D., Norderhaug, I., & Maddern, G. (2008b). Rapid versus full systematic reviews: Validity in clinical practice? *ANZ Journal of Surgery*, *78*(11), 1037–1040. https://doi.org/10.1111/j.1445-2197.2008.04730.x
Webster, R. K., Brooks, S. K., Smith, L. E., Woodland, L., Wessely, S., & Rubin, G. J. (2020). How to improve adherence with quarantine: rapid review of the evidence. *Public Health*, *182*, 163–169. https://doi.org/10.1016/j.puhe.2020.03.007
Wieser, H., & Tröger, N. (2016). Exploring the inner loops of the circular economy: Replacement, repair, and reuse of mobile phones in Austria. *Journal of Cleaner Production*, *172*, 3042–3055. https://doi.org/10.1016/j.jclepro.2017.11.106
Wright, B., & Bragge, P. (2018). Interventions to promote healthy eating choices when dining out: A systematic review of reviews. *British Journal of Health Psychology*, *23*(2), 278–295. https://doi.org/10.1111/bjhp.12285