Circular supply chains for small and medium enterprises: A multiple case study analysis

Sassanelli C.*, Rosa P.*, Terzi S.*

** Department of Management, Economics and Industrial Engineering, Politecnico di Milano, Piazza Leonardo da Vinci, 32 20133 – Milan – Italy (claudio.sassanelli@polimi.it, paolo1.rosa@polimi.it, sergio.terzi@polimi.it)*

Abstract: Circular Economy (CE) is emerging as an alternative industrial paradigm to linear economic models, aiming at promoting more sustainable patterns and production processes. However, empirical researches explaining how companies can adopt CE in practice are still limited to either specific sectors or big companies. This way, European Small and Medium Enterprises (SMEs) are coping with big issues during the transition from linear to circular behaviours. To this aim, the paper focuses on the practical adoption of CE through a description of four case studies sharing a similar aim, or the upcycling of materials from e-wastes. The explorative nature of this work must be intended as a first step towards the implementation of multi-sectorial (SME-oriented) circular supply chains able to get real benefits from the adoption of circular practices.

Keywords: Circular Economy; Circular Supply Chains; Small and Medium Enterprises; Multiple Case Study.

1. Introduction

Circular Economy (CE) represents a new industrial paradigm for production and resources consumption, proposed as an alternative to traditional (linear) economic models (Geissdoerfer, Savaget, Bocken, & Hultink, 2017; Su, Heshmati, Geng, & Yu, 2013). Through CE, wasted materials, components and products are reused, recycled or recovered at End-of-Life (EoL) stage through different closed-loop production patterns (Ghisellini, Cialani, & Ulgiati, 2016). Given the high attention of policymakers on environmental issues during the last decades (Geng, Zhu, Doberstein, & Fujita, 2009; Prendeville, Hartung, Purvis, Brass, & Hall, 2011; Tukker, 2015), there was a huge proliferation of CE-oriented policies and regulations (Murray, Skene, & Haynes, 2017; The Ellen MacArthur Foundation, 2015). However, only recently experts assessed the effect of CE on companies' Business Models (BMs) (Bocken, Short, Rana, & Evans, 2014; Witjes & Lozano, 2016), by forging the concept of Circular Business Models (CBMs). This way, lots of efforts are still needed to understand how companies can manage their business in circular contexts. To this aim, the paper presents four European case studies demonstrating how, starting from a similar waste source, the adoption of circular practices can open the way to completely new (multi-sectorial) supply chains able to widen the product-service portfolio of the involved companies. The reference sectors in this paper are represented by e-waste management, additive manufacturing, and jewellery. E-waste management is an increasingly expanding market, especially because of the impressive growth rate of e-wastes all around the world. Even if international environmental regulations succeed in improving reuse, recovery and recycling performances, there are still big issues in terms of how to valorise materials once they are recovered from e-wastes. Additive manufacturing is a new sector where companies are trying to cope with reducing the production process cost in order to substitute current practices to more sustainable ones. However, materials needed in additive manufacturing processes are very specific and require high quality levels. This way, they are produced starting from virgin materials. Jewellery is a well-established sector searching for both new production technologies and ideas in order to attract new customers. However, the jewellery market does not allow to drastically change the material content of products. Even if these three sectors appear very different in their characteristics and issues, the CE paradigm can offer reciprocal benefits to all of them, by acting as a disruptive innovation.

The paper is structured as follows. Section 2 presents an overview on recent circular supply chains. Section 3 explains the rational of the methodology and presents a brief description of the sampled case studies. Section 4 summarises the main results. Finally, Sections 5 and 6 respectively discuss theoretical and managerial implications of results and depict some concluding remarks.

2. Literature review

In literature, a surge of interest in Supply chain management (SCM) has been registered from the early 1980s, with the proposition of conceptual frameworks and methods. Several terms were used to refer to the SCM domain, among which network sourcing, supply pipeline management, value chain management, and value stream management (Croom, Romano, & Giannakis, 2000). 'Supply chain management encompasses materials/supply management from the supply of basic raw materials to final product (and possible recycling and re-use). Supply chain management focuses on how firms utilise their suppliers' processes, technology and capability to enhance competitive advantage. It is a management philosophy that extends traditional intra-enterprise activities by bringing trading partners together with the common goal of optimisation and efficiency' (Tan, Kannan, & Handfield, 1998). Some researchers began to recognize SCM as a mean to improve competitiveness. In detail, single companies do not aim at reaching cost and efficiency enhancements leveraging on the partners composing the SC they belong to. On the contrary, they attempt to improve its competitiveness as a whole (Croom et al., 2000). Therefore, traditionally, SC collaboration is aimed to deliver products to customers in order to optimize long-term profit for all SC partners and achieve competitive advantage for the entire ecosystem (Ebikake, Sassanelli, & Terzi, 2018; Simatupang & Sridharan, 2008). When SC efforts are focused on the supply side of the SC, rather than the entire SC, the focus is on procurement (Arnette, Brewer, & Choal, 2014) with the main aim of improving product performance in the long-term in sustainable way (Brewer & Arnette, 2017). Widening the field of action of procurement, logistics impacts also activities as packaging, transportation, distribution and reverse logistics (Arnette et al., 2014), confirming environmental sustainability as a very important aspect of SCM.

2.1 Circular economy and supply chain management

The advent of CE has also influenced the Supply Chain Management (SCM) of companies. Terms like sustainable supply chains (Masoumi, Kazemi, & Abdul-Rashid, 2019), green supply chains (Zhang, Wang, Liu, Chu, & Cui, 2010), closed-loop supply chains (Choi, Li, & Xu, 2013), reverse logistics (Kumar & Putnam, 2008), industrial symbiosis (Song, Yeo, Kohls, & Herrmann, 2017) and industrial ecology (Despeisse, Ball, Evans, & Levers, 2012) became even more relevant in the extant literature after the CE paradigm evolution. Here, many contributions offer interesting elements for additional research. In parallel, also the effect of Industry 4.0 on SCM raised with time, adding to those effects related with CE (Gupta, Chen, Hazen, Kaur, & Santibañez Gonzalez, 2019; Kache & Seuring, 2017; Saberi, Kouhizadeh, Sarkis, & Shen, 2019). However, most of these works focus on either a specific sector/product (e.g. automotive, mass electronics) or a specific issue related with SCM (e.g. sustainability assessment, network design/optimization, inventory planning, etc.). In addition, SMEs are rarely considered as reference cases. This trend is similar also considering more specific papers focusing on Waste from Electrical and Electronic Equipment (WEEE) SCM.

3. Methodology

The paper adopts a multiple case study methodology, by assessing four European case studies – named "Case A", "Case B", "Case C" and "Case D" for confidentiality reasons – operating at different level in the manufacturing industry. Table 1 summarises the key information about the cases.

Table 1: Key information on cases

ID	Sector	Founded (year)	Employees	Revenues (mln €)
A	Metal powders	1994	25	2.1
B	3D printed jewels	2008	2	1.1
C	3D printing equipments	2012	44	2.7
D	WEEE management	2007	14	0.7

The four sampled cases represent some complementary options for exploiting the recovered materials from Printed Circuit Boards (PCBs).

3.1 Case studies empirical analysis

Case A is a SME producing metal powders for additive manufacturing processes. The company was born starting from an innovative principle of solid-state synthesis and developed over time a portfolio of technological systems and an industrial structure capable of producing innovative metal powders that found very extensive applications in several industrial sectors, such as coatings, composites and materials for energy storages. Metal powders produced by Case A are characterised by a high technological content, with unique characteristics, suitable to be subsequently transformed into new products. Case A offers to the market innovative materials that can be processed using conventional processes of powder metallurgy and deposition, such as laser sintering, thermal spraying, and sintering. The powdered materials produced find application in a series of different supply chains, such as conventional and rapid sintering, laser sintering and coating deposition. The production process starts from electronic scraps that are brought to the plant by either private and industrial customers and finishes with metal powders as final products. The peculiarity of Case A is that the metallic material entering the manufacturing process is recovered from different kinds of e-wastes. These wastes, once disassembled to recover hazardous components, are reduced in powders. Then, powders are separated in metal and non-metal powders, and only some specific metals present in powders are refined completely through bio-hydrometallurgical processes and optimised by classification and jet-mills to be used in industrial 3D printing, thermal spraying or sintering processes.

Case B is a start-up specialised in 3D printing and 3D scanning processes. The purpose of Case B is providing professional 3D printing and 3D scanning services, developing 3D printing materials (i.e., filaments as well as binders and powders) and customised 3D printing and 3D scanning solutions (both hardware and software), plus 3D design and support/training services. Case B is also characterised by a depth operational experience in helping to refine systems for taking orders automatically through localised points of sales and processing and printing in 3D these orders centrally through a cloud-based system. The production process of Case B is like that of Case A but, instead of finishing with metal powders as final products, it finishes with 3D printed jewels. Case B is related with the production of 3D printed jewels from "green" precious metals.

Case C is a spinoff of a research centre producing 3D printing equipments and spare parts, plus related services. is providing 3D printing equipments, services and spare parts for both industrial and private users. Case C is also related with the production of either additive manufacturing (AM) materials or 3D printing filaments from wasted materials. The production process is like Cases A and B but finishing with AM materials or 3D printing filaments.

Case D is a WEEE management company. The purpose of Case D is collecting WEEE from both industrial and private users in order to disassemble them, recycle basic materials (e.g. steel, copper, aluminium and plastics) recover valuable components (e.g. PCBs) and sell them to metal refining companies. Differently from Case A, B and C, a demanufacturing process is applicable in this case.

3.2 Sample identification and selection

The identification of the cases was based on a convenient sampling criterion, allowing easy accessibility and availability of information at a given time (Voss, Tsikriktsis, & Frohlich, 2002). The selected cases are part of the H2020 FENIX project. This project has, among its main objectives, to demonstrate in small-scale the real benefits coming from the adoption of CE principles in manufacturing supply chains. In addition, the manufacturing industry is particularly interesting to analyse from a CE perspective. Starting from globalisation, the European manufacturing sector faced with an increasing lack of stability in the market together with a need for quicker responses to customers' demands (Rosa, Sassanelli, & Terzi, 2018). Over time, these two elements disincentivised long-term investments of companies and shifted attention to higher-value markets characterised by lower volumes. Then, production was moved abroad, and the use rates of plants' capacity felt down quickly. This negative scenario affected the overall performance of SMEs, however called to remain competitive into the markets (European commission, 2012). In parallel, there was an increasing awareness about the environmental impact of products and processes, as well as about the importance of a sustainable consumption of resources (Reuter et al., 2013). In this context, the CE approach is getting more and more success (Lieder & Rashid, 2016). For instance, empirical evidences forecast "an annual net material cost savings opportunity up to USD 380 billion in a transition scenario and up to USD 630 billion in an advanced scenario, looking only at a subset of EU manufacturing sectors" (The Ellen MacArthur Foundation, 2013). Accordingly, companies were selected because they are designing a CBMs in novel supply chains of the manufacturing industry.

3.3 Data gathering

From the analysis of extant research, a semi-structured interview protocol with open-ended questions for the interviews was established. Six first-line managers and senior researchers were interviewed. The decision to interview first-line managers and senior researchers was taken because these people are the ones inside a company with a legitimate right to decide on the implementation of managerial practices for BM design (Helfat & Martin, 2015). In addition, as for the sample size of key informants in qualitative research, recommends at least six participants for phenomenological studies (Morse, 2000). Coherently with this, and both with the actual dimension of the case studies and the novelty of the supply chains within which they operate, the number of first-line managers and senior researchers involved in the interviews was sufficient to finally enhance credibility, transferability, dependability and confirmability of all of the gathered information. Each key respondent was interviewed at least twice. Interviews lasted from one hour and half to two hours for over twenty hours. All the interviews were recorded and transcribed. Therefore, a coding process in content analysis was performed to capture all the relevant information (Guest, Bunce, & Johnson, 2006). In case of not-clear information, the interviews were followed-up by e-mails or phone-calls with questions of clarification for our key respondents. As a following step, a within-case analysis was performed by each author, and a cross-case analysis was conducted to identify, corroborate and compare the recurrent patterns of useful information. All information gathered were triangulated with secondary sources of information to avoid post-hoc rationalisations, and to add to interview data (Eisenhardt & Graebner, 2007) secondary documents and archival records (Amankwah-Amoah, 2016) regarding case studies. Initially, each author independently reviewed all the information of the transcribed interviews and all the secondary sources to verify their validity and avoid potential ambiguous and equivocal data to be included in the database. Then, each author contrasted or corroborated his own analyses with the ones of the others to reach a shared understanding and interpretation of the whole information under investigation. Finally, the authors triangulated all the accepted information.

4. Results

The empirical results coming from the four use cases can be summarized with pictures. Figure 1 depicts the current situation, with independent supply chains. Then, Figure 2 presents the new situation after the adoption of a circular supply chain.

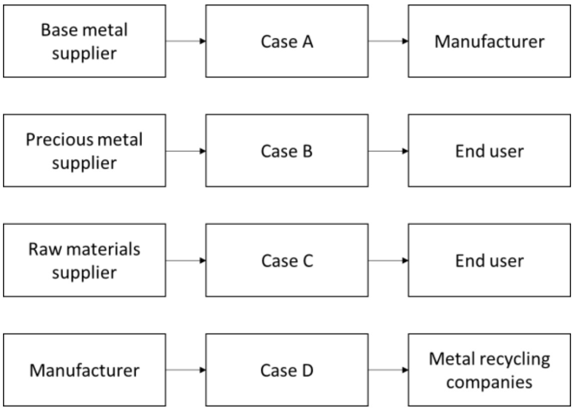

Figure 1: Independent supply chains

In the current state, all use cases act independently. Case A gets its base metals from raw materials suppliers and, after a sequence of high energy ball-milling processes, sells its metal powders to manufacturers. Case B gets its precious metals from raw materials suppliers and, after a sequence of 3D scanning, wax 3D shaping and metal injection, sells its jewels to end users. Case C gets its base metals from raw materials suppliers and, after a set of extruding steps, sells its filaments to end users. Case D gets obsolete products from either manufacturers or private users and, after a sequence of disassembly, shredding and materials separation steps, sells components and materials to metal recycling companies.

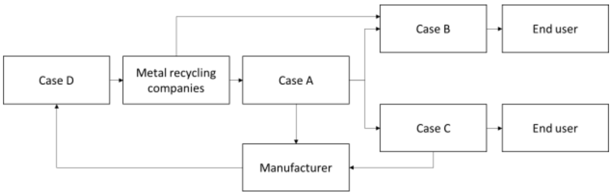

Figure 2: The circular supply chain

In a circular context, all use cases are connected, so constituting a completely new (multi-sectorial) supply chain. In this context, Case D represents the raw material supplier that, with the support of a metal recycling company, sells precious metals directly to Case B for making jewels. About base metals, they are sold to Case A for an additional transformation step. Subsequently, metal powders can be sold to Case B and C for either the production of non-precious metal-based jewels or advanced filaments. These last ones can be sold by Case C also to manufacturers of other products. Case A can also sell its metal powders to manufacturers to produce other kind of products. Finally, manufacturers close the loop by re-connecting with Case D during the EoL management of their products.

5. Theoretical and practical implications

5.1 Theoretical implications

From a theoretical view, this article adds knowledge from three perspectives. First, it points out how PSS-based BMs (e.g. product-oriented and result-oriented ones) can support the transition towards CE offering great benefits for companies (Rosa, Sassanelli, & Terzi, 2019). Here, the four cases propose new BMs making full use of the entire range of by-products coming from the recycling of e-wastes, by reintroducing them as new functional materials in closed-loop supply chains. Together, the four cases allow dealing with the full recovery of wasted metal and non-metal fractions. Precious metals can be upcycled in 3D printed jewels and non-precious metals can be used to make metal powders and 3D printing filaments. From the BM point of view, the four cases create new (multi-sectorial) circular supply chains, by targeting innovative markets with enormous growth potentials like AM technologies, 3D printing filaments and customized jewellery. Second, the paper confirms the literature findings about the role of PSS design and Design for X (Sassanelli, Urbinati, Rosa, Chiaroni, & Terzi, 2020) in supporting the transition towards CE, by enabling the involvement of upstream and downstream stakeholders of the supply chain. Finally, the emerging research stream assessing the relation between CE and Industry 4.0 (Rosa, Sassanelli, Urbinati, Chiaroni, & Terzi, 2020) can find strong fundamentals in this research, especially about the benefits of exploiting 3D printing, AM, software platforms and cloud-based systems in a CE context.

5.2 Practical implications

From a practical view, this article demonstrates in practice how the CE paradigm can enable new (multi-sectorial) circular supply chains. Firstly, it evidences through real use cases how SMEs can exploit CE to create value from wastes. In addition, the same waste stream can open the way to multiple supply chains in very different sectors. Here, materials recovered from e-wastes can be reused for multiple purposes, by enabling the production of jewels, metal powders and 3D printing filaments. Their production is currently in a prototyping phase within the H2020 FENIX project. Secondly, the CE paradigm can enable new links among different sectors, by increasing the product-service portfolio of companies. Thirdly, the support of I4.0 technologies can allow an optimization of benefits coming from the adoption of CE from several perspectives. From one side, simulation (and related decision-support systems) can support managers in optimizing the production process and the exploitation of the available capacity of plants. From another side, the adoption of I4.0 technologies can ease the development of new product-services. Here, the introduction of AM and 3D printing processes offer a good opportunity in terms of new markets for either secondary materials recovered from e-wastes or new products made of secondary materials.

6. Conclusions

The paper aimed at presenting through a reference set of use cases how SMEs can implement completely new (multi-sectorial) supply chains just considering wastes as a valuable source of materials. Four European use cases operating at different level in the manufacturing industry have been linked together just by sharing their interest in transforming their business in a circular context. Here, WEEE recovered from both industrial and private users are recycled in order to recover a set of specific materials (both metal and non-metal ones). Basing on the final exploitation intent, these materials have been subsequently transformed in very different products like metal powders, jewels, and advanced filaments. This way, a WEEE management company that (in a linear economy) occupies the EoL stage of product lifecycles became a supplier of secondary raw materials for three different supply chains. From a theoretical perspective, the paper adds knowledge in three different ways. First, it points out how PSS-based BMs (e.g. product-oriented and result-oriented ones) can support the transition towards CE offering great benefits for companies. Second, the paper confirms the literature findings about the role of PSS design and Design for X in supporting the transition towards CE, by enabling the involvement of upstream and downstream stakeholders of the supply chain. Finally, the emerging research stream assessing the relation between CE and Industry 4.0 can find strong fundamentals in this research, especially about the benefits of exploiting 3D printing, AM, software platforms and cloud-based systems in a CE context. From a practical perspective, this article demonstrates how the CE paradigm can enable new (multi-sectorial) circular supply chains. In addition, the same waste stream can open the way to multiple supply chains in very different sectors. Secondly, the CE paradigm can enable new links among different sectors, by increasing the product-service portfolio of companies. Thirdly, the support of I4.0 technologies can allow an optimization of benefits coming from the adoption of CE from several perspectives. It allows a better optimization of processes and resource management (e.g. through simulation tools) and ease the development of new product-services (e.g. through additive manufacturing and 3D printing). Future researches may be needed to better evidence the dynamics allowing to gather the highest benefits from circular supply chains and, eventually, how to widen them or how to connect them with others. Although several interesting findings come from this research, the paper has also some limitations. From one side, the number of use cases considered is very limited and does not allow to make more generalizable results, for example extending the research field to the whole manufacturing sector. From another side, the qualitative analysis induces the paper to neglect quantitative elements that could strengthen the empirical findings and the interpretation of results.

Acknowledgements

This work has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 760792. In any case, the present work cannot be considered as an official position of the supporting organization, but it reports just the point of view of the authors.

References

Amankwah-Amoah, J. (2016). Global business and emerging economies: Towards a new perspective on the effects of e-waste. *Technological Forecasting & Social Change*, *105*, 20–26. https://doi.org/10.1016/J.TECHFORE.2016.01.026

Arnette, A. N., Brewer, B. L., & Choal, T. (2014). Design for sustainability (DFS): The intersection of supply chain and environment. *Journal of Cleaner Production*, *83*, 374–390. https://doi.org/10.1016/j.jclepro.2014.07.021

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

Brewer, B., & Arnette, A. N. (2017). Design for procurement: What procurement driven design initiatives result in environmental and economic performance improvement? *Journal of Purchasing and Supply Management*, *23*(1), 28–39. https://doi.org/10.1016/j.pursup.2016.06.003

Choi, T.-M., Li, Y., & Xu, L. (2013). Channel leadership, performance and coordination in closed loop supply chains. *International Journal of Production Economics*, *146*(1), 371–380. https://doi.org/10.1016/j.ijpe.2013.08.002

Croom, S., Romano, P., & Giannakis, M. (2000). Supply chain management: An analytical framework for critical literature review. *European Journal of Purchasing and Supply Management*, *6*(1), 67–83. https://doi.org/10.1016/S0969-7012(99)00030-1

Despeisse, M., Ball, P. D., Evans, S., & Levers, A. (2012). Industrial ecology at factory level - a conceptual model. *Journal of Cleaner Production*, *31*, 30–39. https://doi.org/10.1016/j.jclepro.2012.02.027

Ebikake, O. E., Sassanelli, C., & Terzi, S. (2018). PSS design through Design for Supply Chian: State of the art review. In *Procedia CIRP* (Vol. 70, pp. 198–203). Elsevier B.V. https://doi.org/10.1016/j.procir.2018.03.279

Eisenhardt, K. M., & Graebner, M. E. (2007). Theory Building from Cases: Opportunities and Challenges. *The Academy of Management Journal*, *50*(1), 25–32. https://doi.org/10.1177/0170840613495019

European commission. (2012). *'A European strategy for Key Enabling Technologies – A bridge to growth and jobs.'*

Geissdoerfer, M., Savaget, P., Bocken, N. M. P., & Hultink, E. J. (2017). The Circular Economy – A new sustainability paradigm? *Journal of Cleaner Production*, *143*, 757–768. https://doi.org/10.1016/J.JCLEPRO.2016.12.048

Geng, Y., Zhu, Q.-H., Doberstein, B., & Fujita, T. (2009). Implementing China's circular economy concept at the regional level: A review of progress in Dalian, China. *Waste Management*, *29*(2), 996–1002. https://doi.org/10.1016/j.wasman.2008.06.036

Ghisellini, P., Cialani, C., & Ulgiati, S. (2016). A review on circular economy: The expected transition to a balanced interplay of environmental and economic systems. *Journal of Cleaner Production*, *114*, 11–32. https://doi.org/10.1016/j.jclepro.2015.09.007

Guest, G., Bunce, A., & Johnson, L. (2006). How Many

Interviews Are Enough? An Experiment with Data Saturation and Variability. *Field Methods*, *18*(1), 59–82. https://doi.org/10.1177/1525822X05279903

Gupta, S., Chen, H., Hazen, B. T., Kaur, S., & Santibañez Gonzalez, E. D. R. (2019). Circular economy and big data analytics: A stakeholder perspective. *Technological Forecasting & Social Change*, *144*, 466–474. https://doi.org/10.1016/j.techfore.2018.06.030

Helfat, C. E., & Martin, J. A. (2015). Dynamic Managerial Capabilities: Review and Assessment of Managerial Impact on Strategic Change. *Journal of Management*, *41*(5), 1281–1312. https://doi.org/10.1177/0149206314561301

Kache, F., & Seuring, S. (2017). Challenges and opportunities of digital information at the intersection of Big Data Analytics and supply chain management. *International Journal of Operations & Production Management*, *37*(1), 10–36. https://doi.org/https://doi.org/10.1108/IJOPM-02-2015-0078

Kumar, S., & Putnam, V. (2008). Cradle to cradle: Reverse logistics strategies and opportunities across three industry sectors. *International Journal of Production Economics*, *115*(2), 305–315. https://doi.org/10.1016/j.ijpe.2007.11.015

Lieder, M., & Rashid, A. (2016). Towards circular economy implementation: A comprehensive review in context of manufacturing industry. *Journal of Cleaner Production*, *115*, 36–51. https://doi.org/10.1016/j.jclepro.2015.12.042

Masoumi, S. M., Kazemi, N., & Abdul-Rashid, S. H. (2019). Sustainable Supply Chain Management in the Automotive Industry: A Process-Oriented Review. *Sustainability*, *11*(3945), 1–30. https://doi.org/10.3390/su11143945

Morse, J. M. (2000). Determining Sample Size. *Qualitative Health Research*, *10*(1), 3–5. https://doi.org/10.1177/104973200129118183

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*, 369–380. https://doi.org/10.1007/s10551-015-2693-2

Prendeville, S., Hartung, G., Purvis, E., Brass, C., & Hall, A. (2011). Makespaces: From redistributed manufacturing to a circular economy. In *Smart Innovation, Systems and Technologies* (Vol. 52, pp. 577–588). https://doi.org/10.1007/978-3-319-32098-4_49

Reuter, M. A., Hudson, C., van Schaik, A., Heiskanen, K., Meskers, C., & Hagelüken, C. (2013). *Metal Recycling: Opportunities, Limits, Infrastructure, A report of the Working Group on the Global Metal Flows to the International Resource Panel*. UNEP.

Rosa, P., Sassanelli, C., & Terzi, S. (2018). Circular Economy in action: uncovering the relation between Circular Business Models and their expected benefits. In *XXIII Summer School Francesco Turco – Industrial Systems Engineering* (pp. 228–235). AIDI - Italian Association of Industrial Operations Professors.

Rosa, P., Sassanelli, C., & Terzi, S. (2019). Circular Business Models versus Circular Benefits: An Assessment in the Waste from Electrical and Electronic Equipments Sector. *Journal of Cleaner Production*, *231*, 940–952. https://doi.org/10.1016/j.jclepro.2019.05.310

Rosa, P., Sassanelli, C., Urbinati, A., Chiaroni, D., & Terzi, S. (2020). Assessing relations between Circular Economy and Industry 4.0: a systematic literature review. *International Journal of Production Research*, *58*(6), 1662–1687. https://doi.org/10.1080/00207543.2019.1680896

Saberi, S., Kouhizadeh, M., Sarkis, J., & Shen, L. (2019). Blockchain technology and its relationships to sustainable supply chain management. *International Journal of Production Research*, *57*(7), 2117–2135. https://doi.org/10.1080/00207543.2018.1533261

Sassanelli, C., Urbinati, A., Rosa, P., Chiaroni, D., & Terzi, S. (2020). Addressing Circular Economy through Design for X approaches: A Systematic Literature Review. *Computers in Industry*, *120*(103245), 1–23.

Simatupang, T. M., & Sridharan, R. (2008). Design for supply chain collaboration. *Business Process Management Journal*, *14*(3), 401–418. https://doi.org/10.1108/14637150810876698

Song, B., Yeo, Z., Kohls, P., & Herrmann, C. (2017). Industrial Symbiosis: Exploring Big-data Approach for Waste Stream Discovery. *Procedia CIRP*, *61*, 353–358. https://doi.org/10.1016/j.procir.2016.11.245

Su, B., Heshmati, A., Geng, Y., & Yu, X. (2013). A review of the circular economy in China: moving from rhetoric to implementation. *Journal of Cleaner Production*, *42*, 215–227. https://doi.org/10.1016/J.JCLEPRO.2012.11.020

Tan, K.-C., Kannan, V., & Handfield, R. (1998). Supply Chain Management: Supplier Performance and Firm Performance. *International Journal of Purchasing & Materials Management*, *34*(3). Retrieved from https://digitalcommons.usu.edu/manage_facpub/278

The Ellen MacArthur Foundation. (2013). *Towards the Circular Economy Economic and business rationale for an accelerated transition*. Retrieved from https://www.ellenmacarthurfoundation.org/assets/downloads/publications/Ellen-MacArthur-Foundation-Towards-the-Circular-Economy-vol.1.pdf

The Ellen MacArthur Foundation. (2015). *Towards a Circular Economy: Business Rationale for an Accelerated*

Transition. https://doi.org/2012-04-03

Tukker, A. (2015). Product services for a resource-efficient and circular economy – a review. *Journal of Cleaner Production*, *97*, 76–91. https://doi.org/10.1016/j.jclepro.2013.11.049

Voss, C., Tsikriktsis, N., & Frohlich, M. (2002). Case research in operations management. *International Journal of Operations & Production Management*, *22*(2), 195–219. https://doi.org/10.1108/01443570210414329

Witjes, S., & Lozano, R. (2016). Towards a more Circular Economy: Proposing a framework linking sustainable public procurement and sustainable business models. *Resources, Conservation and Recycling*, *112*, 37–44. https://doi.org/10.1016/j.resconrec.2016.04.015

Zhang, T., Wang, X., Liu, X., Chu, J., & Cui, P. (2010). Automotive Green Supply Chain Management Based on the RFID Technology. In *ICAMS 2010 - IEEE International Conference on Advanced Management Science* (Vol. 2, pp. 617–619).