https://doi.org/10.1595/205651320X15706349546439 Johnson Matthey Technol. Rev., 2020, **64**, (1), 59–68

JOHNSON MATTHEY
TECHNOLOGY REVIEW

www.technology.matthey.com

Building Circular Products in an Emerging Economy: An Initial Exploration Regarding Practices, Drivers and Barriers

Case studies of new product development from medium and large Brazilian companies

Daniel Jugend*
Production Engineering Department, São Paulo State University (UNESP), Av. Eng. Luiz Edmundo Carrijo Coube, 14-01 – Vargem Limpa, Bauru-SP, 17033-360, Brazil

Paula de Camargo Fiorini
Department of Business Administration, Federal University of São Carlos (UFSCar), Rodovia João Leme dos Santos, SP-264, Km 110 – Itinga, Sorocaba-SP, 18052-780, Brazil

Marco Antonio Paula Pinheiro, Hermes Moretti Ribeiro da Silva, Bruno Michel Roman Pais Seles
Production Engineering Department, São Paulo State University (UNESP), Av. Eng. Luiz Edmundo Carrijo Coube, 14-01 – Vargem Limpa, Bauru-SP, 17033-360, Brazil

***Email:** daniel.jugend@unesp.br

The circular economy (CE) is an important approach and current trend in environmental sustainability. The implementation of the CE depends on the adoption of sustainable practices from the planning stages of new product development (NPD). Although the literature recognises the need to apply CE practices into NPD, few studies have tried to provide support for the issues based on real case studies. This article aims to identify and analyse practices, barriers and drivers to the development of circular products. To achieve this objective, a multiple case study was carried out in three medium and large Brazilian companies that have environmental concerns and, at the same time, are continuously involved in NPD activities. The results show that the companies' circular product designs already foresee waste and recycled components as raw materials. In addition, it was found that infrastructural aspects and low awareness of customers regarding sustainability are challenges to overcome. Finally, for the adoption of CE practices, regulatory legislation stood out as a significant driver. This article contributes to theory and practice by providing empirical evidence of how companies have planned to build circular products by incorporating circular practices into the NPD process.

1. Introduction

Concern over scarce resources, environmental preservation and global warming has grown among consumers and influenced governments to introduce tougher regulations for companies to make them rethink the environmental impact of their activities (1–2). Consumers and society have raised the demand for and are paying more attention to green products (3). The need to shift the linear production system to a more sustainable and circular model has been recognised for some years by international organisations (4, 5) and is discussed in current research on sustainability (1, 6).

The trend towards adoption of the CE has also demanded changes in consumption patterns favouring more environmentally sustainable products and services (7). These changes imply the adoption of concepts such as dematerialisation (8) and the sharing of products and services (9, 10). In order to move towards a more circular approach – from cradle to cradle – slowing the consumption of natural resources, the CE theory has proposed the recirculation of material resources from the planning stage of NPD (11, 12). However, it is known that traditional and green NPD approaches are different (13).

NPD under the CE perspective is aimed at the usage of biodegradable materials and renewable energy and the sharing of products and services (2). The development of new, more energy efficient technologies, equipment, installations and use of the internet and information technology can improve utilisation of resources and prevent pollution (14). The adoption and development of new technologies integrated with products (as such, the internet of things) have allowed the creation of new innovative business models (15, 16).

Since the integration of CE into NPD is one of the most prominent areas in operations management (13, 17) and facing the need to better understand management practices that drive this integration, this article aims to identify and analyse the practices, barriers and drivers of CE integration in NPD. For this, we have carried out a qualitative, multi-case study in three large- and medium-sized Brazilian companies that have environmental concerns and are at the same time continuously involved in NPD activities.

It is important to point out some definitions before proceeding. First, examples of practices analysed in the article are the use of production waste, remanufacturing, reuse, recycling, reverse logistics and environmental assessment. Second, drivers are motivational factors that lead organisations to adopt CE in NPD, such as consumer demand and legislation. Third, barriers are factors that hamper the adoption of some of the practices related to CE, for example, need for high investment in technologies and low demand for products made by remanufacturing or with recycled components.

After this introduction, Section 2 presents the theoretical framework on the development of products in the context of a CE. Section 3 presents the activities regarding the research method. In Section 4, the results will be shown. Finally, Section 5 discusses the results in comparison with the literature and outlines this study's conclusions.

2. Circular Product Design

CE is one of the main trends currently considered by academics and practitioners around the world in environmental sustainability (1, 5). The relevance of the CE is that it presents solutions to the challenges of waste generation, resource shortages and carbon dioxide emissions, as well as the potential to offer economic, environmental and innovation benefits (6). According to Kirchherr *et al*. (18), the CE can be defined as an economic system that replaces the concept of 'end-of-life' by 'cradle to cradle' using the reduction, reuse, recycling and recovery of materials in production, distribution and consumption processes. Kjaer *et al*. (19) argue that the CE's main objective is to keep the value of products, materials and resources in the economy for as long as possible. In addition, due to reduced consumption of resources, a CE can also improve economic performance (19).

The Ellen MacArthur Foundation, UK, proposed the ReSOLVE model for the adoption of the CE (5). Some studies have highlighted the importance of the ReSOLVE model to a CE (2, 16). In summary, the principles are: (a) regenerate: aims at restoring the health of the environment by proposing the use of energy and renewable materials; (b) share: maximum use of the product by its sharing among users; (c) optimise: aims to increase the performance of the product, removing waste in the production and supply chain; (d) loop: aims to keep components and materials in closed loops; (e) virtualise: deals with the development of digital solutions to reduce the production cycle and its environmental impacts; and (f) exchange: replaces old materials from non-renewable technologies by applying new technologies.

Several factors have motivated and driven the adoption of CE practices (2, 7, 20, 21). Jesus and Mendonça (20) define three different categories: technical stimulus; economic and market factors; institutional, regulatory and social motivations. Technical stimulus comprises the technological availability that facilitates the optimisation of resources, remanufacturing and the development of sharing solutions. Institutional, regulatory and social motivations are associated with increasing environmental concern and connected to the social demand for the protection of the environment and changes in consumer preferences.

Among the drivers for the adoption of CE practices, Govindan and Hasanagic (21) pointed out regulatory aspects which promote cleaner production, such as the recent concern on climate change and global warming, the demand for renewable energy and the increased value of products that are designed to last longer, among others. However, transitioning from a linear to a CE is not trivial and several studies have pointed out barriers that must be acknowledged (20–23). Some factors that stand out as relevant and that should be considered in this transition are technological aspects (technological immaturity, for example), market and economic factors (high investments and uncertainty of returns) and institutional and regulatory challenges (lack of legislation to regulate or stimulate the adoption of CE) (20).

Bressanelli *et al*. (24) identified the following challenges that may hinder CE adoption: economic and financial viability, market, product characteristics, standards and regulation, supply chain management, technology and consumer behaviour. The risk of product development and production that is unattractive to customers, the longer return on investment, especially in cases where companies are proposing servitisation and the few legal incentives can be barriers to CE adoption (24).

In classifying barriers to CE adoption, Govidan and Hasanagic (21) proposed eight clusters: government, economic, technological, knowledge and skill, management (for example, top management support), culture and social, market and other solutions. Govidan and Hasanagic (21) also highlighted aspects such as ineffective CE legislation and high costs associated with recycled material as market barriers towards the CE.

The effective adoption of a CE depends fundamentally on practices associated with NPD (11). However, the NPD process in the CE context is strictly different from conventional NPD (13), because in CE the economic and environmental values of products are preserved as long as possible, either by extending the product's useful life or by creating the possibility of reusing it (25). Among these characteristics of circularity in the NPD process, it is observed that these decisions must envisage, from the planning stage of the project, the use of the principles of material circulation and energy reduction (26), regeneration (5) and the preservation of materials for as long as possible (27).

The adoption of these principles aims, overall, to keep the products in the economic system, so as to avoid as much as possible the extraction of virgin raw material from nature (28, 29). In addition, as observed by Hollander *et al*. (25), the economic and environmental value of products developed under the principles of the CE should be designed for maximum preservation to prolong their life cycle or return the products and their components to the market. Thus, it is essential that the principles of regeneration, sharing, optimisation, recycling, remanufacturing, virtualisation and the substitution of toxic and non-renewable materials for non-toxic and renewable ones should be regarded in NPD (2).

A circular product should also be attentive to product designs that meet the principles of life extension (25–29); the use of renewable energy (11, 28); ease of disassembly (29); ease of product maintenance (11) and updating (25); and sharing products and services, for example through the use of the internet and information technology (1, 16) and even by adopting the product service system (PSS) (9).

Concern over extension of the product's useful life cycle also makes it necessary to extend the use of products that compose the product portfolio (27), preventing them from becoming obsolete from a physical and emotional point of view (25). The physical obsolescence of products can be avoided through projects that allow remanufacturing, reuse, remodelling and recycling (6, 11, 28, 29). From the emotional point of view, products should involve the consumer over a long period of time (emotional durability) (25); this is a challenge, especially for designers and the area of marketing (27, 30).

In prior research, Stahel (31) proposed that businesses rooted in linear production systems need to look towards new service-oriented business models to close resource loops. In this context, the definition of servitisation has coalesced as the process of building revenue streams for manufacturers from services (32). From an industrial perspective, a transition from a linear to a closed-loop system requires a move from the conventional model of selling physical products to selling access to functionality or service. In such service-based business models, including leasing or pay-per-use, the manufacturers retain ownership of their products and take them back after use for the purpose of value recovery and redistribution (33).

This new circular product design perception is founded on the fact that a proportion of all the materials ever extracted are in today's built environment (34). In circular product design, most products that would have been disposed of in the linear model are reused, for example as a raw material. Thus, the value of raw materials is kept within the system for the longest possible time (35). A circular design offers the opportunity to meet emerging consumer needs and respond to dynamic technological changes as well as social changes that require more sustainable solutions (13). The nature of the circular product design process is to understand early failures and uncertainties in order to continually iterate toward better environmental solutions (13).

3. Research Method

Aiming at reducing the gap in practices, barriers and drivers of CE integration into NPD, this research comprised case studies in three large- and medium-sized Brazilian companies that have environmental concerns and that are deeply involved in NPD activities. We intentionally considered ISO 14001-certified companies or companies that are currently implementing this certification since they tend to adopt more appropriate environmental management practices (36). The case study method was chosen because, besides being a useful approach to increase knowledge about certain topics, it allows an analysis of the researched situations, as the study is accomplished through interviews, observations and document analysis, allowing a better evaluation of the context (37).

Considering that it is an emerging topic and has been recently discussed (9, 12, 27), the qualitative procedure was the most appropriate. According to Yin (37) and Eisenhardt (38), the method is adequate when seeking a better understanding of the facts. To gain familiarisation with the object of study and to capture and understand the perceptions of the professionals involved with the integration of CE practices into NPD processes, the application of this qualitative method with the presence of a researcher in the field was considered important (37). The process of data collection was subsidised by a documentary analysis of companies' policies and reports and involved observation and interviews with key respondents. The Appendix presents the case study protocol.

In addition to being located in Brazil, an emerging economy, the criteria for selecting the companies also included the following aspects: (a) to have implemented or be in the process of adopting ISO 14001 certification; (b) to develop and manage a broad portfolio of products that have environmental concerns; (c) to be involved in NPD activities; and (d) to provide full access to the researchers. In order to maintain the confidentiality of the participating companies, we designated them as Companies A, B and C. In Company A, the sustainability manager and the technology development manager joined the interview. In Company B, the regulatory matters manager and quality analysts were interviewed. Finally, in Company C, the environmental manager participated in the interview. **Table I** presents a characterisation of the companies studied.

4. Results

The presentation of the results was classified into three topics: circular practices; drivers and motivations; and barriers.

4.1 Practices for Integrating Circular Economy into New Product Development

Regarding practices for integrating the CE into NPD, Company A has been designing products considering the use of production waste, residues and used products to develop families of dishes and shower products. The adoption of reverse logistics programmes and partnerships with major retailers in Brazil has enabled the company to receive used materials. This was clarified by the following observations:

> "We anticipate the use of waste from the own dishes produced in new products and this is already established in the product design. For example, we take the scraps and reuse them

Table I Characterisation of the Cases

Company	A	B	C
Main product line	Floors, wood panels, electric showers, sanitary ware and metals, ceramic floors	Agricultural machines: main products in the lines of sprayers, fertilisers and coffee harvesters	Automotive batteries, developing and producing the packaging of batteries
Number of employees	11,000	1320	210
Certifications	ISO 9001, ISO 14001, OHSAS 18001 and Forest Management Certification (FSC)	ISO 9001, ISO 14001 and OHSAS 18001	ISO 9001 and implementing ISO 14001
Exporting to	More than 50 countries on all continents	Mainly to Southern Common Market (Mercosur) countries	Mexico, Argentina and Uruguay

> within the new projects instead of carrying this waste to the landfill."
>
> Sustainability manager, Company A

> "There is a reverse logistics program for electric shower. This product has a lower life cycle. Besides, it is composed mostly of plastic, which has high recyclability. We have partnerships with retailers to forward this shower already used and offer financial compensation in the purchase of a new one."
>
> Sustainability manager, Company A

Company C highlighted the use of environmental assessment throughout the entire life cycle of its products. Regarding circularity, the adoption of product design practices that use recyclable material as well as the extension of the life cycle, especially of the plastic incorporated into batteries, was observed. According to the environmental manager: "In the case of plastic, the life span is long and ends after the battery".

In addition, Company C pointed out a concern about investigations that indicate materials to replace the virgin raw materials currently used in its products. Partnerships between companies and universities were recommended to reduce this gap. In Company A, the PSS model was mentioned as a future trend. Respondents indicated that the firm already has floor rental projects for corporations and residences, which will have measured performance and other services added to those floors with the use of industry 4.0 technologies.

Company B does not adopt specific tools for NPD and environmental management, such as eco-design, but it has some internalised practices. The reuse and recycling strategies are considered only in the production process, but the company indicates strategic plans to implement policies of reuse and extension of the product life cycle that can make them the protagonist of this process.

4.2 Drivers for Adopting Circular Economy into New Product Development

The first driver found for the adoption of CE in NPD in Companies B and C is consumer demand for environmentally sustainable products. In addition, Company A also mentioned the environmental issues currently experienced by several Brazilian cities as motivation for the development of ecologically sustainable products. Company A justified that by illustrating the water crisis of 2014 faced by Brazil and, especially, the state of São Paulo. According to the interviewee, the situation stimulated the company to develop products that consume less water during the in-use phase of their life cycle: "With water scarcity, people are beginning to think more about water saving and us about eco-efficient products".

Companies B and C highlighted the role of customers as a stimulus to improve environmental performance. In this sense, customers of Company C (mainly the automotive market) have demanded from their main suppliers the adoption of specific environmental practices and ISO 14001 certification, affecting product development activities. Company C also emphasised compliance with environmental legislation and standards as a means of stimulating and driving the company towards adopting circular practices in NPD. Brazil's National Solid Waste Policy was widely cited throughout the interviews in the three companies as a standard that has guided environmentally sustainable practices in product development.

Furthermore, Company B highlighted a longer product life and lower fuel consumption during the use stage as a way to meet customer needs and thus make products more competitive. The interviewees pointed out that this concern, besides assisting customers' demands, also generated positive environmental impacts:

> "We have developed machines that consume less fuel and cause less impact on the soil, creating distinctive features. It leads to cost reduction, with higher productivity and less fuel use and also to lower weight and, consequently, reduced impact on the environment."
>
> Regulatory matters manager, Company B

4.3 Barriers to the Incorporation of Circular Economy into New Product Development

Among the main barriers observed for the incorporation of the CE into NPD were infrastructure characteristics of cities and awareness and education of the population regarding sustainability. Company B mentioned that an obstacle to the incorporation of the CE into NPD is the poor general education of society in the environmental domain, which affects process activities and the development of new products. According to the company's regulatory matters manager:

> "There is a lack of environmental awareness of the people on the consumption and disposal of products, even with our everyday rubbish such as the plastic coffee cups used in the company."
>
> Regulatory matters manager, Company B

Companies A and C mentioned infrastructure-related barriers to incorporating the CE into NPD. Respondents at Company A pointed out that even while developing products that are eco-efficient in terms of water consumption, the basic sanitation and the drainpipe conditions of many cities do not allow such planned savings in product design, such as water for the flush toilet. According to the sustainability manager of this company: "Due to infrastructure condition and sewage systems, you cannot reduce the volume of water used in the flush toilets". In addition, he emphasises: "The trend is to use less and less water for this type of product, but for that, you have to overcome the infrastructure barriers of the countries".

Reinforcing the infrastructure aspect, Company C mentioned that, unlike automotive batteries, which already have a well-structured and cost-effective reverse logistics process, the company faces an obstacle in reverse logistics for the packaging of batteries with returnable material (mainly cardboard). In addition, the cost of reusing this material is not attractive from a financial perspective, discouraging the development of a product considering the reuse of raw material.

Another barrier pointed out by Company B concerns the competitive scenario in which it is inserted. Although its competitors engage in a discourse of sustainability, it was observed that the development of new products is oriented to the specific needs of the market that it reaches (business-to-business). That is, it aims to add more value to the customer, better product performance and lower costs, instead of implementing innovations that promote sustainability and may affect profit margins or price.

5. Discussion and Final Remarks

The topic of the CE and especially the integration of its principles into the NPD process is coming to light. Despite their recent importance, it is challenging for manufacturing firms to embrace these principles. Some studies have already proposed ways to incorporate these principles into NPD (2, 11), but very few provide support for these issues in real situations in companies. This article contributes to theory and practice by identifying how companies concerned with environmental sustainability have adopted some of these practices.

When we compared our findings with the literature, we noticed that the companies studied are still in the early stages of adopting and making CE viable starting from the product design stage. For instance, contrasting the practices of these companies with the ReSOLVE framework (5) indicates that the firms have a long way to go before fully incorporating CE into NPD. The level of maturity in management should also be considered when analysing and proposing the incorporation of the principles of the CE. Company A, for example, seems to be more structured and mature than the others; it has already adopted a higher set of circularity-oriented practices from the early stages of the NPD process. It is also interesting to observe that none of the companies cited projects that avoid the physical obsolescence of their products.

Table II shows the barriers and opportunities contributed by this article to the literature for the adoption of CE into NPD, in addition to the highlighted practices. Regarding practices for the integration of CE into NPD, the project started by Company A to adopt the PSS model for ceramic flooring by integrating emerging technologies stands out. National legislation oriented to CE, such as the National Solid Waste Policy in Brazil, also contributes to the adoption of circular practices. It is known that there is specific legislation for the CE in several regions in the world, such as in the European Union and China.

As indicated by Company A, national and municipal infrastructure issues, such as inefficient systems, are obstacles to adopting CE practices in NPD. In this case, it is observed that the macro level of the CE (for instance, government actions) impacts the micro level, that is, it hinders the adoption of practices towards circularity in companies. This finding brings implications especially for emerging nations, which on the one side are seeking to advance and promote environmental practices following developed countries, but on the other, still have difficulties in providing infrastructure for the population.

In line with other studies (20, 41), it was also observed in Companies B and C that the use of circular products may be more expensive and less attractive to consumers, which represents

Table II Summary of the Results

Dimensions	Synthesis of results	Literature	References
CE practices	Use of recyclable material and reuse of waste; extension and assessment of product life cycle; incorporation of services and new technologies (such as PSS); adoption of reverse logistics programmes	Regenerate Share Optimise Loop Virtualise Exchange	(2, 5, 16, 39, 40)
Drivers when adopting CE into NPD	Consumer pressure; country legislation (for example, in Brazil, the National Solid Waste Policy)	Institutional, governmental and legislation; economic factors; consumer preferences	(2, 7, 20, 21, 40)
Barriers when adopting CE into NPD	National and regional environmental problems; problems of urban infrastructure (water pipes, for example); increase in the cost of products	Economic and financial uncertainty; organisational and managerial issues; technological advancements	(2, 20–24, 41)

a significant challenge (24). It seems to be an interesting finding since, on the one hand, there is consumer demand for eco-friendly products and on the other hand, there must be a balance regarding the price to be paid for those environmentally sustainable products.

Accordingly, Company B emphasised that a barrier to CE stems from a possible increase in the cost of its products caused by the adoption of circular practices. In this way, breaking market barriers can lead to customer losses due to higher prices and margin losses, ultimately affecting financial results and shareholders. Therefore, resolving the dilemma between customer requirements, competitors' offerings and the challenges of circularity is relevant to future studies on CE.

Among the managerial implications, we highlight the possibility of integrating circular product design practices, such as those presented and discussed in this study, into specific business models and oriented to circular business models, such as that proposed by Hofmann (42), which contemplates not only product development activities but also aspects such as the application of new technologies (such as digital) and stimuli for consumer behaviour changes to assist managers in the transition from linear to CE.

In addition to the practices associated with circular product development (such as product sharing; design for updating; Reduce, Reuse, Recycle (3Rs); ease of disassembly and product maintenance, among others), and in light of the drivers and barriers identified and discussed in this study, it is important that managers interested in the development of circular products monitor the willingness of market segments to purchase products or components derived from reuse, recycling and sharing, among others. In the same way, when the circular product is more expensive than the traditional or linear product, it is also relevant to study the willingness of customers to purchase these products. Thus, boosting demand for circular products may be a strategy for companies and governments interested in stepping up CE adoption.

A noteworthy result is that legislation can be both a driver and a barrier to CE adoption. This was observed in the theoretical review and also in the case studies. As a stimulus, if legislation is in line with CE principles, it can drive companies to develop circular products. By adopting these practices from product design activities, the environmental impacts of the product throughout its life cycle tend to be significantly lower. On the other hand, vague legislation or even the absence of legislation tend to discourage companies from adopting CE (21, 43), representing a barrier to its implementation.

This result also has implications for policymakers. These implications arise from legislation as a major element in stimulating (or discouraging) firms' CE adoption and customer behaviour. Given this, national or regional governments need to draft legislation that effectively encourages the adoption of CE principles while at the same time lowering possible barriers. It is essential for laws to be designed that push companies to opt for product designs that are easily updated, disassembled, remanufactured, reused and consider the use of biodegradable materials, for example.

Additionally, policymakers could raise and discuss with companies interested in adopting CE, the urban and infrastructure problems that lead to wastage of resources such as water and energy. Benchmarking with successful existing legislation can also help guide governments in encouraging CE adoption. In this line, we suggest that future studies identify and analyse these cases of benchmarking.

Finally, this study has some limitations that should be recognised. The main one is related to the research method adopted. Although we applied a multiple case study, the results presented cannot be widely generalised since it was based on only three companies and a single-country perspective – an emerging context. Therefore, it is recommended that future studies identify, analyse and disseminate other practices, barriers and stimuli for the adoption of CE into NPD in a larger number of companies and in those that operate in different countries and economic contexts.

Acknowledgments

The authors would like to thank São Paulo Research Foundation (FAPESP) for financial support. Grant nº: 18/23972-1.

Appendix

Case Study Protocol

Research question: How have companies integrated CE into NPD? What are the practices, barriers and drivers to the development of circular products?

Unit of analysis: Integration of CE into NPD; practices; barriers; drivers.

Organisations: Three Brazilian companies that implement or are implementing ISO 14001 certification.

Sources of data and reliability: Cross-referencing of data collected through interviews with target respondents, documentary analysis and observation.

Construct and external validity: Multiple sources of evidence (interviews, observation and documents). Replication logic in multiple case studies and discussion of empirical results in light of the state-of-the-art.

Examples of key questions of the questionnaire: Does the company have projects in which product development has a direct alignment with environmental sustainability? Does the company implement cradle-to-cradle approach practices? Is there any product or project that uses recycled or reconditioned materials as raw material? Are there reuse policies in new product designs? How does it occur? What are the end-of-life concerns about products? How does reverse logistics or the proper disposal policy work? Are these aspects incorporated into new product planning? What are the main challenges the company faces in implementing circular product development practices? What are the drivers or reasons for the company to integrate CE into product development?

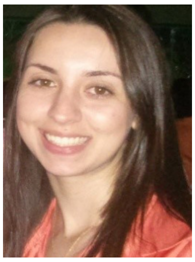
References

1. T. C. McAloone and D. C. A. Pigosso, 'From Ecodesign to Sustainable Product/Service-Systems: A Journey Through Research Contributions over Recent Decades', in "Sustainable Manufacturing. Sustainable Production, Life Cycle Engineering and Management", eds. R. Stark, G. Seliger and J. Bonvoisin, Springer International Publishing AG, Cham, Switzerland, 2017, pp. 99–111
2. M. A. P. Pinheiro, B. M. R. P. Seles, P. De Camargo Fiorini, D. Jugend, A. B. Lopes de Sousa Jabbour, H. M. R. da Silva and H. Latan, *Manag. Decis.*, 2019, **57**, (4), 840
3. A. A. Bailey, A. Mishra and M. F. Tiamiyu, *J. Consum. Mark.*, 2016, **33**, (7), 562
4. "Report of the World Commission on Environment and Development", A/42/427 82e Environment, World Commission on Environment and Development, United Nations, New York, USA, 4th August, 1987, 374 pp
5. "Growth Within – A Circular Economy Vision for a Competitive Europe", Ellen MacArthur Foundation, Cowes, Isle of Wight, 25th June, 2015, 98 pp
6. M. Lieder and A. Rashid, *J. Clean. Prod.*, 2016, **115**, 36
7. C. Jaca, V. Prieto-Sandoval, E. L. Psomas and M. Ormazabal, *J. Clean. Prod.*, 2018, **181**, 201
8. B. V. Kasulaitis, C. W. Babbitt and A. K. Krock, *J. Ind. Ecol.*, 2019, **23**, (1), 119
9. T. T. Sousa-Zomer and P. A. Cauchick Miguel, *J. Clean. Prod.*, 2018, **171**, S119
10. A. Tukker, *Bus. Strateg. Environ.*, 2004, **13**, (4), 246
11. J. Singh and I. Ordoñez, *J. Clean. Prod.*, 2016, **134**, (Part A), 342
12. V. Prieto-Sandoval, M. Ormazabal, C. Jaca and E. Viles, *Bus. Strateg. Environ.*, 2018, **27**, (8), 1525
13. N. Subramanian, A. Gunasekaran, L. Wu and T. Shen, *Int. J. Prod. Res.*, 2019, **57**, (8), 1525
14. M. K. Tiwari, P.-C. Chang and A. Choudhary, *Int. J. Prod. Econ.*, 2015, **164**, 193

15. G. Bressanelli, F. Adrodegari, M. Perona and N. Saccani, *Sustainability*, 2018, **10**, (3), 639
16. A. B. Lopes de Sousa Jabbour, C. J. C. Jabbour, M. Godinho Filho and D. Roubaud, *Ann. Oper. Res.*, 2018, **270**, (1–2), 273
17. N. M. P. Bocken, I. de Pauw, C. Bakker and B. van der Grinten, *J. Ind. Prod. Eng.*, 2016, **33**, (5), 308
18. J. Kirchherr, D. Reike and M. Hekkert, *Resour. Conserv. Recycl.*, 2017, **127**, 221
19. L. L. Kjaer, D. C. A. Pigosso, M. Niero, N. M. Bech and T. C. McAloone, *J. Ind. Ecol.*, 2019, **23**, (1), 22
20. A. de Jesus and S. Mendonça, *Ecol. Econ.*, 2018, **145**, 75
21. K. Govindan and M. Hasanagic, *Int. J. Prod. Res.*, 2018, **56**, (1–2), 278
22. S. Shahbazi, M. Wiktorsson, M. Kurdve, C. Jönsson and M. Bjelkemyr, *J. Clean. Prod.*, 2016, **127**, 438
23. S. Ritzén and G. Ö. Sandström, *Procedia CIRP*, 2017, **64**, 7
24. G. Bressanelli, M. Perona and N. Saccani, *Int. J. Prod. Res.*, 2019, **57**, (23), 7395
25. M. C. den Hollander, C. A. Bakker and E. J. Hultink, *J. Ind. Ecol.*, 2017, **21**, (3), 517
26. Y. Geng and B. Doberstein, *Int. J. Sustain. Dev. World Ecol.*, 2008, **15**, (3), 231
27. M. Pinheiro and D. Jugend, 'Minding the Gap: The Road to Circular Business Models', Research Perspectives in the Era of Transformations, 18th–21st June 2019, Academy for Design Innovation Management, London, UK, 13 pp
28. P. Ghisellini, C. Cialani and S. Ulgiati, *J. Clean. Prod.*, 2016, **114**, 11
29. P. Vanegas, J. R. Peeters, D. Cattrysse, P. Tecchio, F. Ardente, F. Mathieux, W. Dewulf and J. R. Duflou, *Resour. Conserv. Recycl.*, 2018, **135**, 323
30. M. C. Olsen, R. J. Slotegraaf and S. R. Chandukala, *J. Mark.*, 2014, **78**, (5), 119
31. W. R. Stahel, 'The Performance Economy: Business Models for the Functional Service Economy', in "Handbook of Performability Engineering", Springer-Verlag London Ltd, London, UK, 2008, pp. 127–138
32. T. Baines, A. Ziaee Bigdeli, O. F. Bustinza, V. G. Shi, J. Baldwin and K. Ridgway, *Int. J. Oper. Prod. Manag.*, 2017, **37**, (2), 256
33. M. Lieder, F. M. A. Asif, A. Rashid, A. Mihelič and S. Kotnik, *Int. J. Adv. Manuf. Technol.*, 2017, **93**, (5–8), 1953
34. B. Sanchez and C. Haas, *Constr. Manag. Econ.*, 2018, **36**, (6), 303
35. E. Bodova, *Modern Machinery Sci. J.*, 2017, 1700
36. P. González, J. Sarkis and B. Adenso-Díaz, *Int. J. Oper. Prod. Manag.*, 2008, **28**, (11), 1021
37. R. K. Yin, "Case Study Research – Design and Methods", Sage Publications Inc, Thousand Oaks, USA, 2014, 282 pp
38. K. M. Eisenhardt, *Acad. Manag. Rev.*, 1989, **14**, (4), 532
39. G. Heyes, M. Sharmina, J. M. F. Mendoza, A. Gallego-Schmid and A. Azapagic, *J. Clean. Prod.*, 2018, **177**, 621
40. J. M. F. Mendoza, M. Sharmina, A. Gallego-Schmid, G. Heyes and A. Azapagic, *J. Ind. Ecol.*, 2017, **21**, (3), 526
41. J. Kirchherr, L. Piscicelli, R. Bour, E. Kostense-Smit, J. Muller, A. Huibrechtse-Truijens and M. Hekkert, 2018, *Ecol. Econ*., **150**, 264
42. F. Hofmann, *J. Clean. Prod.*, 2019, **224**, 361
43. C. J. C. Jabbour, D. Jugend, A. B. L. de Sousa Jabbour, K. Govindan, D. Kannan and W. Leal Filho, *J. Environ. Manage.*, 2018, **206**, 236

The Authors

Daniel Jugend received his PhD in Production Engineering from Federal University of São Carlos (UFSCar), Brazil. He is an Associate Professor at São Paulo State University (UNESP), Brazil, where he supervises Master's thesis students and teaches graduate and undergraduate courses in operations management. His current research interests include environmentally sustainable products, eco-design, NPD and product portfolio management.



Paula de Camargo Fiorini is Assistant Professor at UFSCar. She holds a Bachelor's degree in Information Systems from UNESP with an international period at the University of Ontario Institute of Technology (UOIT), Canada. Paula holds a PhD in Production/Operations Management from UNESP and she has been a Visiting Scholar at Montpellier Business School, France. Her research interests include information systems and technology management, operations management, innovation and sustainability.

Marco Antonio Paula Pinheiro is a Research Intern at Polytechnique Montreal, Canada, with research focused on the performance of companies when developing products based on circular economy management practices. He is a PhD student and holds a Master's degree in Production Engineering from UNESP. He also holds an MBA in Operations Management from the University of São Paulo (USP), Brazil, a specialisation in Small Business Management from the City College of San Francisco (CCSF), USA, and a degree in Marketing Management from the Methodist University of São Paulo, Brazil.

Hermes Moretti Ribeiro da Silva is Assistant Professor at UNESP. He holds a Bachelor's degree in Administration from Instituição Toledo de Ensino (ITE), Brazil. Hermes holds a PhD in Administration from Fundação Getúlio Vargas (FGV), Brazil, and an MSc in Administration from USP. His research interests include marketing management, consumer behaviour, marketing research, CE and sustainability.

Bruno Michel Roman Pais Seles is a researcher at the Department of Production Engineering, UNESP. Bruno Michel holds a Bachelor's degree in Business Administration from UNESP. He has a Master's and a PhD degree in Production Engineering: Operations and Systems Management from UNESP. His research interests include business administration, operations management, environmental management, corporate social responsibility and sustainable supply chain management.

