Business innovation towards a circular economy

An ecosystem perspective

Konietzko, J.C.

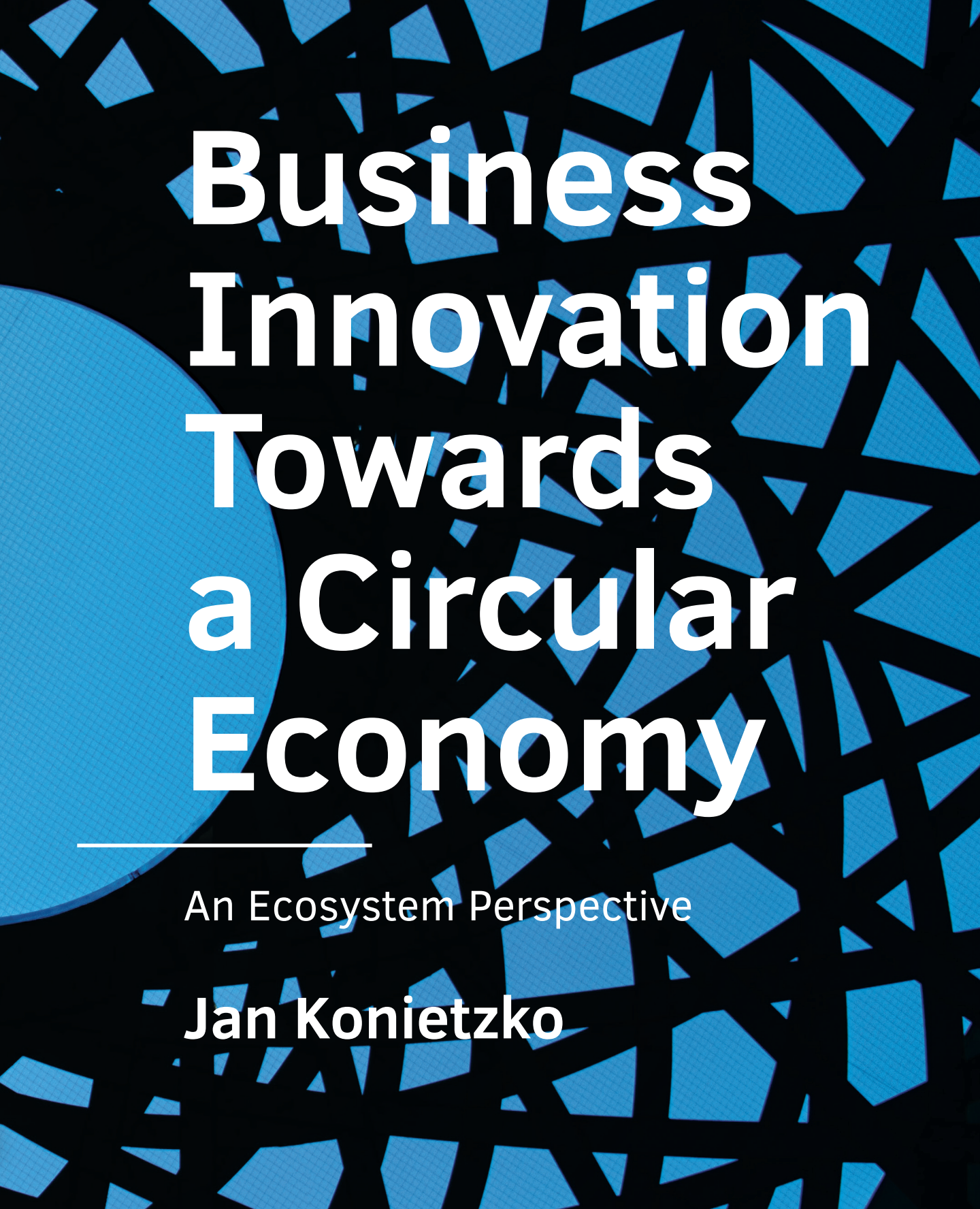
DOI
10.7480/abe.2020.22

Publication date
2021

Document Version
Final published version

Citation (APA)
Konietzko, J. C. (2021). *Business innovation towards a circular economy: An ecosystem perspective*. [Dissertation (TU Delft), Delft University of Technology]. A+BE | Architecture and the Built Environment. https://doi.org/10.7480/abe.2020.22

Important note
To cite this publication, please use the final published version (if applicable).
Please check the document version above.



Business Innovation Towards a Circular Economy

An Ecosystem Perspective

Jan Konietzko

Business Innovation Towards a Circular Economy

An Ecosystem Perspective

Jan Konietzko

TOC

A+BE | Architecture and the Built Environment | TU Delft BK

21#01

Design | Sirene Ontwerpers, Véro Crickx

Cover photo | Paul Bergmeir

ISBN 978-94-6366-351-9
ISSN 2212-3202

This dissertation is open access at https://doi.org/10.7480/abe.2021.01

TOC

Business Innovation Towards a Circular Economy

An Ecosystem Perspective

Dissertation

for the purpose of obtaining the degree of doctor
at Delft University of Technology
by the authority of the Rector Magnificus, prof.dr.ir. T.H.J.J. van der Hagen
chair of the Board for Doctorates
to be defended publicly on
Thursday, 7th January 2021 at 12:30 o'clock

by

Jan Christoph KONIETZKO
Master of Science, Leipzig University, Germany
born in Wangen (Allgäu), Germany

TOC

This dissertation has been approved by the promotors.

Composition of the doctoral committee:

Rector Magnificus,	chairperson
Prof.dr. E. J. Hultink	Delft University of Technology, promotor
Prof.dr. N.M.P. Bocken	Delft University of Technology, copromotor

Independent members:

Prof. dr. R. Mugge	Delft University of Technology
Prof. dr. P. Ritala	Lappeenranta University of Technology
Prof. dr. M. Halme	Aalto University
Prof. dr. F. Luedeke-Freund	ESCP Europe Business School
Prof. dr. J.P.L.Schoormans	Delft University of Technology (Reserve member)

This study was financed by the European Commission, as part of the Marie-Sklodowska-Curie Innovative Training Network “Circ€uit” - Circular European Economy Innovative Training Network, within the Horizon 2020 Program of the European Commission (grant agreement number: 721909)

To my parents and my brother,
for their love and support.

Preface

This book is the result of a four-year journey. I set out to better understand how companies can move towards a circular economy: how they can keep the value of their products, components and materials high. And how they can cut emissions, waste and pollution. After these four years, we are in the midst of a global pandemic. Given this unprecedented time and uncertainty, I have to conclude that, in the spirit of Socrates: "I neither know nor think that I know".

I am humbled by the complexity of the challenges in front of us. We are far from knowing how we as societies can thrive within planetary boundaries. The next ten years will be decisive. They will put us on a path towards a stabilized climate, one that supports life and biodiversity. Or they will push us onto an irreversible trajectory towards 'Hothouse Earth'.

This thesis is a small and humble contribution to try and make this complexity a bit more tangible, and a bit more actionable for companies.

At the start of this PhD journey, I was confronted with a stunning theory-practice gap in the research on sustainable innovation. There is a disconnect between what academics research and discuss, and what practitioners think and do. The former emphasize rigor and depth, the latter speed and action. This thesis is an attempt to strike a balance between the two. I wanted to be close to practice, conduct interviews, workshops, and see what can help practitioners to organize for the sustainability transition.

That said, I hope this book will be useful. For me, it was an incredible learning experience. It showed me that we have everything we need to create this change. The technology is there. We know what to do and why it is important. The biggest bottleneck is human behavior and psychology. It won't be easy. And we have to start yesterday. I hope to see you on the other side.

Acknowledgements

I am grateful that I received the opportunity to do this thesis. This would not have been possible without the support of many people along the way.

First of all, I would like to thank my family. Vielen Dank für die bedingungslose Liebe und Unterstützung, die ich von Euch erfahren habe. Ich habe mich immer geliebt und beschützt gefühlt, und bin privilegiert, aus so einem liebevollen und sicheren Umfeld zu kommen. Meine Herkunft hat einen großen Teil dazu beigetragen, wer ich bin, und was ich bis heute geschafft habe. Dafür danke ich Euch, liebe Mama, Papa, Harald, Frauke, Jens und Gerlind, Jörg, Johanna, Angelika und Uli, Jobst und Dorothee, Uli, Annette und Fritz, Katharina und Sophia.

Second, I would like to thank Priscilla, for being such a great inspiration and source of love, joy and wisdom.

Third, I would like to thank my friends Julius, Simon, Matze, Tim, Paul, Hanna, Alisa, Brian, Phil, Nadja, Ugo, Claudia, Torben, Nico, Naftalie, and Esther.

Fourth, I want to thank my supervisors, Nancy and EJ: Thank you for accepting me onto this PhD journey, for supporting me and always being available. Your responsiveness during this time was impressive. I learned a great deal from both of you. You never said no to any of the crazy ideas I had along the way. It was a smooth and constructive collaboration.

Further gratitude goes out to my PhD colleagues for many valuable and joyful moments in the PhD room on the fourth floor. And also to the Circuit Squad, the 14 other crazy PhD heads in this project that made these four years incredibly insightful and fun.

Last but not least, I want to thank the European Commission for the generous financial support and the ability to do this PhD.

TOC

Contents

List of Tables 16
List of Figures 17
Summary 19
Samenvatting 21
List of publications 23

1 Introduction 25

1.1 A circular economy and circular strategies 25
1.2 An innovation ecosystem perspective to implement the circular strategies 28
1.3 Outline, research questions and contributions of this thesis 32

2 Circular economy ecosystems 35

A review of relevant analogies and an integrative framework

2.1 Introduction 36

2.2 Method: Literature review and actionable framework 38
2.2.1 Literature review: search strings, filter criteria and snowballing 39
2.2.2 Literature analysis and synthesis: a concept matrix and prescriptive knowledge 40

2.3 Results: Main ecosystem analogies in the context of a circular economy 40
2.3.1 Business and innovation ecosystems 42
2.3.2 Industrial ecosystems 42
2.3.3 Urban ecosystems 43
2.3.4 Platform & digital ecosystems 43
2.3.5 Service ecosystems 44
2.3.6 Entrepreneurial ecosystems 45
2.3.7 Knowledge ecosystems 46

2.4 An integrative framework of action for circular economy ecosystems 46
2.5 Discussion and conclusion 50

3 **The Circularity Deck** 53

A tool that can help organizations analyze, ideate and develop their innovation ecosystems towards a circular economy

3.1 **Introduction** 54

3.2 **Conceptual background** 56
3.2.1 An ecosystem perspective on the circular economy 56
3.2.2 Circular strategies 59
3.2.3 Research gaps and goal of this study 63

3.3 **Method** 64
3.3.1 Literature and practice review to derive principles 64
3.3.2 Tool development and evaluation 66

3.4 **Results** 68
3.4.1 The Circularity Deck 68
3.4.2 How to use the Circularity Deck 79
3.4.3 Evaluation and iterations of the Circularity Deck 84

3.5 **Discussion** 88
3.6 **Conclusion** 90

4 **Circular ecosystem innovation** 91

An initial set of principles

4.1 **Introduction** 92

4.2 **Conceptual background** 94
4.2.1 A circular economy and circularity as a systemic property 94
4.2.2 Ecosystem innovation 96

4.3 **Method** 98
4.3.1 Initial pattern matching template 99
4.3.2 Case study 100
4.3.2.1 Case description 101
4.3.2.2 Case data 104
4.3.2.3 Case data analysis 104

4.4 **Findings** 105
4.4.1 Circular ecosystem collaboration 109
4.4.1.1 Define a partner selection process 109
4.4.1.2 Involve new actors from different industries and sectors 109
4.4.1.3 Establish and maintain trust 110
4.4.1.4 Get commitment and buy-in 110
4.4.1.5 Align individual and shared interests 110
4.4.1.6 Re-define actor roles and responsibilities 111
4.4.1.7 Develop a decentralized and collaborative governance structure 111
4.4.1.8 Develop joint circular strategies and goals 112
4.4.1.9 Ensure fair value capture among involved actors 112
4.4.2 Circular ecosystem experimentation 113
4.4.2.1 Design a circular ecosystem value proposition 113
4.4.2.2 Reframe the meaning of resources 113
4.4.2.3 Map a local minimum viable circular ecosystem 114
4.4.2.4 Prototype the circular ecosystem assets 114
4.4.2.5 Test the minimum viable circular ecosystem in a local experimentation space 115
4.4.2.6 Get commitment from real customers early on 115
4.4.3 Circular ecosystem platformization 116
4.4.3.1 Create a modular technological architecture with open interfaces 116
4.4.3.2 Enable others to build and innovate on top of the platform 116
4.4.3.3 Define platform openness 117
4.4.3.4 Specify key boundary resources 117
4.4.3.5 Decide upon pricing structures and platform control mechanisms 117
4.4.3.6 Govern and manage data flows 118

4.5 **Discussion and conclusion** 118

5 **Circular business model experimentation** 121

Demystifying assumptions

5.1 **Introduction** 122

5.2 **Conceptual background** 123
5.2.1 Business model 123
5.2.2 Business model experiments 124
5.2.3 Circular business model experiments and the need for an ecosystem perspective 126
5.2.4 Research gap and contribution 129

5.3 **Method** 129
5.3.1 Design and validate the contexts of experimentation 130
5.3.2 Design and validate principles for experimentation 131
5.3.2.1 Data collection 133
5.3.2.2 Data analysis 134

5.4 **Results** 136
5.4.1 How the participants develop and test their assumptions 136
5.4.1.1 What they find important 136
5.4.1.2 What they know 139
5.4.1.3 Whom they know 140
5.4.2 Principles to help improve circular business model experimentation 141
5.4.2.1 Before experimentation 141
5.4.2.2 During experimentation 142

5.5 **Discussion** 143
5.5.1 Contribution to circular business model experimentation research 143
5.5.2 Contribution to circular business model experimentation practice 144
5.5.3 Limitations of this study 145

5.6 **Conclusion** 146

6 **Discussion and conclusion of this thesis** 147

6.1 **Contributions of this thesis and future research** 147

6.2 **Implications for industry and innovation management** 149
6.2.1 Any organization can take an ecosystem perspective 149
6.2.2 Organizations should care to take an ecosystem perspective 149
6.2.3 How organizations can start taking an ecosystem perspective 150
6.2.4 Challenges of taking an ecosystem perspective 152

6.3 **Implications for design and engineering** 154
6.4 **Implications for design education** 155
6.5 **Limitations of this thesis** 155
6.6 **Concluding remarks** 157

References 159

Appendices 177

Appendix A The search strings used and articles retrieved from the literature review 178

Appendix B The form used to evaluate the ease-of-use and usefulness of the Circularity Deck 179

Appendix C The workshop feedback: rating and qualitative feedback 180

Appendix D Some example cards from the first version of the Circularity Deck 193

Appendix E Search strings and strategy 194

Appendix F Gathered interview data from the case 196

Appendix G A list of questions that were asked during the semi-structured interviews 198

Appendix H Interview themes and questions for the first workshop 199

Appendix I Feedback form 200

Appendix J Example metrics for desirability, viability and circularity 201

About the author 203

List of Tables

1.1 Common innovation perspectives in a circular economy and what an ecosystem perspective can add 29

1.2 Research questions and contributions of this thesis 32

2.1 The seven main ecosystem analogies, their role for a circular economy and environmental sustainability, and the articles that went through a full review 41

3.1 The Circularity Deck: a set of circularity principles for product, business model and ecosystem innovation 70

3.2 The feedback from the workshops and the changes made 85

4.1 The initial and the final template of principles for collaboration, experimentation and platformization 106

5.1 List of possible tests that was available for the first workshop (retrieved from Schuit et al. 2017; Bocken et al. 2018; Ries 2011; Osterwalder et al. 2014) 132

5.2 List of collected data from the three workshops 134

5.3 Questions that the participants in the three workshops found important to investigate 138

List of Figures

1.1 Circular strategies framework 27

2.1 Overview of the method 38

2.2 An integrative framework for innovation in circular economy ecosystems 47

3.1 An ecosystem perspective: product/service, business model, and ecosystem 58

3.2 Circular strategies: narrow, slow, close, regenerate and inform material and energy flows 60

3.3 The process of the literature and practice review 66

3.4 Example cards from the Circularity Deck 69

3.5 Analyzing and developing the circularity potential of a hypothetical circular food ecosystem 80

3.6 How the Circularity Deck has been used in one of the workshops 82

4.1 A circular economy: narrow, slow, close and regenerate material and energy flows. 94

4.2 Through an ecosystem perspective, an innovator sees the product or service, the business model and the wider ecosystem. 95

4.3 Overview of the method. 99

4.4 Overview of involved organizations and contributions. 101

4.5 The adaptable vehicle (e.g. taxi, transport) on the left, the 'operating ecosystem' on the right (figure by ACM). 102

4.6 The intended circularity of the project. 103

5.1 The business model 124

5.2 Circular strategies: narrow, slow, close and regenerate material and energy flows 127

5.3 A framework to design and research workshop formats for circular business model experiments (based on Romme and Reymen, 2018) 130

5.4 Initial test cards and the validation graph. Based on Osterwalder et al. (2014) 132

5.5 The resulting coding structure from the data analysis 135

Summary

We currently live in a carbon intensive linear economy. On the basis of burning fossil fuels, we take, make and waste an increasing amount of materials. This has pushed us against serious planetary boundaries. Radical reductions in environmental impact are needed over the coming decades. Entire economies and societies will have to reorganize. A promising candidate to support this reorganizing is a circular economy. It cuts waste, emissions and pollution, and it keeps the value of products, components and materials high over time.

Companies can innovate towards a circular economy by following five key resource strategies: narrow, slow, close, regenerate, and inform. This thesis explores these strategies – through case research and a design science approach. It shows how companies can implement them. The main proposition is that an ecosystem perspective is necessary to do so. The thesis shows how companies can take an ecosystem perspective, and how they can put it into action. This can help companies to develop circular ecosystem value propositions: that propose a positive collective outcome. One that fulfils user needs in exciting ways, and one that minimizes environmental impact.

Samenvatting

We leven momenteel in een koolstof intensieve lineaire economie. Op basis van de verbranding van fossiele brandstoffen nemen, maken en verspillen we steeds meer materialen. Dit duwt ons tegen de planetaire grenzen. De komende decennia is een drastische vermindering van de milieubelasting nodig. Economieën en samenlevingen zullen zich moeten reorganiseren. Een veelbelovende kandidaat om deze reorganisatie te ondersteunen is een circulaire economie. Het vermindert afval, uitstoot en vervuiling, en het houdt de waarde van producten, componenten en materialen hoog.

Bedrijven kunnen innoveren in de richting van een circulaire economie door vijf belangrijke strategieën te volgen: narrow, slow, close, regenerate en inform. Deze thesis verkent deze strategieën – door middel van casestudy's en een design science benadering. Het laat zien hoe bedrijven deze strategieën kunnen implementeren. De belangrijkste stelling is dat daarvoor een ecosysteem perspectief nodig is. Het maakt duidelijk hoe bedrijven een ecosysteem perspectief kunnen hanteren en hoe ze dit in de praktijk kunnen brengen. Dit kan bedrijven helpen bij het ontwikkelen van circulaire ecosysteem waardeproposities: die een positief collectief resultaat opleveren. En die op een uitdagende manier tegemoet komt aan de behoeften van de gebruikers, en de impact op het milieu minimaliseert.

List of publications

This thesis

Chapter 3: Konietzko, J., Bocken, N., Hultink, E.J., 2020c. A Tool to Analyze, Ideate and Develop Circular Innovation Ecosystems. Sustainability 12, 417. https://doi.org/10.3390/su12010417

Chapter 4: Konietzko, J., Bocken, N., Hultink, E.J., 2020b. Circular ecosystem innovation: An initial set of principles. J. Clean. Prod. 253, 119942. https://doi.org/10.1016/j.jclepro.2019.119942

Chapter 5: Konietzko, J., Baldassarre, B., Brown, P., Bocken, N., Hultink, E.J., 2020. Circular business model experimentation: Demystifying assumptions. J. Clean. Prod. 122596. https://doi.org/10.1016/j.jclepro.2020.122596

Other publications

Konietzko, J.; Bocken, N.M.P.; Hultink, E.J. Ecosystem servitization - Looking at Nature as a Service Business. In Proceedings of the Proceedings of the Spring Servitization Conference: Internationalisation through Servitization, 15-17 May 2017; 2017.

Baldassarre, B., Konietzko, J., Brown, P., Calabretta, G., Bocken, N., Karpen, I.O., Hultink, E.J., 2020. Addressing the design-implementation gap of sustainable business models by prototyping: A tool for planning and executing small-scale pilots. J. Clean. Prod. 255, 120295. https://doi.org/10.1016/j.jclepro.2020.120295

Konietzko, J.; Bocken, N.; Hultink, E.J. Online platforms and the circular economy. In Innovation for Sustainability - Business transformations towards a better world; Bocken, N., Ritala, P., Albareda, L., Verburg, R., Eds.; Palgrave, 2019.

Konietzko, J.; Bocken, N.; Hultink, E.J. Exploring circular business experimentation: a case study on a systems level. In Proceedings of the 25th innovation and product development management conference; Porto, Portugal, 2018.

1 Introduction

We currently live in a carbon intensive linear economy. On the basis of burning fossil fuels, we take, make and waste an increasing amount of materials. The global annual extraction rate of materials has more than tripled since 1970 and continues to grow (Steffen et al., 2015). This economy has improved the lives of many and brought great welfare, especially to Western countries (Tukker et al., 2016). But it has also had damaging effects for biodiversity and the global climate system: the extraction of materials accounts for 90 % of biodiversity loss and water stress, and is responsible for around 50 % of global greenhouse gas emissions (IRP, 2019; OECD, 2012). We now live in a world in which 85 % of global biodiversity is gone, demonstrated by decreased species abundance (Newbold et al., 2016). For example, of all mammals on this planet today, 33 % are humans, 63 % are animals that humans use, and only 3 % are wild, caused by human farming and land conversion practices (Bar-On et al., 2018). In addition, a global warming beyond 2 °C is expected to trigger important points in the global climate system to tip over, like the Arctic ice sheet or vast amounts of Permafrost (IPCC, 2018; Ripple et al., 2017). This global warming can push the planet into an irreversible 'hot-house' state (Lenton et al., 2019). It is therefore fair to say that the current environmental status of the planet is a collective failure. The linear take-make-dispose economy is becoming obsolete, and it is doing so fast.

1.1 A circular economy and circular strategies

To achieve radical environmental impact reductions over the coming decades, entire economies and societies will have to reorganize how they create value. A promising candidate, and an alternative to a linear economy, is a circular economy. A circular economy – embedded within a just and equitable society – minimizes waste, emissions and pollution, and maximizes the value of products, components and materials over time (Blomsma and Brennan, 2017; Geissdoerfer et al., 2017).

With origins in diverse fields like industrial ecology and ecological economics, this concept has gained renewed interest in the last decade for its ability to contribute to environmental sustainability (Frosch and Gallopoulos, 1989; Ghisellini et al., 2016).

Organizations can apply at least five inter-related circular strategies – that apply to products, business models, or the wider ecosystems of an organization – to influence material and energy flows (Konietzko et al., 2020b, based on Bocken et al., 2016; McDonough and Braungart, 2002; Stahel, 2008): 1) *Narrow*: use fewer products, components, materials and energy during different life cycle stages; 2) *Slow*: use products, components and materials longer (which also conserves embodied energy); *Close*: bring production and post-consumer waste back into the economic cycle; *Regenerate*: manage and sustain natural ecosystem services, use renewable and nontoxic materials, and power different life cycle stages with renewable energy; *Inform*: use information technology to support the narrowing, slowing, closing and regenerating of material and energy flows (Figure 1.1) (for details see Konietzko et al., 2020b). To implement these strategies, organizations need to coordinate changes with multiple actors across industries, sectors and hierarchical levels (Adams et al., 2016; Ceschin and Gaziulusoy, 2016).

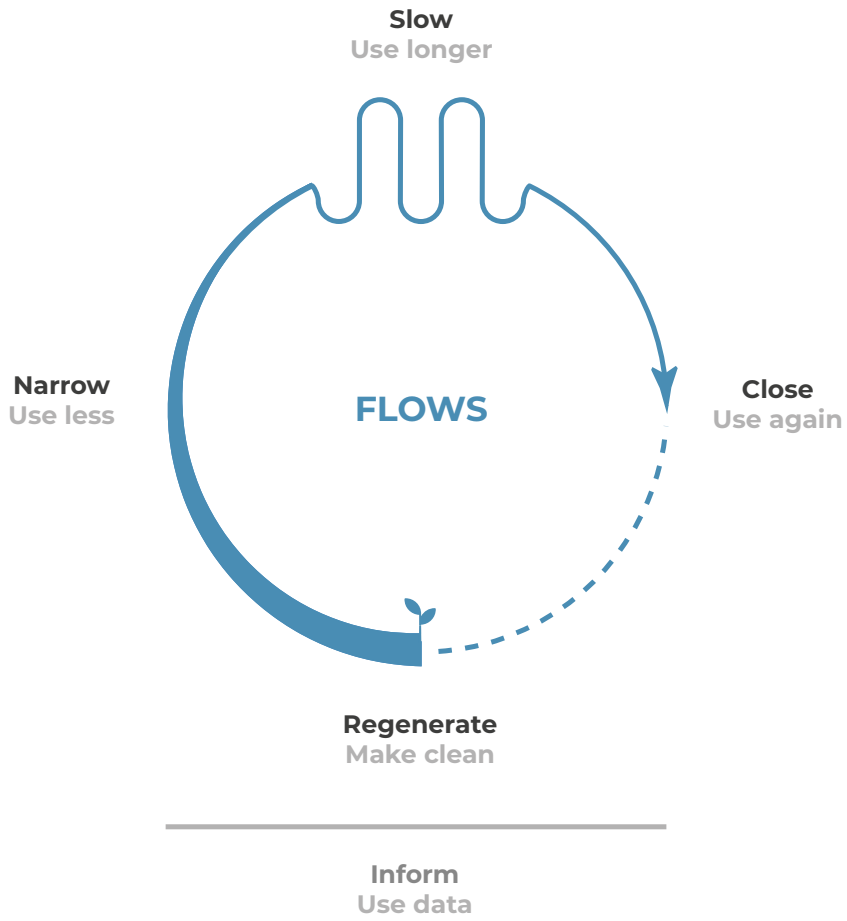


FIG. 1.1 Circular strategies framework

TOC

1.2 An innovation ecosystem perspective to implement the circular strategies

This thesis proposes that the ecosystem, as an analogy and starting point to innovate, is beneficial and useful to explore how the circular strategies can be implemented. The main proposition of this thesis is that circularity is a collective outcome, and not the outcome of how one organization does business. An ecosystem is defined here as a set of actors – producers, suppliers, service providers, end users, regulators, civil society organizations – that contribute to a collective outcome (Konietzko et al., 2020; Talmar et al., 2018).

Ecosystems can be viewed as complex adaptive systems. Systems are entities with several related components (Von Bertalanffy, 1972). The behavior of a system becomes more complex as the number of components increases. They change in non-linear ways. That is, they might change slowly for a longer period of time, before they change rapidly and in drastic ways. This non-linearity makes the behavior of complex adaptive systems difficult to predict (Anderson, 1999). The components of a complex adaptive system adapt and learn through their immediate experience, often locally, and without central control.

Our systems of production and consumption can be seen in this way. They are shaped by the interactions among many diverse people and organizations, and are subject to dynamic resource and inter-organizational material and energy flows. They are complex adaptive systems that need to be better understood and influenced, to implement the circular strategies. Complex adaptive systems have the following features: they focus on the interdependencies of a set of diverse actors in a defined context and environment, are nested in a hierarchy of higher-order and lower-order systems, and recognize how actors, contexts and boundaries are interdependent, self-organize, and co-evolve over time in nonlinear ways that are difficult to predict (Currie, 2011; Levin, 1998; Phillips and Ritala, 2019). Ecosystem boundaries can either be drawn through a defined space, a period of time, or through stocks and flows, as well as processes that belong to it (Currie, 2011; Ritala and Almpanopoulou, 2017).

When you accept that our production and consumption systems are complex and adaptive, an important question is how these systems can be changed to implement the circular strategies. This thesis argues that an ecosystem perspective is necessary to do this. An ecosystem perspective changes how organizations approach

circularity, including in relation to the important areas of product design, business model innovation, or supply chain management (Table 1.1) (Lieder and Rashid, 2016). In the following, I describe how the ecosystem analogy can add value to these areas.

TABLE 1.1 Common innovation perspectives in a circular economy and what an ecosystem perspective can add

Approaches	Description	What an ecosystem perspective adds
Circular product design	Focuses on the physical product, to design it for durability, repair and maintenance and recycling. Adopts life cycle thinking. Aims at product integrity and recyclability.	Lets you think about complementary innovations needed to deliver circularity. Shifts product design from the focus on one product, to a focus on a number of products and services. A key question is how they fit together, to enable circularity in the higher-order ecosystem.
Circular business model innovation	Focuses on the value proposition, value creation and delivery, and value capture mechanisms of a focal firm. Explores servitized or product-as-a-service models Multi-stakeholder and multi-level view.	Puts an emphasis on the importance of other business models than the one of a focal firm Shifts from a focal firm value proposition to a collective outcome, or ecosystem value proposition. By putting the focus on interactions of different business models, it can help to manage rebound.
Circular supply chain management	Focus on the operations management of a focal firm to coordinate the flow of tangible products (including reverse logistics). Manages cost and quality. Assumes fixed actor positions and roles.	Explores how actor positions and roles can evolve Helps to consider other relevant actors, like regulators, civil society or service providers. Helps to think about the collective outcome and the ecosystem value proposition, to better align supply chain and other actors.

First, a product design perspective in a circular economy adopts life cycle thinking and aims at product integrity and recyclability (den Hollander et al., 2017). The focus of this perspective is on the physical product – what materials it should contain, and what kind of product architecture it will have. The idea is to make a product that can be easily disassembled, repaired, refurbished, remanufactured (if applicable) and recycled. Design for a circular economy thus adopts a systemic perspective, because it looks at the entire life cycle of products (Bakker et al., 2014).

An ecosystem perspective can add value to circular product design. It lets you think about the types of loosely coupled actors, often from different industries, that provide the complementarities necessary for circularity (Jacobides et al., 2018). Complementarities in the circular economy occur when the value maximization of a product depends on the product or service from a different organization (Konietzko et al., 2020). Think of recyclable packaging that depends on the complementary service of recycling. This service likely needs to be performed by a different company – and there needs to be some alignment on the packaging, and how it is designed to fit in with the technology of the recycling firm.

Product designers can benefit from thinking about the different actors and the types of complementarities that are needed to enable circularity. This perspective triggers them to carefully consider, and organize for the required alignment structure of their envisioned circular ecosystem (Adner, 2016). It thereby shifts product design from the focus on one product, to a focus on a number of products and services and how they fit together. In a nutshell, an ecosystem perspective adds questions like: who will have access to the product? Who will repair, maintain and recycle it, or provide renewable electricity to power it? Who will orchestrate the required activities and how (Parida et al., 2019)? What are the co-innovation and co-adoption risks of aligning with new actors on how things are being done (Talmar et al., 2018)?

Second, a business model innovation perspective focuses on changing the value proposition, the value creation and delivery, and the value capture mechanisms of a focal firm (Richardson, 2008). These mechanisms can be seen as a system of activities, that are performed by a focal firm or third parties, like suppliers or customers. As an activity system, the business model spans the traditional boundaries of the firm (Zott and Amit, 2010). This view has been extended by research on sustainable business models (Boons and Lüdeke-Freund, 2013), which has included the notion of multiple stakeholders (Freudenreich et al., 2020) and multiple forms of value, including social and environmental value (Bocken et al., 2013). Organizations and their business models are embedded in higher-level systems, in which various actors jointly enable or inhibit sustainability (Starik et al., 2016). A particular kind of business model – one that is key to a circular economy – is the product-as-a-service model, also called a product-service system (Tukker, 2004). It gives an organization an incentive to invest in products that last for a longer time, and that can be easily maintained and repaired (Tukker, 2015).

From an ecosystem perspective, the business models of other actors are as important as the one of a focal firm (Adner, 2016). Through this perspective, an organization sees multiple business models, and how they interact and depend on each other. While the business model centers around a focal firm, the ecosystem centers around a collective outcome, like circularity, or a superior, overall experience. This also transcends the notion of the focal firm value proposition. It becomes an ecosystem value proposition, like a 'zero emissions, affordable and inclusive mobility system' (Talmar et al., 2018).

By focusing on a collective outcome, an ecosystem perspective is also a promising way of managing rebound. Rebound effects happen when a product - that has been designed to have a positive impact, and lowered resource use – leads to a net increase in environmental impact and resource use. Think of more efficient lighting through LED, and the sharp increase in the use of LEDs in new applications (Zink and

Geyer, 2016). All the new lights lead to a net increase in the energy and resource use of lighting. An ecosystem perspective – or an 'ecology of business models' (Bocken et al., 2019a; Boons and Bocken, 2017) – can help to better understand how and where these rebounds may occur. And this helps to identify and prevent potential positive feedback loops that reinforce consumption (Zink and Geyer, 2017).

Third, supply chain management focuses on the operations management of a focal firm, usually in terms of cost and quality, and is used to coordinate the flow of tangible inputs and outputs among upstream and downstream partners (Carter et al., 2015). This perspective assumes fixed actor positions and roles, and can usually be decomposed into bilateral links and relationships (Adner, 2016). In the context of a circular economy, the supply chain has been extended to include reverse logistics, to coordinate how products can be returned to be reused, repaired, remanufactured or recycled (Guide Jr and Van Wassenhove, 2009).

An ecosystem perspective helps to go beyond direct suppliers and distributors, and beyond a focus on tangible products. It explores how actor positions and roles can evolve (Adner, 2016), and also pays attention to the roles of other relevant actors – regulators, civil society organizations, or service providers – that are outside of the traditional scope of a supply chain perspective. Lastly, the supply chain is not aligned around a focal value proposition. An ecosystem perspective can help to realign actors around an ecosystem value proposition – who may or may not be positioned within a supply chain – to provider a superior user experience, and to enable circularity (Konietzko et al., 2020).

In sum, this thesis explores business innovation towards a circular economy, from an ecosystem perspective. It adds to the existing perspectives on product design, business model innovation and supply chain management. A lot of aspects of ecosystem innovation in the context of a circular economy are underexplored. In the following, I outline the research questions and contributions of this thesis.

1.3 Outline, research questions and contributions of this thesis

TABLE 1.2 Research questions and contributions of this thesis

CH	Research questions	Contribution to theory	Contribution to practice	Published in?
2	Which different analogies of ecosystems co-exist in the context of a circular economy? How can organizations put them into action?	Provides an overview of relevant analogies in the literature. Helps management scholars be more explicit about the ecosystem analogy they use, to avoid conceptual ambiguity.	Helps practitioners leverage the insights from the different analogies and shows how they can be put into action.	To be submitted to Journal of Cleaner Production
3	How can organizations be facilitated to take a circular ecosystem perspective?	Provides conceptual clarity and a novel mapping of circular strategies and principles.	Produces the Circularity Deck, a tool than can help organizations analyze, ideate and develop their innovation ecosystems towards a circular economy. After the first six months of publication, the Circularity Deck was used by more than 30 organizations.	Sustainability
4	What principles does the (business) literature recommend on how to successfully innovate in ecosystems? How relevant and useful are these principles for circular oriented innovation?	Reviews and categorizes prescriptive knowledge form the innovation ecosystem literature. Shows how these principles can be used to innovate towards a circular economy. This can serve to further investigate success factors of using the principles in different contexts.	Produces a list of principles that can inform circular ecosystem innovation projects, to learn from prior experience and ensure a meaningful process.	Journal of Cleaner Production
5	How do the innovation participants develop and test their assumptions during circular business model experimentation? How can a better understanding of this decision-making logic help improve this process?	Illuminates the effectual decision-making logic of business model experimentation and shows the subjective and opportunistic nature of formulating and testing assumptions. Shows that assumptions about circularity are often not tested and ignored.	Proposes principles that can help practitioners make the experimentation process more rigorous, to increase the chances of innovations that can reduce environmental impacts.	Journal of Cleaner Production

This thesis consists of four chapters that address several important and under-explored questions about ecosystem innovation in a circular economy. Each chapter is a stand-alone publication that details the conceptual background[1], research gap, the method used to address a question, and the contribution it makes to theory and practice. Table 1.2 lists the research questions and the contributions of each chapter.

The second chapter explores the different analogies of ecosystems that co-exist in the context of a circular economy, and it shows how organizations can put them into action. Several analogies exist – like industrial, innovation, service, or platform ecosystems – and clarity is needed on how they can advance a circular economy. We therefore conducted a systematic literature review to provide an overview of the relevant analogies. This overview can help management scholars be more explicit about the analogy they use, to avoid conceptual ambiguity. For practitioners, it offers insights on how to analyze circular ecosystems, and how to innovate towards them.

The third chapter investigates how organizations can be facilitated to take an ecosystem perspective on the circular economy. So far, circular economy innovation support for organizations has mostly focused on product and business model innovation, and there are few tools that take multi-actor and systemic perspectives (Konietzko et al., 2020a). The output from this study is the Circularity Deck, a tool that helps organizations take an ecosystem perspective on the circular economy. A literature and practice review served to distill strategies and principles for circular oriented innovation from product, business model and ecosystem perspectives. This review served to provide conceptual clarity and a novel mapping of circular strategies and principles. These were then used to develop the tool, which was subsequently tested in twelve workshops with a total of 136 innovation managers, designers and entrepreneurs. The tool is easy to use and useful for different types of organizations to ideate, analyze and develop the circularity of their innovation ecosystems.

The fourth chapter explores what principles the (business) literature recommends on how to successfully innovate in ecosystems, and how relevant and useful these principles are for circular oriented innovation. This is based on a concise literature review and 20 interviews from a circular ecosystem case study at the intersection

1 Except chapter two: the conceptual background of this unpublished chapter is part of this thesis introduction. Because each chapter is standalone, the reader will notice some repetition in the conceptual background sections of chapters three, four and five. I decided that this is the best way to go, to avoid a lot of rewrite of published work, and to make sure each chapter is clear on its distinct conceptual background.

of the mobility, energy and ICT industries. The resulting recommended principles are categorized in three groups: collaboration, experimentation and platformization. For management scholars, this study contributes an overview and categorization of relevant prescriptive knowledge from the literature. This can help investigate success factors of using these principles in different contexts. For practitioners, it produces a list of principles that can inform future circular ecosystem innovation projects, to learn from prior experience and ensure a meaningful process.

The fifth chapter focuses on experimentation with new circular business models. It investigates how innovation participants develop and test their assumptions during the process, and how can a better understanding of this decision-making logic can help to improve it. Using three experimentation workshops with novice entrepreneurs, one incumbent and experienced circular startups, this study shows the subjective and opportunistic nature of formulating and testing assumptions, and finds that assumptions about circularity are often not tested and ignored. Based on these insights, the chapter suggests a number of principles that can help improve the experimentation process. The chapter also shows that an ecosystem perspective can help scrutinize ideas about circularity.

2 Circular economy ecosystems

A review of relevant analogies and an integrative framework

To be submitted in Journal of Cleaner Production:
Jan Konietzko, Nancy Bocken, Erik Jan Hultink

ABSTRACT The ecosystem is an important analogy to describe the complex and interdependent nature of innovation, and to explore the transition to a circular economy. The literature contains diverse analogies, like innovation, industrial, platform, urban, or service ecosystems. They focus on different types of inter-organizational interactions, flows and processes, like material and energy, or data and information. In this study, we conduct a systematic literature review of relevant analogies in the context of environmental sustainability and a circular economy, and integrate them in a common framework for action. Researchers can use the framework to better position their ecosystem studies. Organizations can use it to put an ecosystem perspective into action. The framework reveals a hierarchy of increasing thematic focus, from broad analogies like urban ecosystems, to more focused ones like knowledge or industrial ecosystems. Future research can further build on this work and investigate how organizations can put an ecosystem perspective into action.

KEYWORDS Circular economy; Sustainability; Industrial ecosystems; Innovation ecosystems; Circular business; Literature review

2.1 Introduction

The ecosystem has become a popular analogy in organization studies, to describe the complex, dynamic and interdependent interactions of organizations over time (Phillips and Ritala, 2019; Suominen et al., 2019). The term ecosystem emerged in ecology in 1935, to integrate the study of ecological communities and populations with their interactions with the physical environment (Tansley, 1935). To this date, ecosystems have remained contested in ecology, where they are now seen as complex adaptive systems (Levin, 1998). They consist of key processes and flows – like primary production, soil formation, or nutrient cycling – that cross multiple scales, interact with different organisms, populations and communities, and that change in ways that are difficult to predict (Currie, 2011).

The ecosystem has become a popular analogy to describe complex social interdependencies. The first mention of the term ecosystem in social science dates back to Amos Hawley, who conceptualized humans as an interdependent species that acts within larger units (Hawley, 1986). The ecosystem has also been used in the context of a circular economy, a business-driven concept for environmental sustainability (Blomsma and Brennan, 2017). Take, for example, the analogy of an industrial ecosystem, which aims to improve local and inter-organizational material and energy flows (Wolf et al., 2007; Zucchella and Previtali, 2019); or the innovation ecosystem, which helps to align diverse actors around common goals and sustainable and circular value propositions (Planko et al., 2019; Talmar et al., 2018); or digital and platform ecosystems, which facilitate information flows to collaborate for sustainable development (Elia et al., 2020; Konietzko et al., 2019). As these examples illustrate, several relevant ecosystem analogies coexist in the context of a circular economy.

The existing diversity of analogies may produce confusion and ambiguity. It can be difficult for scholars to describe the ecosystem they investigate. This confusion might also spill over to practitioners, who see the ecosystem as an abstract concept that is difficult to put into action. Some have started to lift the confusion (Aarikka-Stenroos et al., 2020). We build on this initial work through a systematic literature review of relevant ecosystem analogies, in the context of a circular economy and environmental sustainability. We ask the following timely research questions:

1. Which relevant ecosystem analogies coexist in the context of environmental sustainability and a circular economy?
2. How can these analogies be integrated in a common framework for action?

We make two main contributions to the extant literature: First, to the growing literature on innovation ecosystems in the context of a circular economy, we clarify and provide a systematic overview of the relevant analogies (Parida et al., 2019; Planko et al., 2019; Zucchella and Previtali, 2019). Several reviews of different ecosystem analogies exist, but they have not investigated the role these analogies play in a circular economy[2]. More clarity can help scholars to recognize, better define and distinguish the ecosystem concepts they use. This increased clarity may also help to combine relevant analogies – and their underlying focal flows and interactions – to gain new insights. For instance, a recent study combined innovation and industrial ecosystems, to understand how an organization developed a 'waste is food' restorative ecosystem (Zucchella and Previtali, 2019).

The second contribution is to managerial practice, where the integrative framework can help to put an ecosystem perspective into action. While describing the framework, we provide several suggestions on how organizations can use a given analogy to advance their ecosystem strategy. An ecosystem perspective can help firms face systemic risks and opportunities that come from resource scarcity and nature degradation (Heuer, 2011; WEF, 2020), tightening regulations (China and EU, 2018; EU, 2016) and civil society pressure to act on environmental issues (Gomez-Carrasco and Michelon, 2017). To mitigate these risks, organizations will have to innovate and transform their products and technologies, business models, supply chains and – the subject of this study – the wider ecosystems they are part of (Tukker, 2004).

The remainder of this study proceeds as follows. Because the conceptual background was explained in the thesis introduction, we proceed with a descriotion of how we searched for, selected and analyzed the literature on ecosystem analogies in the context of a circular economy. The results section then describes the analogies that we identified: business & innovation, industrial, urban, digital & platform, service, entrepreneurial and knowledge ecosystems. After describing them briefly, we integrate them in a common framework for circular economy ecosystems. We describe the framework from the viewpoint an organization that wants to put an ecosystem perspective into action. This is to increase the practical value of this review. We then discuss future research opportunities.

2 For example, there are ecosystem reviews on innovation (Gomes et al., 2018; Suominen et al., 2019), services (Holmqvist and Diaz Ruiz, 2017), B2B markets (Aarikka-Stenroos and Ritala, 2017), industrialization (Guedes et al., 2018), entrepreneurship (Brown and Mason, 2017; Cao and Shi, 2020; Ojaghi et al., 2019), or digitalization (Mukhopadhyay and Bouwman, 2019).

2.2 Method: Literature review and actionable framework

To answer the research questions, we conducted a systematic literature review (Tranfield et al., 2003), divided into three main stages (Figure 2.1): 1) the literature review, in which we identified search strings, defined selection criteria and applied snowballing to find further relevant literature, 2) the literature analysis, in the form of a concept matrix (Webster and Watson, 2002), and 3) the literature synthesis (Sandelowski et al., 1997), in the form of an integrative framework, with a focus on how organizations can put an ecosystem perspective into action. We will describe each step in more detail below.

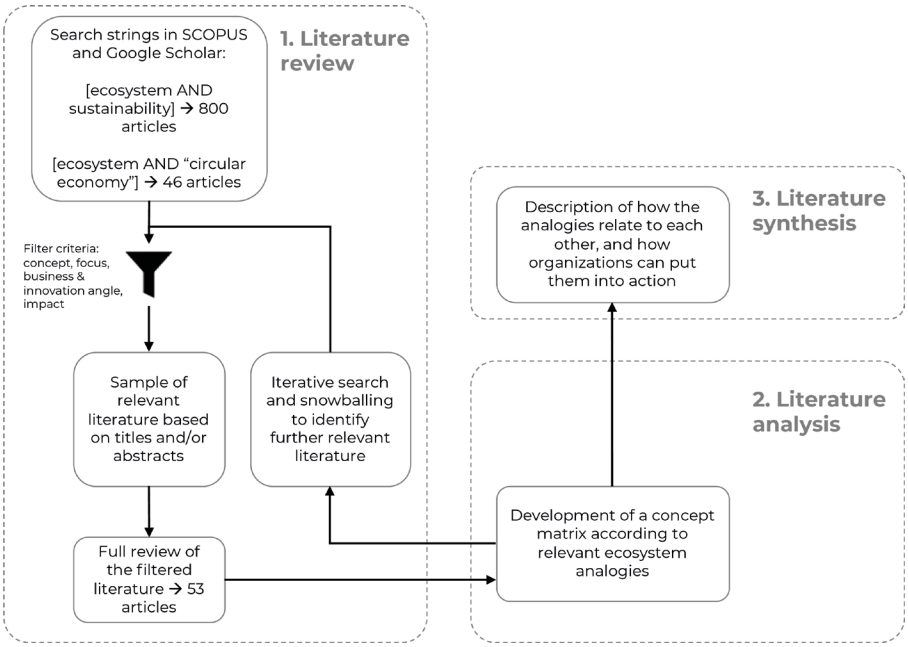


FIG. 2.1 Overview of the method

TOC

2.2.1 Literature review: search strings, filter criteria and snowballing

We searched the titles, abstracts and keywords of the literature in SCOPUS, one of the leading academic databases, in March 2020. We used the search strings [ecosystem AND sustainability] and [ecosystem AND "circular economy"], filtered for the business, management and accounting literature. This is because we take a business and organizational perspective, and because the main target group of this research is innovation and organization scholars, managers, entrepreneurs and designers. We searched for the broader and less defined concept of sustainability to account for the literature on environmental sustainability that is also relevant in the context of a circular economy. In addition, we used the same search strings (with the addition "AND business") to search Google Scholar. The review only accounted for peer reviewed journal articles. The first search string revealed 800 articles, the second 46. We then read the abstracts and filtered the articles according to the following criteria, to identify the relevant ecosystem analogies.

1. Concept: there is explicit usage of an ecosystem concept, in the form of an analogy;
2. Focus: the article is about a circular economy and/or environmental sustainability;
3. Business and innovation angle: it is relevant for business strategy and innovation, which excludes more policy and civil society focused concepts and theories; and
4. Impact: there is a visible impact of the study in terms of citations. That is, more than 20 citations, or, alternatively, the article is no older than two years. This is to account for recent articles that are relevant to this review.

Based on the identified analogies, we iterated the search several times, to identify how organizations can operationalize a given analogy. For example, one ecosystem analogy is the industrial ecosystem, from the field of industrial ecology, which has focused originally on inter-organizational material and energy flows in industrial parks (Frosch and Gallopoulos, 1989). After we found this important analogy, we used the search strings ["industrial ecosystem" AND prescriptive OR practice OR principle*], to find additional literature on how to put an industrial ecosystem perspective into action. We conducted this search with every analogy we found and applied snowballing (Wohlin, 2014) to identify other relevant articles. The selected articles from this second search and the snowballing were then again filtered through the above four filter criteria. A total of 53 articles went through the full review (listed in Table 2.1 below).

2.2.2 Literature analysis and synthesis: a concept matrix and prescriptive knowledge

The first sample of the review was analyzed through a concept matrix that plots the identified ecosystem analogies within the extant literature (Webster and Watson, 2002). This helped to develop an overview and description of the existing, relevant analogies. We then synthesized the different analogies in a common framework for action. As a third step, we sought to better understand how organizations can put the analogies into action. Getting this knowledge from the literature can be difficult. Most academic literature on sustainable innovation is descriptive and analytic, and not prescriptive (Zollo et al., 2013). We therefore read the literature and asked: "how can organizations use this?"; "What are the practical implications of this?". There is a subjective nature to this process. We used the outcome from this research to describe the framework, based on how organizations can put an ecosystem perspective into action. With this we hope to increase the practical impact of this research, and help close the theory-practice gap of sustainable innovation research (Baldassarre et al., 2020; Tranfield et al., 2003).

2.3 Results: Main ecosystem analogies in the context of a circular economy

We identified the following analogies, in order of the number of identified articles, from highest to lowest: business & innovation, industrial, urban, platform & digital, service, entrepreneurial and knowledge ecosystems (Table 2.1). Below, we describe each of the analogies briefly, in the context of a circular economy. This description includes other seminal articles that were not part of the review, to provide better definitions and descriptions of the analogies. These are marked with an Asterix.

TABLE 2.1 The seven main ecosystem analogies, their role for a circular economy and environmental sustainability, and the articles that went through a full review

Ecosystem analogy	Description	References
Business & Innovation ecosystems	Refers to a set of actors, like producers, suppliers, service providers, end users, regulators, or civil society organizations that contribute to a collective outcome.	(Bocken et al., 2019; Boons and Bocken, 2017; De Bernardi and Azucar, 2020; Hellström et al., 2015; Khavul and Bruton, 2013; Konietzko et al., 2020b; Ma et al., 2018; Oskam et al., 2020; Parida et al., 2019; Planko et al., 2019; Rajala et al., 2016; Seebode et al., 2012; Stead and Stead, 2013; Tencati and Zsolnai, 2009; Zucchella and Previtali, 2019)
Industrial ecosystems	Apply the idea of circular flows from natural ecosystems to industrial processes, and serve to optimize the consumption of materials and energy, and minimize waste by channeling them as inputs into other processes.	(Côté and Hall, 1995; Despeisse et al., 2012; Frosch and Gallopoulos, 1989; Harper and Graedel, 2004; Jelinski et al., 1992; Korhonen, 2004; Korhonen et al., 2004; Leduc and Van Kann, 2013; Nielsen, 2007; Scheel, 2016; Tsvetkova and Gustafsson, 2012; Yang and Lay, 2004)
Urban ecosystems	Describe cities as ecosystems that provide habitats for citizens and institutions, provide ecosystem services, and experience an inflow and outflow of materials and energy.	(Elmqvist et al., 2015; Filho et al., 2020; Li et al., 2017; Macke et al., 2018; McPhearson et al., 2015; Pickett et al., 2013; Pincetl, 2012; Sun et al., 2016; Voytenko et al., 2016; Xue and Luo, 2015)
Digital & platform ecosystems	Refer to technological and online platforms that are developed by one or more organizations to enable a large number of other organizations to build complementary products and services on top of it – and thereby increase value and attract more users.	(Abella et al., 2017; George et al., 2020; Konietzko et al., 2020b, 2019; Kumar et al., 2020; Ooms et al., 2020; Stuermer et al., 2017; Wei et al., 2020)
Service ecosystems	Describe how value-proposing actors integrate resources and co-create value. These actors are connected through shared institutional logics and embedded within an evolving spatial and temporal structure	(Anderson et al., 2013; Bolton, 2020; Konietzko et al., 2020b; Trischler et al., 2020)
Entrepreneurial ecosystems	Focuse on the founding of new ventures in a regional community of interdependent actors – like startups, large firms, universities, regulators. It incorporates the role of different contextual elements – and their dynamic interactions – that can enable successful innovation and entrepreneurship.	(Cohen, 2006; Henry et al., 2020; Planko et al., 2016)
Knowledge ecosystems	Often initiated by public research organizations, they focus on the use and production of knowledge in pre-competitive stages.	(Aarikka-Stenroos et al., 2020)

2.3.1 Business and innovation ecosystems

The analogy of a business ecosystem emerged in the early 1990s to describe firm interdependencies and a new industrial landscape shaped by competition among ecosystems, rather than competition among single organizations (Moore, 1993*). This view has been extended to include the concept of an innovation ecosystem, which helps to design ecosystem value propositions. Ecosystem value propositions are end-user facing value propositions that require multiple actors to be materialized (Adner, 2016*, 2006*; Talmar et al., 2018*). Business and innovation ecosystems may be distinguished by their focus and narrative: the former deals with value capture and global competition, the latter with value creation and collaboration (Gomes et al., 2018*; Hakala et al., 2020*).

In the context of a circular economy, business and innovation ecosystems can serve to organize the needed multisector and multi-stakeholder structure that can help to bring together diverse interests and facilitate collective action (Stead and Stead, 2013). The main value of this analogy in this context is its strategic focus on actor alignment and new types of flows and interactions among organizations, their complementary products and services, and users. This informs how companies can align around circular ecosystem value propositions – that transcend their focal firm business models (Konietzko et al., 2020b).

2.3.2 Industrial ecosystems

Industrial ecosystems focus on tangible, inter-organizational material and energy flows, and how these can be influenced to achieve more sustainable outcomes (Frosch and Gallopoulos, 1989). Being at the foundation of a circular economy, this analogy comes the field of industrial ecology and applies the idea of circular natural flows to industrial processes (Blomsma and Brennan, 2017*). Industrial ecosystems seek to optimize the consumption of materials and energy, and minimize waste by channeling them as inputs into other processes (Harper and Graedel, 2004). This may happen within one factory (Despeisse et al., 2012), an eco-industrial park with a variety of organizations exchanging materials and energy (Côté and Cohen-Rosenthal, 1998), or within an extended urban context, which goes beyond production, and includes the consumption and end-of-life stages of products (Harper and Graedel, 2004; Leduc and Van Kann, 2013). The Kalundborg eco-industrial park in Denmark is one of the most famous examples of an implemented industrial ecosystem, focusing on production (Jacobsen, 2006*).

2.3.3 Urban ecosystems

Cities as ecosystems provide habitats for citizens and institutions, provide natural ecosystem services, and experience an inflow and outflow of materials and energy (Pincetl, 2012). Urban ecosystems host multiple actors, from diverse groups, sectors and industries, with diverse and often conflicting interests. The actors within urban ecosystems share the same locality and can therefore be brought together to collaborate and align, to ensure sustainable development and a high quality of life for the citizens of a city (Macke et al., 2018). Urban ecosystems also include natural flows and processes. These provide important ecosystem services, like clean air through parks, or cooling during hot summers through a higher density of tree canopy cover (Elmqvist et al., 2015; Filho et al., 2020). Ecosystem services play an important role in the resilience of cities to environmental shocks, like persistent heat waves or flooding from heavy rainfalls (McPhearson et al., 2015).

This analogy is important in the context of a circular economy. It relates to the concept of the urban metabolism, which describes how material and energy flow in and out of cities. The urban ecosystem is also more generic and inclusive than other analogies, because it accounts for natural flows and the ecosystem services that they provide (Leduc and Van Kann, 2013; Morris et al., 2018*; Sun et al., 2016).

2.3.4 Platform & digital ecosystems

Digital and platform ecosystems refer to technological and online platforms that are developed by one or more organizations, to enable a large number of other organizations to build complementary products and services on top of it – and thereby increase the value of platforms and attract more users (Gawer, 2014). The goal is to achieve network effects, or a positive feedback loop, in which complementary products make the platform more valuable for users, and more users make it more attractive for complementors to provide additional products and services (Gawer and Cusumano, 2014*). Common examples of organizations with platform based business models include Apple, Google, Facebook and Amazon. These organizations inscribe norms and values about how interactions should take place. In the beginning of the 2000s, many people were excited about the potential of the internet and the emerging platform ecosystems to drive a more participatory and inclusive culture. This has changed in the 2010s, with growing concerns about data privacy, worker's rights, racial profiling, or the propagation of hate speech (Rhue, 2019*; van Dijck et al., 2018*).

It is unclear if platform ecosystems can help establish a circular economy and reduce net environmental impacts. On the one hand, they may increase material and energy use, as they require additional hardware and infrastructure to operate, and large amounts of data that need to be stored on power-consuming servers (Frenken and Schor, 2017). On the other hand, they can serve to market, operate and co-create circular products, components and material (Konietzko et al., 2019). Their ability to collect and analyze data, and to increase coordination and trust among actors can inform better decisions about environmental aspects on an ecosystem level (George et al., 2020).

For example, in the city of Copenhagen, sensors have been deployed in bicycles to measure noise, congestion and pollution, to inform better decisions about how to evolve the mobility ecosystem towards environmental sustainability (Wei et al., 2020). This potential can be increased further if platform ecosystems favor open licensing regimes, shared tacit knowledge, a participatory culture, good governance and diversified funding sources (Stuermer et al., 2017). These aspects have been mentioned repeatedly in the context of smart cities (Abella et al., 2017; Kumar et al., 2020). Platform ecosystems can further increase their sustainability potential if the complementors on the platforms are selected based on their ability to add environmental or social value (Ooms et al., 2020; Wei et al., 2020). For example, an urban mobility ecosystem could restrict access to those complementary mobility providers that can demonstrate how they help to cut urban emissions, pollution and waste.

2.3.5 Service ecosystems

Service ecosystems are based in service science and on the service-dominant logic. This analogy of ecosystems has emerged to describe the dynamic, multi-actor and systemic nature of service exchange and value creation. Service ecosystems describe how value-proposing actors integrate resources and co-create value. These actors are connected through shared institutional logics, and embedded within an evolving spatial and temporal structure (Vargo and Lusch, 2011*). Service ecosystems help to identify how services impact the environment (Anderson et al., 2013; Bolton, 2020). They change through institutionalization: the maintenance, disruption and change of the rules, norms, beliefs and meanings around what people find valuable. These institutions are nested within micro (personal, household), meso (organizations, industries), and macro (societies) levels. Due to their subjective nature, views on value may differ and result in conflict, depending on the context and the people involved (Vargo et al., 2015*).

Institutions can be changed by 1) including new and unusual actors in the innovation process, 2) redefining the roles of the involved actors, and 3) reframing the meaning of resources (Koskela-Huotari et al., 2016*). This is relevant in a circular economy. New actors may be needed to fulfill critical and complementary ecosystem functions, to maximize the use value of products and components over time, like repair, maintenance, renewable energy supply, or the maximizing of use capacity (Konietzko et al., 2020b). Roles may redefined, based on the requirements of new complementary products and services. An example is the role of the user, which might change from a mere consumer to a producer and participant in the development and provision of products and services (Trischler et al., 2020).

2.3.6 Entrepreneurial ecosystems

Entrepreneurial ecosystems focus on the founding of new ventures in a regional community of interdependent actors – like startups, large firms, universities, regulators, or banks (Brown and Mason, 2017*). It analyzes the industrial, technological, organizational, institutional and policy, social, temporal and spatial contexts – and their dynamic interactions – that can enable successful innovation and entrepreneurship (Autio et al., 2014*). Ecosystem actors can be decomposed into dedicated roles – actors, connectors and resource providers – that are needed to stimulate successful innovation in a given entrepreneurial ecosystem. Incubators and co-working spaces are examples of actors, professional associations, clubs and business brokers act as connectors, and banks, venture capital firms, business angels, and crowdfunding and peer-to-peer lenders act as resource providers (Brown and Mason, 2017*).

In the context of a circular economy, sustainable and circular entrepreneurial ecosystems can be viewed as interdependent actors in a regional community who commit to a circular economy and sustainable development and build new ventures (Cohen, 2006). This analogy recognized the importance of a favorable socio-economic network to stimulate innovation (Planko et al., 2016). This includes informal networks – families, colleagues, friends – who are important if the formal network, with support from regulatory, financing or other bodies, is underdeveloped for sustainability or a circular economy. This may be due to a lack of knowledge and/or interest in the topic, which depends on the local context and culture. The European cities of London, Berlin, and the Randstad region in the Netherlands, for example, have been identified as prominent entrepreneurial ecosystems for a circular economy (Henry et al., 2020). Universities and regulators can support the emergence of these ecosystems. The former can generate and disseminate useful

knowledge and develop and commercialize sustainable technologies. The latter can foster entrepreneurial ecosystems through advanced regulatory frameworks that target emission, pollution and waste reductions (Cohen, 2006).

2.3.7 Knowledge ecosystems

Knowledge ecosystems consist of users and producers of knowledge, who are organized around a collective search for knowledge (Järvi et al., 2018*). They focus on the early stages of new knowledge production, in pre-competitive and pre-commercial settings. Frequently led by universities or other public research institutions, the focus tends to be on technology within a regional cluster of organizations (Clarysse et al., 2014*). The key outcome from knowledge ecosystems is the collaborative exploration of new knowledge, driven by higher-order goals that organizations cannot attain alone (Järvi et al., 2018*).

In the context of a circular economy, knowledge ecosystems are regional clusters that aim at new knowledge about the circular economy. This can be around specific industries or topics, like textiles (Aarikka-Stenroos et al., 2020), or the circularity of e-vehicle batteries (acatech, 2020*). The produced knowledge can then be disseminated in the form of reports and dissemination events, to increase the likelihood that they turn into circular innovation ecosystems (Clarysse et al., 2014*).

2.4 An integrative framework of action for circular economy ecosystems

Based on the literature, we pose that the ecosystem analogies inform how to analyze and influence different types of inter-organizational flows and processes – consisting of people, products, components, materials, energy, information, money or knowledge – to generate different ecosystem outcomes, like circularity (Figure 2.2). We also identify a hierarchy in these analogies. Starting with urban ecosystems, they assume an increasing thematic focus. Knowledge ecosystems, for example, focus on the users and producers of knowledge. This hierarchy can help an organization to recognize its embeddedness within diverse ecosystems. Each analogy, which its

particular perspective, can thereby help to identify points of action. In the following, based on the insights from the literature, we describe how an organization can use this framework to put an ecosystem perspective into action.

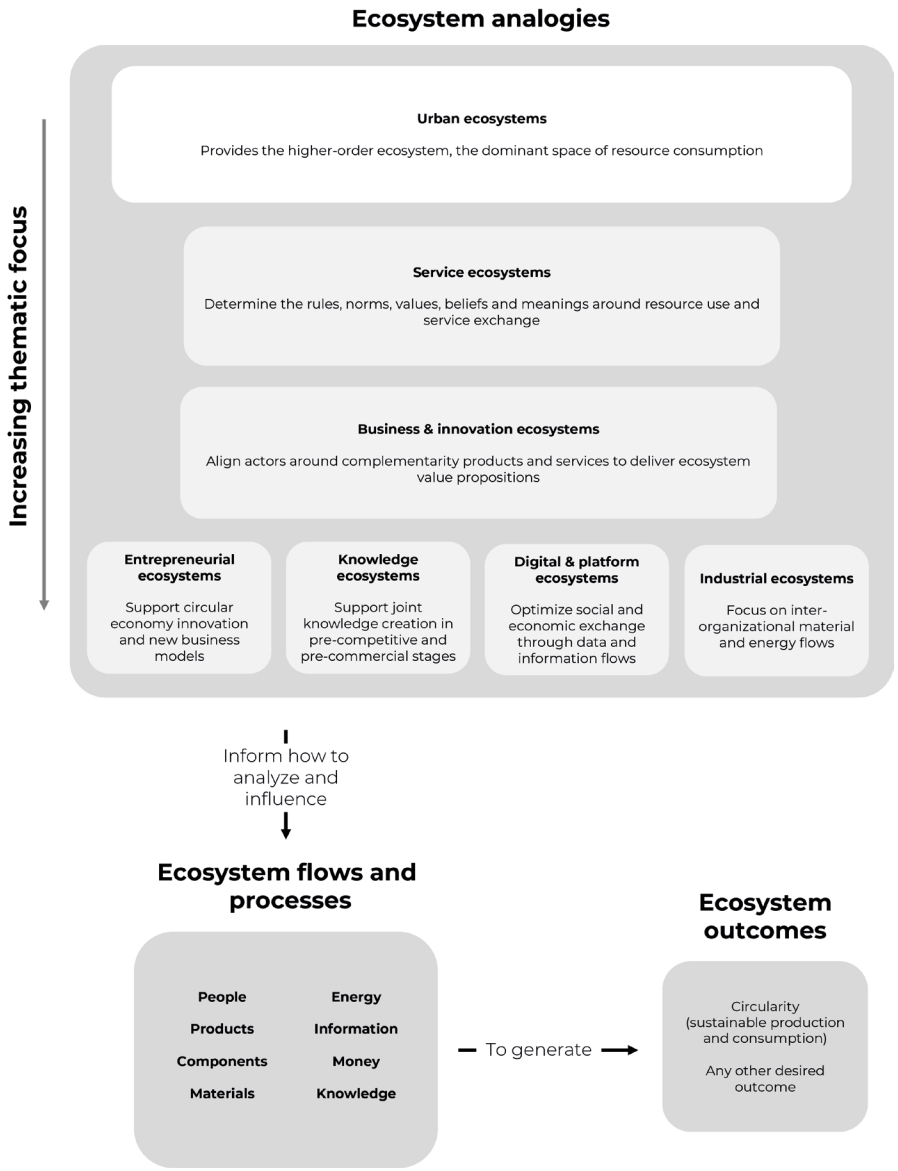


FIG. 2.2 An integrative framework for innovation in circular economy ecosystems

TOC

Urban ecosystems mark the starting point of an ecosystem perspective. They are dominant spaces of consumption. 80 % of the global population are expected to live in cities by 2050 (Pickett et al., 2013). With so many people, cities are hot spots of pressing environmental challenges like overconsumption, pollution, waste and emissions (Pincetl, 2012).

Within a city, an organization can study the local vision, strategy and policy for sustainability and circularity. For example, the city of Amsterdam has chosen to focus its circularity efforts on food and organic waste, consumer goods, and the built environment (Amsterdam, 2020). It has also been making it harder for cars to drive in the city, creating opportunities for new mobility solutions (Bloomberg, 2019). The viability of evolving innovation ecosystems will depend increasingly on the vision and regulatory environment within cities. For example, the shared mobility ecosystem in Shanghai had to be significantly reshaped by its complementors, to fit to the evolving vision and regulations of the city government around sustainability (Ma et al., 2018). Another policy instrument is the provision of spaces for experimentation, like urban living labs. Spaces to experiment can help developing cities to leapfrog, and developed cities to further develop towards healthier, safer and more environmentally friendly cities. They stimulate learning and citizen participation (Voytenko et al., 2016). Other forms of participatory urban innovation are makerspaces, that can be stimulated through more flexible funding schemes, or more open designs that people can modify (Trischler et al., 2020). A city may also provide valuable complementary resources to innovate, like a favorable ICT infrastructure (Ma et al., 2018). An organization can identify its preferred urban ecosystem context and look for ways to allow for experimentation.

The next step – moving from the urban to the service ecosystem perspective – involves the study of norms, values and beliefs that govern value co-creation and service exchange in an urban ecosystem. For a circular economy, norms and values might have to shift towards seeing waste as a resource, or prioritizing use value over transactional value (Konietzko et al., 2020b). If this happens, then an organization has higher chances to support the emergence of circular business and innovation ecosystems.

From the institutions that govern value co-creation, an organization can then focus on its own business and innovation ecosystems. It can identify the kinds of complementary products and services that are needed from other organizations, to provide superior end user value, and to enable circularity (Hellström et al., 2015; Oskam et al., 2020; Rajala et al., 2016; Tencati and Zsolnai, 2009). For example, to go from recyclability to actual recycling, a recyclable product needs the complementary service of recycling and a compatible recycling infrastructure

(Konietzko et al., 2020b). Making this work may require some standardization of products, components and materials. This can be achieved by promoting and co-developing standards among ecosystem actors (Parida et al., 2019). In developing country contexts and due to a lack of advanced infrastructure, designing products and services for complementarity may require strong local embeddedness (Khavul and Bruton, 2013; Stead and Stead, 2013).

An organization needs to decide on the role she wants to play in an ecosystem. Is she an orchestrator (also called leader, or 'keystone species') or a niche player (Stead and Stead, 2013)? Orchestrators are large and resourceful actors that can provide a stable set of assets and ecosystem stability on which other complementors can build products and services (Iansiti and Levien, 2004a*). The orchestrator can play an important role in shaping the vision around circularity (Stead and Stead, 2013), by managing diverse interests, enforcing new rules and standards to align complementary actors around circularity, and by providing a favorable innovation environment through, for example, the provision of an ICT infrastructure, or the open sharing of intellectual property (Parida et al., 2019). Niche players can formulate specific strategies, based on their differentiation and specialization. They may occupy functional modules, such as repair, maintenance, or transport, which they optimize over time to meet human needs within ecological limits. They develop unique capabilities associated with their function, which may give them a competitive advantage (Stead and Stead, 2013).

Once essential questions around the innovation ecosystem and the role are answered, an organization can start building a minimum viable ecosystem for circularity. This is the smallest and simplest alignment structure that can help to develop an initial ecosystem value proposition (Adner, 2012*; Konietzko et al., 2020b). One can look at it as the small seed of change that can enable ecosystem shifts (Scharmer and Yukelson, 2015*). This can be local actors in given urban ecosystem, or more distant ones that contribute crucial complementary products and services, like software. The benefits and desired openness of the minimum viable ecosystem depend on the context: they may lead to path dependencies and unwanted collaborative rigidity in the long term (Korhonen, 2007, 2001). One recommendation to mitigate this is to integrate diverse partners: to involve both large and small organizations, both public and private, from across industries, including service providers and private households. This can be beneficial, but also more difficult, as it may lead to a diversity of interests and conflicts (Korhonen, 2007, 2001).

From the broader questions of innovation ecosystems, an organization can then start to leverage more focused ecosystem perspectives. Knowledge ecosystems, for example, enable collective, pre-competitive and pre-commercial knowledge

development (Järvi et al., 2018*). An organization can use the ones that are dedicated to circularity, to leverage the produced knowledge in its innovation efforts. Digital & platform ecosystems optimize social and economic exchange, through data and information flows. An organization can identify existing platforms in its industry and become a complementor, or it can build a new dedicated platform to enable more efficient social and economic exchange among its surrounding actors and end users. Lastly, industrial ecosystems help an organization to focus on inter-organizational material and energy flows. An organization can use this perspective to try and optimize the consumption of materials and energy, and to minimize waste. It can identify local actors and seek to collect inter-organizational data that can help to trade relevant material and energy. Methods like life cycle and material flow analyses can help to identify the hot spots of environmental impacts (Harper and Graedel, 2004). And local actors may have to develop common material and labelling standards that allow for the reuse of products, components and material (Korhonen, 2007).

2.5 Discussion and conclusion

We have reviewed the different analogies of ecosystems that are relevant in the context of a circular economy, and integrated them in a framework for action. With this, we make the following contributions. First, we complement prior work on this topic (Aarikka-Stenroos et al., 2020), by identifying and adding the important service ecosystem perspective from the existing literature. This perspective is important, because the circular economy puts an emphasis on moving from product-based towards service based business models (Tukker, 2015). Second, we contribute a hierarchy of thematic focus within the analogies. In this way, we reveal how the analogies relate to each other. Prior research has assumed, for example, that industrial ecosystems are a type of innovation ecosystem, without providing further explanation as to why that is the case (Zucchella and Previtali, 2019). We show that the industrial ecosystem is a more focused perspective within business and innovation ecosystems. Third, we provide suggestions for how organizations can put each of the relevant analogies into action. Our description of the framework provides guidance for organizations to get started with their ecosystem innovation efforts. This is an important addition for a literature review, to increase the practical relevance and make it actionable (Tranfield et al., 2003).

This study has several limitations. First, searching around the word 'ecosystem' has ignored the vast literature around the more general 'systems' stream in the context of environmental sustainability (Meadows, 1997; Senge et al., 2015; Williams et al., 2017). We think this is justified, because the focus here was to review anything around the term and analogy of the ecosystem. Future research can use this research to establish the link between ecosystems and systems thinking.

Second, several advocates of an ecosystem perspective have stressed the need to develop an 'ecosystem mindset' (Scharmer and Yukelson, 2015), and systems leadership (Senge et al., 2015), which we have not accounted for in this study. Others have stressed that a circular ecosystem mindset takes into account the impacts of products along their entire life cycle (Kjaer et al., 2019; Sumter et al., 2020), is strategic, user and service oriented (Baldassarre et al., 2020), collaborative and open to different views (Brown et al., 2019; Kania et al., 2014), authentic and reflective (Ehrenfeld, 2019), and adaptive, and geared towards a collective outcome (Kania et al., 2014). The emergence of the field of systemic design adds valuable principles to guide the development of an ecosystem mindset among innovation participants (Bijl-Brouwer and Malcolm, 2020). Future research on circular economy ecosystems can explore how mindsets can be changed towards an ecosystem perspective. Tackling the mindset that drives the need for more consumption will be crucial to decrease the environmental impacts within developed societies.

Lastly, from a managerial perspective, the ecosystem concept has some practical challenges. First, innovating within ecosystems may add significant complexity to contractual agreements and questions of liability. This might be overcome through smart contracts enabled by, for example, blockchain technology (Narayan and Tidström, 2020). But it definitely provides a barrier to organizations when they try to innovate. Second, co-creating ecosystem value propositions may also lock organizations in within a structure that appears desirable at first, but may not work in the mid to long term. This uncertainty about collaboration outcomes is a significant challenge to put an ecosystem perspective into action. This challenge could be overcome by designing open organizational structures, that allow for new actors to get involved and for older actors to leave an ecosystem. Future research is needed to explore the openness of ecosystem structures to facilitate smooth and flexible collaborations in the context of a circular economy.

This study has reviewed the diverse ecosystem analogies that are relevant in the context of a circular economy and integrated them in a framework for action. We have shown how urban, service, business & innovation, as well as industrial, urban, digital & platform, knowledge and entrepreneurial ecosystems can help to take

a circular ecosystem perspective, and put it into action. We hope this will inspire future researchers and practitioners to further grow our understanding of ecosystem analogies and their power to drive systemic change.

3 The Circularity Deck

A tool that can help organizations analyze, ideate and develop their innovation ecosystems towards a circular economy

Publication:
Konietzko, J.; Bocken, N.; Hultink, E.J. A Tool to Analyze, Ideate and Develop Circular Innovation Ecosystems. Sustainability 2020, 12, 417.

ABSTRACT The circular economy may help organizations to maximize the value of their material resources and minimize the overall resource use, waste, pollution and emissions of their business activities. Implementing a circular economy program requires radical changes in product, business model and ecosystem innovation. Most research on circular oriented innovation takes a product or business model perspective. Few publications have explored how to innovate in ecosystems: how a group of loosely coupled organizations can change how they interact with each other to achieve a collective outcome. This study proposes the Circularity Deck: a card deck-based tool that can help organizations to analyze, ideate and develop the circularity potential of their innovation ecosystems. The tool is based on a literature review of circular oriented innovation principles, and of practical examples that show how these principles have been applied. The principles are organized according to the intended circular strategy outcome that they pursue (i.e., narrow, slow, close, regenerate and inform material and energy flows), and the extent of the innovation perspective that is needed to operationalize a principle (i.e., product, business model, or ecosystem innovation). This review and categorization process first produced a novel analysis of the circular economy innovation landscape, using an ecosystem perspective. Second, these results served to develop the Circularity Deck, which was further

developed and tested for ease-of-use and perceived usefulness in 12 workshops with 136 participants from 62 different organizations. The Circularity Deck provides an approach for future research and practice to integrate new principles and examples that can help organizations to analyze, ideate and develop circular innovation ecosystems.

3.1 Introduction

The circular economy may help organizations to decarbonize and dematerialize their business activities (Blomsma and Brennan, 2017; Geissdoerfer et al., 2017). Organizations can pursue five integrated strategies towards a circular economy: they can narrow (use less material and energy), slow (use products and components longer), close (use material again), regenerate (use non-toxic material and renewable energy) and inform (use information technology to pursue circularity) the resource and energy flows that are associated with their business activities (Bocken et al., 2016; EMF, 2015; Geissdoerfer et al., 2017; McDonough and Braungart, 2002). To combine these five strategies, organizations need to transform the higher-order production and consumption systems that they form part of (De los Rios and Charnley, 2017; Elia et al., 2016; Govindan et al., 2014; Mont, 2008; Moreno et al., 2016b; Pigosso et al., 2010; Urbinati et al., 2017; Walls and Paquin, 2015). This requires a broad innovation perspective; one that innovates products/services, business models, and ecosystems (Bakker et al., 2014; Bocken et al., 2016; Ghisellini et al., 2016; Talmar et al., 2018; Tate et al., 2019). Product/service innovation develops, produces and commercializes new products/services (Boer and During, 2001). Business model innovation changes what an organization offers and to whom, how an organization creates and delivers the offering, and how it captures value from it (Bocken and Short, 2016; Chesbrough, 2010; Richardson, 2008). Ecosystem innovation changes how a group of loosely coupled organizations interact with each other to achieve a collective outcome (Jacobides et al., 2018).

Existing tools and approaches that may help organizations to improve their environmental sustainability have focused on product and business model innovation. Product-focused and organization-internal tools include eco-design tools like life-cycle assessment, diagrams, checklists and guidelines (Rossi et al., 2016). Product design tools propose strategies and principles to design for X (X = maintenance, reparability, durability, behavior change, etc.) (Bocken et al., 2016; Haines-Gadd et al., 2018; Wastling et al., 2018). Business model innovation tools

and approaches for sustainability or circularity (Bocken et al., 2019e; Pieroni et al., 2019) include, for example, adapted versions of the business model canvas (Bocken et al., 2018; Joyce and Paquin, 2016; Nußholz, 2018), maps of the value landscape of an organization (Bocken et al., 2013), or maps of customer intervention points, where organizations have more or less control over a product's lifecycle (Sinclair et al., 2018).

Many existing business model approaches have, albeit implicitly, taken system perspectives. For example, some approaches suggest the need to integrate multiple, complementary business models or value logics (Laasch, 2018), collaborate with important stakeholders to achieve system-level sustainability (Stubbs and Cocklin, 2008), recognize trends, drivers and involve stakeholders at the ecosystem level (Antikainen et al., 2016), include the supply chain as a whole in innovation efforts (Leising et al., 2018), rethink complexity management for the circular economy (Velte and Steinhilper, 2016), or experiment within an 'ecology of business models' (Bocken et al., 2019a). However, none of these approaches differentiates between a business model and an ecosystem perspective (Bocken et al., 2019d; Pieroni et al., 2019), although this difference is well documented in the innovation and strategic management literatures (Adner, 2016; Fuller et al., 2019). In addition, existing tools for circular oriented innovation have rarely been tested in practice to understand their usefulness and ease-of-use (Bocken et al., 2019e; Pieroni et al., 2019). This is problematic because tools from academic research may therefore not be used in practice, which reinforces the theory-practice gap of organizational research (Van de Ven, 2007).

The objective of the present study is to address these two gaps in the literature on circular oriented innovation: 1) the need to integrate ecosystem perspectives into circular oriented innovation, and 2) the need to develop tools that are thoroughly evaluated against criteria like perceived usefulness and ease of use. This objective is guided by the following main research question: *how can organizations be facilitated to take an ecosystem perspective on circular oriented innovation?*

To address this question, we develop the Circularity Deck: a card deck-based tool and approach to analyze, ideate and develop the circularity potential of innovation ecosystems. The tool is based on a literature and practice review of circular oriented innovation principles. Principles are solution-oriented guidelines (Romme and Reymen, 2018) that can achieve a desired result (Denyer et al., 2008). Each principle is illustrated with an example. The principles and examples are organized according to the chosen circular strategy (i.e., narrow, slow, close, regenerate and inform material and energy flows), and the required scope of the innovation perspective to operationalize the principle (i.e., product, business model, or ecosystem innovation).

This review and categorization process served to develop the Circularity Deck, which was subsequently tested for ease-of-use and perceived usefulness in 12 workshops with 136 participants from 62 different organizations, both incumbent and startups. The tool development process revealed that 1) clear and concise examples help the participants to understand the tool content and concepts and make it more useful and easier to use, 2) participants may benefit from an exercise without the tool, to be free from the possible constraints that it imposes, and to show the participants its power once they get to use it, and 3) the tool is most useful when actively facilitated by an expert who is familiar with the background concepts. Our tool and categorization process may be enriched through future reviews of new principles and examples. While we intend to propose a generic Circularity Deck, future research may develop customized Circularity Decks for the mobility, food or construction industries as these industries have the highest global life-cycle environmental impact (Tukker et al., 2016).

3.2 Conceptual background

3.2.1 An ecosystem perspective on the circular economy

A circular economy maximizes the value of material resources and minimizes overall resource use, waste, pollution and emissions (Blomsma and Brennan, 2017; Geissdoerfer et al., 2017). It is a systemic concept: authors have argued that a circular economy requires higher degrees of collaboration among actors (Brown et al., 2019; Urbinati et al., 2017), whole-systems design (Moreno et al., 2016b), a transformation of production and consumption systems (De los Rios and Charnley, 2017; Walls and Paquin, 2015), reverse/cascading skills, cross cycle and cross sector collaboration (Elia et al., 2016), a shift from supply chains to value networks (Mont, 2008), life-cycle thinking (Pigosso et al., 2010), and sustainable supply chain network designs (Govindan et al., 2014). The Ellen MacArthur Foundation, a popular advocate of the circular economy, has suggested that a circular food system, for example, *"will require a global systems-level change effort that is cross-value chain [and that] spans public and private sectors"* (EMF, 2018). This suggestion illustrates that circularity – a situation in which economic and social structures are organized so that they maximize the value of material resources and minimize

overall resource use, waste, pollution and emissions – is a property of a system; for example, the mobility system of a city, rather than a property of an individual product or service; for instance, a car or car sharing service (Adams et al., 2016; Ceschin and Gaziulusoy, 2016). As a systemic property, circularity is subject to emergence (Flood, 2010): it emerges out of changes in how different actors, products, components and material interact with each other.

The existing literature on the circular economy has suggested that business model innovation may lead to higher circularity (Lewandowski, 2016; Patala et al., 2016), because sustainable and circular business models take a broad perspective on an organization's value creation. They look at the value an organization creates; for itself, as well as for a its stakeholders, including the environment (Bocken et al., 2013; Joyce and Paquin, 2016). However, a business model perspective usually focuses on how one organization does business (Magretta, 2002). An ecosystem perspective goes beyond this level, because it pays equal attention to the business models of other relevant actors. It looks at how a multitude of business models could be combined to achieve a collective outcome (Fuller et al., 2019). We therefore argue that a business model perspective is too narrow to achieve higher levels of circularity (Bocken et al., 2019). In addition to products and business model innovation, it is necessary to widen the innovation perspective to include the 'ecosystem' (Figure 3.1) (Adams et al., 2016; Adner, 2016; Ceschin and Gaziulusoy, 2016; Talmar et al., 2018).

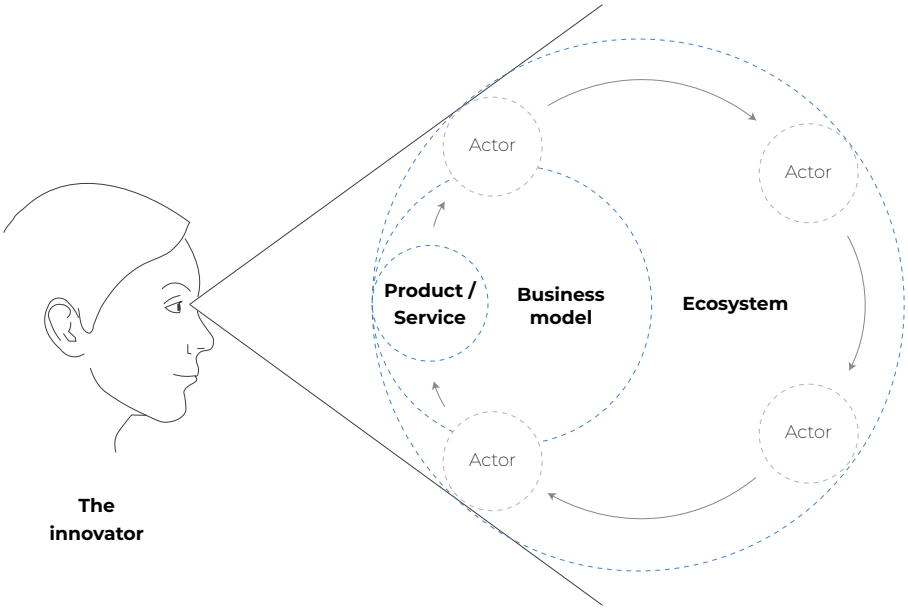


FIG. 3.1 An ecosystem perspective: product/service, business model, and ecosystem

Ecosystems are comprised of any set of actors – producers, suppliers, service providers, end users, regulators, and civil society organizations – that contribute to a collective outcome (Jacobides et al., 2018). Ecosystems have the following characteristics. They 1) consist of multiple locally, regionally or globally distributed entities that do not belong to a single organization, 2) involve dynamic, collaborative and competitive relationships, 3) imply flows of data, services, and money, 4) often involve complementary products, services and capabilities, and 5) evolve as actors constantly redefine their capabilities and relations to others (Fuller et al., 2019; Jacobides et al., 2018). Ecosystems are different from supply or value chains. The latter often involve bilateral supply relationships with clear upstream and downstream positions. Ecosystems on the other hand often involve a re-positioning of actors (Adner, 2016). Ecosystem innovation aims at changing how actors relate to each other, and how they interact to achieve a desired outcome. This outcome can be achieved by developing co-specialized and complementary products and services (Teece, 2007). Products and services are complementary if they are more valuable when combined than when they are used alone (Jacobides et al., 2018). The value of a smartphone, for example, is higher when combined with apps. The same principle, we argue, applies to circular products and services: they often maximize their circularity in conjunction with other assets. For example, a product

that contains recyclable materials, that has mono-material components, and that is easy to disassemble, only maximizes its 'recycling value' when embedded in a functioning collection system, and when treated in proper recycling facilities. A circular ecosystem perspective thus goes beyond the question *"what is our value proposition?"* Instead, it asks: *"how does our offering complement other products and services that together can provide a superior and circular ecosystem value proposition?"*

3.2.2 Circular strategies

Organizations can innovate towards a circular economy through five interrelated strategies. They can narrow, slow, close, regenerate and inform product, component, material and energy flows (Figure 3.2) (Bocken et al., 2016; Konietzko et al., 2019; McDonough, W.; Braungart, 2002; Stahel, 2008). The 'narrow', 'slow' and 'close' strategies have been proposed in previous research (Bocken et al., 2016). We add the strategy 'regenerate' to account for two additional aspects that are important for 'cleaner production' (Hens et al., 2018) and that have been stressed in early conceptions of the circular economy (McDonough and Braungart, 2002): the minimized use of toxic substances; i.e., substances that are persistent and liable to bio-accumulate (Cardoso et al., 2009), and the need for an increase of renewable materials and energy in a circular economy (EMF, 2015; Stahel, 2008). In addition, we include 'inform' as a support strategy for organizations because several publications have emphasized the importance of information technology in enabling a circular economy (Alcayaga et al., 2019; Ellen MacArthur Foundation, 2019a; Kerin and Pham, 2019; Konietzko et al., 2019; Pagoropoulos, 2017). The blue line in Figure 3.2 indicates the key strategies that can influence material and energy flows. The grey line below the blue circle indicates the support strategy 'inform'. Each strategy can be decomposed into innovation principles (solution-oriented guidelines) (Denyer et al., 2008). These principles may require product, business model, or ecosystem perspectives. In the following, we describe each strategy and give some examples of corresponding product, business model and ecosystem innovation principles.

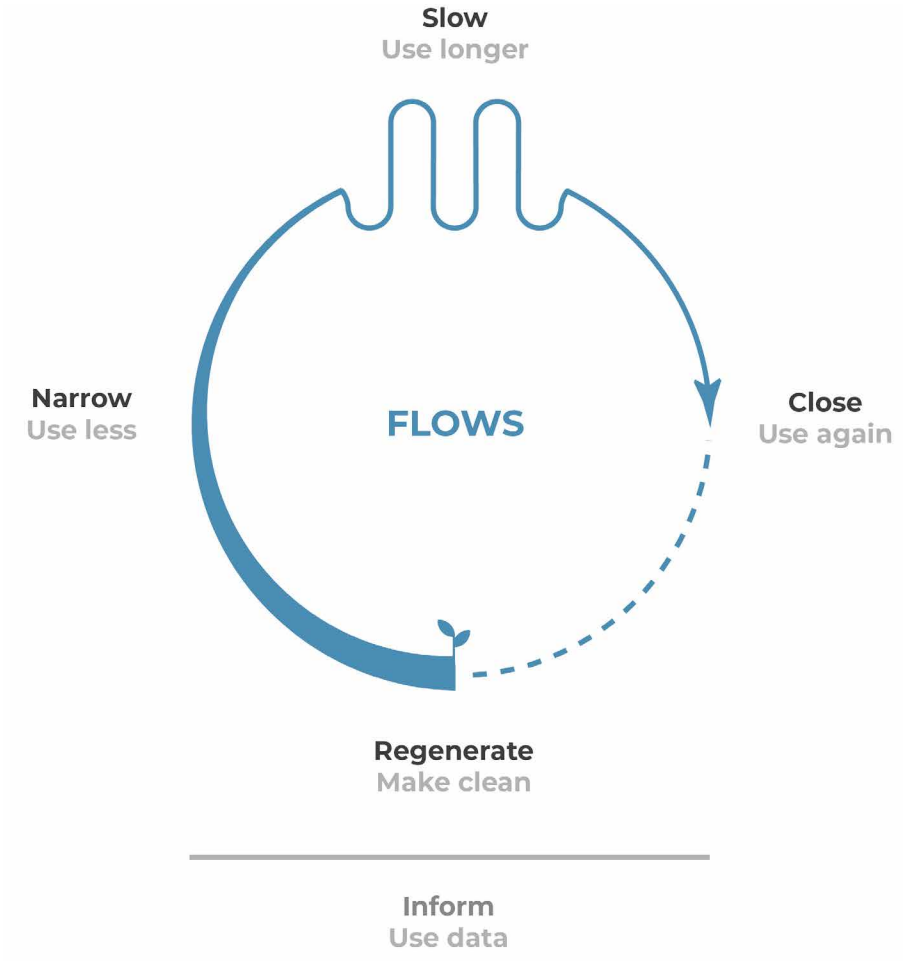


FIG. 3.2 Circular strategies: narrow, slow, close, regenerate and inform material and energy flows

Narrowing refers to using fewer products, components, materials and energy during design and production (Baumann et al., 2002), and during delivery, use and recovery (Bocken et al., 2012). A *product principle* for narrowing is 'design with low-impact inputs' (Baumann et al., 2002). Impossible Foods, for instance, has designed a plant-based burger with a meat texture. Compared to the beef alternative, it requires ca. 7 m^2 less land, 300l less water and 5kg less CO_2 (Ellen MacArthur Foundation, 2018; Impossible Foods, 2019). A *business model principle* for narrowing is, for instance, 'incentivize users to consume less'. An example is HOMIE, a company that

TOC

offers washing machines through a pay-per-wash model, monitors user behavior and provides advice and price incentives to wash with lower temperatures and the right amount of detergent. As a result, the organization's users wash 30% less often and at lower average temperatures (Bocken et al., 2018). An *ecosystem principle* for narrowing is 'maximize the use capacity of products'. This is sometimes referred to as 'sharing', where multiple user groups have access to the same product. This sharing can decrease the overall number of products in an ecosystem. Maximized use capacity may require the coordination of multiple actors in a given ecosystem. The online platform Peerby, for example, enables people to share everyday goods like drills or bicycles, which can increase their usage and reduce the overall number of personally owned goods in homes over time (Allwood, 2014; Lacy et al., 2014; Peerby, n.d.).

Slowing refers to using products, components and materials longer (Bakker et al., 2014; Bocken et al., 2016; Cooper et al., 2014; De los Rios and Charnley, 2017; Luttropp and Lagerstedt, 2006; Mont, 2008). A *product principle* for slowing is 'design for physical durability' (Bocken et al., 2016). A product is physically more durable if its performance over time degrades more slowly than comparable products on the market (den Hollander et al., 2017). An example is a cast-iron pan, which can last longer than other pan types. A *business model principle* for slowing is 'offer the product as a service' (Bocken et al., 2016; Kjaer et al., 2019; Lacy et al., 2014; Linder and Williander, 2015a; Mont, 2008, 2002; Tukker, 2015, 2004). Product-as-a-service models can be product-, use-, or results-oriented (Tukker, 2015). The company Kaer, for example, offers a result: cool and fresh air as a service, rather than air conditioners as products (Ellen Macarthur Foundation, 2019). By focusing on results, companies like Kaer can minimize the resource intensity of their offering over time (Bakker et al., 2014; Ellen Macarthur Foundation, 2019). An *ecosystem principle* for slowing is 'turn disposables into a reusable service' (Ellen MacArthur Foundation, 2019b; Haffmans et al., n.d.). TerraCycle, for example, has designed 'Loop'. This service delivers popular consumer goods like shampoo or ice cream in reusable packaging. When new products are delivered, the packaging gets picked up, cleaned and will be used again. Loop is an ecosystem that involves several complementary products and services: end users who order Loop, TerraCycle who coordinates the platform and partnerships, several retail brands like Nestle or Unilever who provide their products in the suggested reusable packaging, as well as external service providers who transport and clean the packaging.

Closing refers to a business activity that brings post-consumer waste back into the economic cycle (Bocken et al., 2016). A *product principle* for closing is 'design with materials suitable for primary recycling'. Aquafil, for instance, has designed the 'Econyl system', which enables Polyamide 6 or Nylon 6 waste to be manufactured

into new Nylon 6, with no loss of quality (Aquafil, 2019). An example of a *business model principle* for closing is 'enable and incentivize product and component returns' (Wastling et al., 2018). An example is Teemill: this clothing company stimulates users to send back old and worn out products. Users can scan a QR code in the wash-care label to generate a free post label, which can be used to send the garment back to Teemill. Sending back products earns users credit for their next purchase (Ellen MacArthur Foundation, 2019c). An *ecosystem principle* for closing is 'organize local waste-to-product ecosystems' (Hopper and Nielsen, 1991; Lacy et al., 2014). The company SOOP, for instance, has orchestrated an ecosystem of several actors that collect waste (coffee grounds and orange peels) from offices, process the waste into raw materials, produce new products from the raw materials (e.g., soap), and then deliver them back to the same offices (SOOP, 2019).

Regenerating refers to a business activity that manages and sustains natural ecosystem services, uses renewable and nontoxic materials, and is powered by renewable energy (EMF, 2015; McDonough and Braungart, 2002). This strategy mostly relates to the 'biological cycle' of the circular economy, but also contains elements that are relevant for the 'technical cycle', especially with regards to the use of renewable energy. A *product principle* for regenerating is 'design with non-toxic materials' (Byggeth et al., 2007; Cradle to Cradle, 2019; Hens et al., 2018; Luttropp and Lagerstedt, 2006; Scruggs, 2013). Vestaron, for example, has found a way to substitute synthetic pesticides with biological ones that are safe for humans, birds, fish and pollinators (Ellen MacArthur Foundation, 2018; Vestaron, 2019). A *business model principle* for regenerating is 'produce with renewable energy'. An example is the company Apple, which has an installed capacity for solar energy of over 400 MW (Techcrunch, 2019). An *ecosystem principle* for regenerating is 'recover nutrients from urban areas'. This principle is about identifying ways to recover valuable nutrients from urban areas that are usually lost. This may require different actors in an ecosystem like end users who produce nutrient output (in the form of sludge or organic waste), as well as organizations who collect, transport, process and re-distribute the nutrients. Lystec Inc., for example, helps the city of Guelph to turn biosolids from wastewater treatment into organic nutrients that are then sold to farms in the area (Ellen MacArthur Foundation, 2018; Lystek, 2019).

Finally, informing refers to using information technology as a support strategy for the circular economy (Ellen MacArthur Foundation, 2019a; Hribernik et al., 2011; Kerin and Pham, 2019; Konietzko et al., 2019; Morlet et al., 2016; Pagoropoulos, 2017). We include this support strategy because several practice and research projects have highlighted the importance of information technology for a circular economy; for example, the role of artificial intelligence (Ellen MacArthur Foundation, 2019a), the internet of things (Morlet et al., 2016), big data (Nobre and Tavares,

2017; Xu et al., 2015), or online platforms (Konietzko et al., 2019). While using information technology may support higher environmental sustainability, it can also lead to adverse effects (Bocken et al., 2019b); for example, regarding the higher energy use requirements of digital infrastructure (Frenken and Schor, 2017). It is therefore important to highlight that information technology needs to be viewed as a means to an end (in this case circularity), and not as an end in itself. The ability of information technology to enable circularity therefore requires thorough assessments to understand its potential to reduce overall environmental impact. Most principles that can inform material and energy flows may support more than one circular strategy. A *product principle* to inform flows is, for example, 'design connected products' (Morlet et al., 2016; Nobre and Tavares, 2017; Pagoropoulos, 2017). Connected products can slow flows by informing maintenance and repair needs. Delta Development, for instance, as part of their product-as-a-service' model, has sensors in some of their elevators to inform maintenance needs (Morlet et al., 2016). Connected products can also help to close flows by knowing the location of products at the end of their lives (Morlet et al., 2016). A *business model principle* for informing is 'track the resource intensity of the product-in-use'. Philips, for example, uses sensors in some of their lighting devices to track data on how their lights are used within their 'lighting-as-a-service' model to save electricity (Nobre and Tavares, 2017). An *ecosystem principle* to inform flows is to 'operate service ecosystems via online platforms' (Ellen MacArthur Foundation, 2019a). An example is the online platform Whim, which operates mobility-as-a-service ecosystems in cities including different private and public modes of transportation (Whim, 2019).

3.2.3 Research gaps and goal of this study

The present study addresses two gaps in the extant literature on circular oriented innovation: 1) a lack of circular oriented innovation approaches that integrate an ecosystem perspective; and 2) the development of circular ecosystem innovation tool that is evaluated against its ease-of-use and perceived usefulness to ensure its practical relevance. To address both gaps, we propose the Circularity Deck: an approach and tool to analyze, ideate and develop the circularity potential of innovation ecosystems. Our objective is to make two main contributions to research and managerial practice. First, for research, the underlying literature and practice review for the Circularity Deck produces a novel way to analyze circular economy innovation strategies, principles and real-world examples. It thereby enables a practical and principle-based ecosystem perspective on the circular economy. Second, for practice, it turns this analysis into an easy-to-use and useful tool for organizations to analyze, ideate and develop the circularity potential within their

ecosystems. These two main contributions are guided by the following research question: *How can organizations be facilitated to take an ecosystem perspective on circular oriented innovation?*

3.3 Method

Our research method is organized in two main steps. The first step contains a literature and practice review to derive a set of circular economy innovation principles and examples (section 3.1.). The second step is about making the principles useful for practice in the form of a card deck based tool, based on a design research approach (Denyer et al., 2008). The tool is iterated and improved through 12 workshops with 136 participants from 62 different organizations (section 3.2.).

3.3.1 Literature and practice review to derive principles

The purpose of the literature and practice review is to derive a set of principles and examples of circular economy oriented innovation. Principles are solution-oriented guidelines (Romme and Reymen, 2018) that can be organized according to the CIMO (context, intervention, mechanism, outcome) logic: the context (the context in which people act), the intervention (the action that happens), the mechanism (the change that the action triggers) and the intended outcome (the resulting situation). The CIMO logic is useful in a design science context, in which research intends to produce prescriptive knowledge that is useful for practitioners (Denyer et al., 2008). In this study, the *context* is business innovation towards a circular economy. The *intervention* is an action that one can take using a product, a business model, and/or an ecosystem perspective; for instance 'design with low-impact inputs' (a product perspective). The strategic *mechanism* is the narrowing, slowing, closing, regenerating or informing and the intended *outcome* is to maximize the value of material resources, and to minimize overall resource use, emissions, waste and pollution. Each principle is supported with a real-world example that illustrates its practical use.

The literature review was conducted with the help of SCOPUS, one of the largest academic databases. We searched for articles using a number of search strings to

identify principles that can narrow, slow, close, regenerate and inform resource and energy flows, for the circular economy in general, and for the circularity strategies in particular. For example, for 'narrowing', we looked for *reduce AND sustainability AND strategies OR principles*. Due to the focus on organizations, we filtered for 'business, accounting and management journals'. The titles, keywords and abstracts of the top 30 cited articles of each of the applied search strings were scanned as to whether they develop or propose prescriptive knowledge in the form of circular oriented design and/or innovation principles. We excluded generic literature reviews or analytical models. This led to 23 selected articles, which were then read to retrieve the principles. Consistent with the framework of this study, we coded these principles according to the type of circular strategy that they propose (i.e., narrow, slow, close, regenerate, inform), and whether they apply to the product, the business model, or the ecosystem. In addition, we retrieved real-life examples if we found them in the articles. Appendix A1 lists all applied search strings and the selected articles from each search.

The practice review complemented the literature review. Often, practice information is ahead of the academic literature and may contain valuable insights for research (Adams et al., 2016; Bocken et al., 2014). We focused the practice review on identifying examples that match the principles. If an example did not match a principle, then we added the principle based on the example. The practice examples were retrieved from the internet (i.e., circular economy related websites, blogs, articles, websites) and the grey literature (e.g., practice reports on circular economy) to complement the results derived from the literature. We searched Google and used the strings ["circular economy" AND principles OR strategy*]. From the first three pages in Google, we selected a number of publications and case studies from reputable organizations and projects in the circular economy field. The publications and case studies we selected came from The Ellen Macarthur Foundation (Ellen MacArthur Foundation, 2018; EMF, 2017, 2012; Morlet et al., 2016), IDEO Circular Design Guide (IDEO, 2019) and the ResCom project (ResCom, 2019). Figure 3.3 summarizes the process of the literature and practice review.

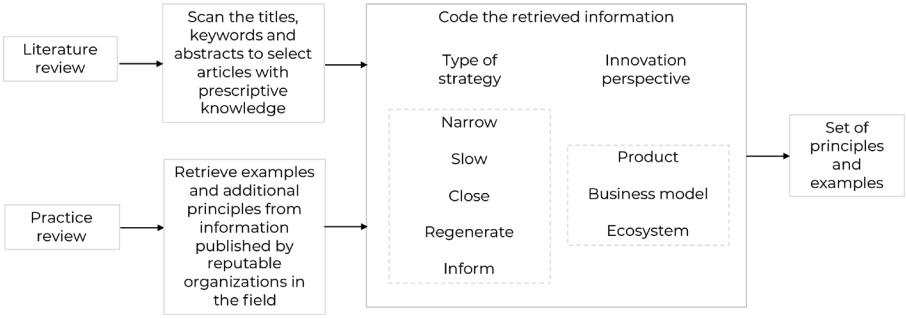


FIG. 3.3 The process of the literature and practice review

3.3.2 Tool development and evaluation

A tool is *"a generic name for frameworks, concepts, models, or methods"* (Jarzabkowski et al., 2015). Tools codify knowledge and make it useful for researchers and practitioners to improve their decisions and actions (ibid.). The principles and examples from the literature and practice review were used to develop the Circularity Deck as a tool that enables organizations to take an ecosystem perspective on the circular economy. The goal of the tool is to help organizations analyze, ideate and develop the potential circularity of their innovation ecosystems. The intended user groups include entrepreneurs, innovation managers, business managers, and designers who want to innovate towards a circular economy. The tool should contain guidance on how it can be used, be adaptable to different contexts (Bocken et al., 2019d), easy to use, haptic and playful. To fulfill this, we decided to base the tool on the use of cards. Design research has recognized cards as an engaging approach to learning and ideating (Friedman and Hendry, 2012; Golembewski and Selby, 2010). Principles of design research include, for example, engaging stakeholders and users, early testing and prototyping, and taking an iterative approach to developing and testing (Peffers et al., 2007; Van Aken and Romme, 2009). Design research has become popular to address sustainability issues on a more strategic level (Baldassarre et al., 2017; Geissdoerfer et al., 2016), next to its obvious use in product design (Ceschin and Gaziulusoy, 2016), perhaps because of its potential to address wicked issues such as climate change and resource issues (Guldmann et al., 2019).

To evaluate and improve the Circularity Deck, we conducted 12 workshops with 136 participants from 62 different organizations. These workshops were conducted with entrepreneurs (7 sessions), innovation and business managers in incumbent organizations (3 sessions), and designers from design agencies (2 sessions) in the following contexts:

- An incumbent organization from the health technology sector (nine participants) who worked on refurbishing and servitizing one of their products;
- Twelve 'circular startups' that were part of the 'Investment Ready Programme' 2018 of the Impact Hub in Amsterdam, Netherlands, an organization that promotes impact entrepreneurship (15 participants). One startup worked on, for example, providing solid home cleaning products under a subscription;
- A mobility design agency based in Amsterdam working on a new shared mobility solution for a client (six participants);
- A group of entrepreneurs and managers from the province of Noord Holland. The workshop was conducted at Impact Hub in Amsterdam (21 participants). One example from the group included a startup that makes euro pellets from otherwise wasted coconut fibers;
- A large engineering service company in the Dutch construction sector (five participants) that wanted to explore how they can offer more circular oriented services in their portfolio;
- A group of entrepreneurs (21 participants) in Lund, Sweden, as part of an international coaching program to develop their circular business models. One group worked on, for instance, how to turn the textile sector circular;
- A group of entrepreneurs, innovation managers and researchers. The workshop was conducted at Impact Hub in Hamburg, Germany (15 participants). One group worked on, for instance, how to make plastic packaging in the fast moving consumer goods sector circular;
- A group of entrepreneurs and innovation managers who joined a workshop as part of a conference in Riga, Latvia (18 participants). One group worked on, for example, establishing a local market place for wasted building materials;
- A design agency based in Helsinki, Finland (6 participants) that wanted to explore how they can integrate circularity into their service design offerings;
- A group of entrepreneurs, innovation managers, designers and researchers from the Helsinki region, Finland (5 participants). One challenge that the group addressed related to a systemic textile project to make Finland's textile industry circular;
- A group of entrepreneurs, innovation managers and researchers from the Helsinki region, Finland (10 participants). One challenge that a group addressed was how to provide circular operating services for buildings;
- A group of entrepreneurs, innovation managers and researchers from the Lappeenranta region, Finland (10 participants). One group included a chairman and

an environmental manager from a big welding company that wanted to explore the circularity of their operations and business model.

We used a simplified version of a well-known technology assessment model to evaluate the ease-of-use and perceived usefulness of our tool (Davis, 1989). At the end of each workshop, we distributed a form among participants, which stated: *"The purpose of the Circularity Deck is to map and analyze circular ecosystems."* It then asked participants to evaluate whether *"The Circularity Deck was useful to address the purpose stated above"* and whether *"The Circularity Deck was easy to use".* For both statements, we provided a Likert scale from 1 – 5 (1 = completely disagree, 5 = completely agree), and included space for qualitative feedback. The form can be found in Appendix A2. Appendix A3 contains the complete qualitative information obtained from the forms. We used this information after each workshop to make changes to the tool. The focus was on lower ratings and associated comments. We went through the qualitative feedback and retrieved ideas for improvement. Through discussions among the co-authors of this study, we evaluated which of the proposed changes to incorporate. The results section (4.3.) covers the proposed changes, what we changed, and what we did not change, based on the user feedback.

3.4 Results

3.4.1 The Circularity Deck

The Circularity Deck enables participants to analyze, ideate and develop the circularity potential of their innovation ecosystems. It contains product, business model and ecosystem innovation principles that can narrow, slow, close, regenerate and inform material and energy flows in a given context, and to analyze which actors are needed to be able to do so. Figure 3.4 shows the final card deck. The colors indicate the circular strategy: orange represents 'narrow', red 'slow', blue 'close', green 'regenerate' and grey 'inform'. The front of each card contains a principle and indicates if it is a product, business model or ecosystem principle (bottom left of the front card). The back side of each card contains a short description of each principle and an example. The full content of the Circularity Deck is listed in Table 3.1.

FIG. 3.4 Example cards from the Circularity Deck

TOC

TABLE 3.1 The Circularity Deck: a set of circularity principles for product, business model and ecosystem innovation

Circular strategy	Circular principle and the required innovation perspective: product (p), business model (bm) or ecosystem (e)	Description and example	Ref.
Narrow	**Design with low-impact inputs (p)**	Design products with 'ingredients' and materials that require less land, energy, water and/or materials to produce. The company Impossible Foods has designed a 'meaty' plant-based burger. Compared to the beef version, it requires ca. 7 m^2 less land, 300l less water and 5kg less CO_2 than the meat-based alternative.	(Ellen MacArthur Foundation, 2018; Impossible Foods, 2019)
Narrow	**Design light-weight products (p)**	Design products that are lighter than comparable products on the market. Lighter products usually require less materials and need less energy to transport. Adaptive City Mobility has designed a car that weighs 650kg incl. battery. This is around 1/3 of an average car (in 2019), leading to ca. 50% less battery to operate.	(Allwood, 2014; Bocken et al., 2011; Luttropp and Lagerstedt, 2006; Tukker et al., 2008)
Narrow	**Design for multiple functions (p)**	Design products with multiple functions. Multi-functional products can reduce the overall number of products and may be usable by different user groups. Studio Davero has designed Puzzle Peace: a modular furniture kit that can be turned into multiple types of furniture; e.g., a bench, table, armchair, chair, bar or display.	(Bocken et al., 2011; Studio Davero, 2019)
Narrow	**Eliminate production waste (bm)**	Eliminate any type of waste from production processes, for example material scraps, food left-overs or excess heat and electricity. The company Winnow helps professional kitchens to reduce food waste and save cost through a bin with a scale, AI-enabled image recognition software and training based on gathered waste data.	(Allwood, 2014; Luttropp and Lagerstedt, 2006; Nissen, 1995; Shahbazi et al., 2016)
Narrow	**Enable and incentivize users to consume less (bm)**	Incentivize users to use less energy or material during the use of energy or material-using goods like washing machines or cars. HOMIE offers washing machines through a pay-per-wash model. By monitoring user behavior, the company increases the resource efficiency of doing laundry.	(Heyes et al., 2018; Luttropp and Lagerstedt, 2006; Nissen, 1995)

>>>

TABLE 3.1 The Circularity Deck: a set of circularity principles for product, business model and ecosystem innovation

Circular strategy	Circular principle and the required innovation perspective: product (p), business model (bm) or ecosystem (e)	Description and example	Ref.
Narrow	**Organize light-weight urban transport (bm)**	Organize lighter forms of transportation, for example using electric tricycles. The lighter the vehicles, the lower the amount of energy and materials required to transport people and goods. RYTLE provides a cargo solution that consists of a light-weight vehicle, an easily exchangeable box, storage hubs and software that connects all entities.	(Rytle, 2019)
Narrow	**Localize supply where appropriate (bm)**	Find more local suppliers, where appropriate. More local suppliers decrease the amount of energy needed to transport goods. The restaurant chain 'Dig Inn' has developed a supply system of local farmers in every region it operates in to provide a scalable, locally adapted and seasonal restaurant model, reducing travel distances for food ingredients and stimulating the regional economy.	(Bocken et al., 2011; Dig Inn, 2019; Govindan et al., 2014)
Narrow	**Maximize capacity use of products (e)**	Maximize the degree to which the capacity of a product is used. This is sometimes referred to as 'sharing', where multiple user groups have access to the same product. This can decrease the overall number of products in an ecosystem. The online platform Peerby enables people to share everyday goods like drills or bicycles, which can increase their usage and reduce the overall number of personally owned goods in homes over time.	(Allwood, 2014; EMF, 2015; Lacy et al., 2014; Planing, 2018)
Slow	**Design for physical durability (p)**	Design products that degrade more slowly than comparable products on the market. A cast-iron pan can last much longer than comparable pan types.	(Bakker et al., 2014; Bocken et al., 2016; Cooper et al., 2014; De los Rios and Charnley, 2017; Luttropp and Lagerstedt, 2006; Mont, 2008)
Slow	**Design for emotional durability (p)**	Design products that users will love and trust over a long period of time. The 'Leatherman', a pocket-knife sized toolkit, has a 25-year warranty and many uses. It lets people collect and experience personal stories and creates an emotional bond between the user and the product.	(Bocken et al., 2016; Mont, 2008)

>>>

TABLE 3.1 The Circularity Deck: a set of circularity principles for product, business model and ecosystem innovation

Circular strategy	Circular principle and the required innovation perspective: product (p), business model (bm) or ecosystem (e)	Description and example	Ref.
Slow	**Design for ease of maintenance and repair (p)**	Design products that can be easily maintained or repaired. Maintaining means inspecting the product to retain its functional capabilities. Repairing is about restoring a product to a sound/ good condition after decay or damage. Fairphone has designed a modular phone that can be easily disassembled to repair and exchange components.	(Allwood, 2014; Bakker et al., 2014; Bocken et al., 2016; De los Rios and Charnley, 2017; Hens et al., 2018; Luttropp and Lagerstedt, 2006)
Slow	**Design for easy dis - and reassembly (p)**	Design products that can be easily separated and reassembled. Gerrard Street has designed a pair of headphones that can be easily separated and reassembled.	(Bocken et al., 2016; Street, 2019)
Slow	**Design for upgradability (p)**	A product is upgradable if its functionality or performance can be improved during or after use. An example is a bicycle with exchangeable and upgradable components.	(Bocken et al., 2016; Chierici and Copani, 2016; De los Rios and Charnley, 2017; Luttropp and Lagerstedt, 2006; Pialot et al., 2017)
Slow	**Design for standardization and compatibility (p)**	Create products, components or interfaces that also fit other products, components or interfaces. A common example of a standardized component is the Mini-USB slot for charging.	(Bocken et al., 2016)
Slow	**Enable users to maintain and repair their products (bm)**	Create services that enable users to care for their product. Fairphone supports users to care for their phones through discussion forums on how to maintain and repair, and an inventory of spare parts.	(Fairphone, 2019; Wastling et al., 2018)
Slow	**Remanufacture existing products and components (bm)**	Recover value from collected end-of-use products by reusing their components for the manufacturing of products with the same functionality. The Chinese company Guangzhou Huadu collects used vehicle parts and remanufactures them into as-new certified spare parts.	(Chierici and Copani, 2016; Ellen MacArthur Foundation, 2019d; Mont, 2008; Nissen, 1995)
Slow	**Repurpose existing products and components (bm)**	Take existing products and components and take them out of their context to create new value with them. Ubitricity turns lamp lanterns in cities into charging stations for electric vehicles.	(Bosch et al., 2017; Gispen, 2019)

>>>

TABLE 3.1 The Circularity Deck: a set of circularity principles for product, business model and ecosystem innovation

Circular strategy	Circular principle and the required innovation perspective: product (p), business model (bm) or ecosystem (e)	Description and example	Ref.
Slow	**Provide an unconditional lifetime warranty (bm)**	Offer your customers a life-time warranty, adding a promise to products that are made to last. The company Darn Tough Vermont produces socks with an unconditional lifetime guarantee. They say: *"If our socks are not the most comfortable, durable and best fitting socks you have ever owned, return them for another pair."*	(Darn Tough Vermont, 2019)
Slow	**Encourage sufficiency (bm)**	Encourage your customers to moderate the consumption of your products. In 2011, the clothing company Patagonia advocated: *"Don't buy this jacket."* With Worn Wear, it opened an online store for used Patagonia clothing, encouraging users to maintain their gear and trade it back once they don't use it anymore.	(Allwood, 2014; Bocken and Short, 2016)
Slow	**Provide the product as a service (bm)**	Offering the product as a service keeps the ownership with the organization and creates incentives to increase their lifetimes. You can offer product-, use-, or results-oriented models. The company Kaer offers a result: cool and fresh air as a service, rather than air conditioners as products.	(Bocken et al., 2016; Kjaer et al., 2019; Lacy et al., 2014; Linder and Williander, 2015a; Mont, 2008, 2002; Planing, 2018; Tukker, 2015, 2004)
Slow	**Organize maintenance and repair services (bm)**	Make sure that your products can last longer through maintenance and repair services. They can be offered by the manufacturer of a product or by third-party providers. The company Nudie Jeans, at its point of sale, has started to offer a free repair service for their Jeans. This has changed the shop appearance into a craftsmanship atmosphere.	(Nudie Jeans, 2019; Pialot et al., 2017; Planing, 2018)
Slow	**Upgrade and adapt existing products (bm)**	A product is upgradable if its functionality or performance can be improved during or after use. Try and integrate upgrading services into your offering. Gispen offers REMADE, a service to repurpose old furniture to fit new trends and work space requirements.	(Bosch et al., 2017; Gispen, 2019; Khan et al., 2018; Pialot et al., 2017; Planing, 2018)

>>>

TABLE 3.1 The Circularity Deck: a set of circularity principles for product, business model and ecosystem innovation

Circular strategy	Circular principle and the required innovation perspective: product (p), business model (bm) or ecosystem (e)	Description and example	Ref.
Slow	**Turn disposables into a reusable service (e)**	Make use of or provide services that replace disposable with durable products. TerraCycle has designed 'Loop', which delivers products like shampoo or ice cream in reusable packaging. The packaging gets picked up, cleaned and used again. Involved actors include retail brands, service providers (e.g. cleaning and transport service) and end users.	(Ellen MacArthur Foundation, 2019b; Loop, 2019)
Close	**Design with recycled inputs (p)**	Design with materials that have been recycled from other products and components. The 'Design for Recycled Content Guide' supports organizations in opting for more recycled content in their products.	(Krikke et al., 2004; Linder et al., 2017; Singh and Ordoñez, 2016; SPC - Design for Recycled Content Guide, 2019)
Close	**Design components, where appropriate, with one material (p)**	Composite materials are often hard to recycle because they cannot be separated. Design components therefore, where appropriate, with only one material to increase recyclability. Adidas has launched Futurecraft.Loop, a shoe made from one recyclable material and no glue. It can be recycled into pellets that can be turned into a new shoe.	(Adidas, 2019; Lacy et al., 2014; Luttropp and Lagerstedt, 2006)
Close	**Design with materials suitable for primary recycling (p)**	Try and design for primary recycling, that is: recycling that can turn materials into materials with equivalent properties. Aquafil has designed the Econyl system, which enables Polyamide 6 or Nylon 6 waste to be manufactured into new Nylon 6, with no loss of quality.	(Allwood, 2014; Aquafil, 2019)
Close	**Design for easy disassembly at the end of the product lives (p)**	Easy disassembly allows product components to be more easily recycled. Magnomer uses magnetizable ink on packaging labels to allow for easier separation during the recycling process.	(Bocken et al., 2016; Kent and Kent, 2016; Magnomer, 2019)
Close	**Reuse and sell components and materials from discarded products (bm)**	Create new value from wasted products and components. Roetz recovers bicycle components that were thrown away, and uses them to let customers assemble their own bikes.	(Roetz, 2019)

>>>

TABLE 3.1 The Circularity Deck: a set of circularity principles for product, business model and ecosystem innovation

Circular strategy	Circular principle and the required innovation perspective: product (p), business model (bm) or ecosystem (e)	Description and example	Ref.
Close	**Enable and incentivize product returns (bm)**	Make sure that you can get the products back that you put on the market. The clothing company Teemill makes users send back old and worn out products. Users can scan a QR code in the wash-care label to generate a free post label, which can be used to send the garment back to Teemill. Sending back products earns users credit for their next purchase.	(Ellen MacArthur Foundation, 2019c; Planing, 2018; Wastling et al., 2018)
Close	**Recycle products in proper facilities (bm)**	Make sure that the products you put on the market get recycled in proper facilities. The initiative 'Closing the Loop' supports users and sellers of phones to be material-neutral and waste free. It collects scrap phones on behalf of customers and recycles them.	(Closing the Loop, 2019)
Close	**Build local waste-to-product loops (e)**	Create local resource loops by turning the waste of a given facility into new products that can be sold back to the facility. SOOP has designed an ecosystem that collects waste (coffee grounds and orange peels) from offices, processes it, and re-delivers products to the offices that are made from to the waste.	(Hopper and Nielsen, 1991; Lacy et al., 2014; SOOP, 2019)
Close	**Engage in industrial symbiosis (e)**	Share or exchange by-products, materials, energy, or waste among nearby organizations. The Kalundborg Eco-industrial park is an example where organizations collaborate to share by-products from their factories.	(Bocken et al., 2016; Herczeg et al., 2018; Lacy et al., 2014; Walls and Paquin, 2015)
Regenerate	**Design with renewable materials (p)**	Design products with renewable and low-carbon materials. Timber wood, for example, can replace non-renewable building materials. Renewable materials should only be chosen when its extraction rate is equal to or lower than its recovery rate. Further, next to its properties, materials need to be selected based on their expected end-of-life treatment to avoid unintended consequences.	(Bocken et al., 2016; Lacy et al., 2014; McDonough and Braungart, 2002; Swilling et al., 2018)
Regenerate	**Design self-charging products (p)**	Design products that can charge themselves with renewable energy. This is especially relevant for mobility assets. The company Sono Motors has designed a car with solar cells integrated into its body, allowing it to charge itself throughout the day.	(Sono Motors, 2019)

>>>

TABLE 3.1 The Circularity Deck: a set of circularity principles for product, business model and ecosystem innovation

Circular strategy	Circular principle and the required innovation perspective: product (p), business model (bm) or ecosystem (e)	Description and example	Ref.
Regenerate	**Design with living materials (p)**	Living materials leverages the properties of natural materials. Ecovative, for example, produces mycelium-based fibers and materials with natural glue properties. Used for packaging, apparel and in the medical industries.	(Ecovative, 2019)
Regenerate	**Design with non-toxic materials (p)**	Avoid using toxic materials and substances in any of your products or operations. Toxic substances tend to accumulate in the biosphere and cause negative health effects for humans and other species. Vestaron substitutes synthetic pesticides with biological ones that are safe for humans, birds, fish and pollinators.	(Berkel et al., 1997; Byggeth et al., 2007; Hens et al., 2018; Luttropp and Lagerstedt, 2006; Scruggs, 2013; Vestaron, 2019)
Regenerate	**Produce and process with renewable energy (bm)**	Build up your capacity as a company to produce and process with renewable energy. In 2019, Apple has been the company with the biggest installed capacity for solar energy, 400 MW.	(Techcrunch, 2019)
Regenerate	**Power transportation with renewable energy (bm)**	Find ways to power your transportation needs with renewable energy. The company Foodlogica links local food, consumers and businesses in Amsterdam's city center through a light-weight mobility system, powered by renewable energy.	(Foodlogica, 2019)
Regenerate	**Power the use of the product with renewable energy (bm)**	Find ways of powering your product with renewable energy, through creative partnerships or product and service design. Waka Waka provides portable devices with photovoltaic panels that can power every-day electronics.	((Waka Waka, 2019)
Regenerate	**Embed renewable energy production in the existing infrastructure (e)**	Find ways of making renewable energy production part of the existing infrastructure. 'Solar Roadways' has developed a modular system of solar panels that can be walked and driven upon.	(SolarRoadways, 2019)
Regenerate	**Recover nutrients from urban areas (e)**	Find ways of recovering valuable nutrients from urban areas that are usually lost. Lystec Inc. helps the city of Guelph to turn biosolids from wasterwater treatment into organic nutrients for surrounding agriculture.	(Ellen MacArthur Foundation, 2018; Lystek, 2019)

>>>

TABLE 3.1 The Circularity Deck: a set of circularity principles for product, business model and ecosystem innovation

Circular strategy	Circular principle and the required innovation perspective: product (p), business model (bm) or ecosystem (e)	Description and example	Ref.
Regenerate	**Regenerate polluted ecosystems (e)**	Contribute to regenerating polluted ecosystems that affect your business. The Ocean Cleanup Project develops technology to clean oceans from plastic pollution.	(The Ocean Cleanup, 2019)
Regenerate	**Manage and sustain critical ecosystem services (e)**	Engage in projects that manage and sustain the natural ecosystems that surround and/or affect your business operations. Nestle's Häagen-Dazs has partnered with the nonprofit Xerces Society to plant the largest pollinator habitat in the United States. Without pollination services from bees, many critical ingredients for the ice-cream would not exist anymore.	(Forister et al., 2019; Häagen-Dazs, 2019)
Inform	**Use artificial intelligence to develop new materials with circular properties (p)**	Developing a new material requires data about the structure and properties of materials. AI can help analyze the required and available data quickly to inform design decisions based on circular requirements. The 'Accelerated Metallurgy project', run by the European Space Agency, has used AI to produce and test new metal alloys. AI enabled the project to speed up the process of finding new materials.	(Ellen MacArthur Foundation, 2019a; European Commission, 2019)
Inform	**Virtualize (p)**	Deliver utility virtually. Virtualizing reduces the need for materials to deliver the same utility. reMarkable has designed a digital device that "feels like paper". A tool for note-taking, reading and reviewing documents.	(EMF, 2015; Manninen et al., 2018)
Inform	**Design connected products (p)**	Design products with sensors that can send and receive different types of data. Delta Development, as part of its product-as-a-service' model, has sensors in some of their elevators to inform maintenance needs.	(Alcayaga et al., 2019; Barile et al., 2016; Främling et al., 2013; Gupta et al., 2019; Lopes de Sousa Jabbour et al., 2018; Nascimento et al., 2019)
Inform	**Use product-in-use data for circular design (bm)**	Data on how a product is used can be valuable to make better design decisions for future products and services. Rolls-Royce aggregates product-in-use data to make their engines more efficient, durable and long-lasting.	(Alcayaga et al., 2019; Gupta et al., 2019; Morlet et al., 2016; Pagoropoulos, 2017)

>>>

TABLE 3.1 The Circularity Deck: a set of circularity principles for product, business model and ecosystem innovation

Circular strategy	Circular principle and the required innovation perspective: product (p), business model (bm) or ecosystem (e)	Description and example	Ref.
Inform	**Track the resource intensity of the product-in-use (bm)**	Tracking the resource use of products while they are used can, for example, help to influence user behavior to decrease the resource intensity of product use. Philips uses sensors to track data on how their lights are used within their lighting-as-a-service model to save electricity.	(Nobre and Tavares, 2017)
Inform	**Track the condition, location, and/or availability of the product (bm)**	Tracking the condition of the products can help to predict when it will be necessary to service (e.g. repair, maintain) them. Tracking the location and availability can, for example, enable the maximizing of their use capacity. Zipcar uses the data to optimize their car sharing service.	(Ge and Jackson, 2014; Morlet et al., 2016)
Inform	**Market circular products, components and materials through online platforms (e)**	Online platforms can serve to market circular products, components and materials. Stuffstr buys and collects used products from consumers and sells them in second hand markets. An AI algorithm helps Stuffstr to set competitive prices for the seller, while offering Stuffstr a good margin on the second hand market.	(Ellen MacArthur Foundation, 2019a; Konietzko et al., 2019)
Inform	**Build material database ecosystems (e)**	Create or leverage material databases. They describe the characteristics of materials and components in products so that products can be more easily reused and their materials recovered. The project 'Buildings as Material Banks' has brought together different stakeholders to develop a material database ecosystem for buildings.	(Jabbour et al., 2019; Luscuere, 2016)
Inform	**Co-create products, components, materials and information via online platforms (e)**	Online platforms can be used to 'crowdsource' design projects for circular products, components and materials. The online platform launchforth.io connects designers and engineers with organizations to co-create new products.	(Konietzko et al., 2019; Launchforth, 2019)

>>>

TABLE 3.1 The Circularity Deck: a set of circularity principles for product, business model and ecosystem innovation

Circular strategy	Circular principle and the required innovation perspective: product (p), business model (bm) or ecosystem (e)	Description and example	Ref.
Inform	**Use artificial intelligence to optimize circular infrastructure (e)**	The circular economy requires the collecting, sorting, separating, treating, and redistributing of products, components and materials. Often, products, components and materials are diverse and difficult to handle. Artificial intelligence can help to optimize the infrastructure required for a circular economy. ZenRobotics uses robots with cameras and sensors to automatically sort all kinds of waste streams with an accuracy level of 98 %.	(Ellen MacArthur Foundation, 2019a; Gupta et al., 2019; ZenRobotics, 2019)
Inform	**Operate service ecosystems via online platforms (e)**	Online platforms can serve to operate service ecosystems that require several actors who need to coordinate their interactions and economic exchange. The online platform Whim operates mobility-as-a-service ecosystems in cities combining different private and public transportation options for a seamless mobility experience.	(Alcayaga et al., 2019; Ellen MacArthur Foundation, 2019a; Konietzko et al., 2019; Whim, 2019)

3.4.2 How to use the Circularity Deck

The use of the Circularity Deck is best illustrated with an example. Figure 3.5 shows the outcome of an exercise to analyze, ideate and develop the circularity potential of a hypothetical food ecosystem. The following paragraph describes the actions that could be derived from analyzing the identified principles with the circular economy framework.

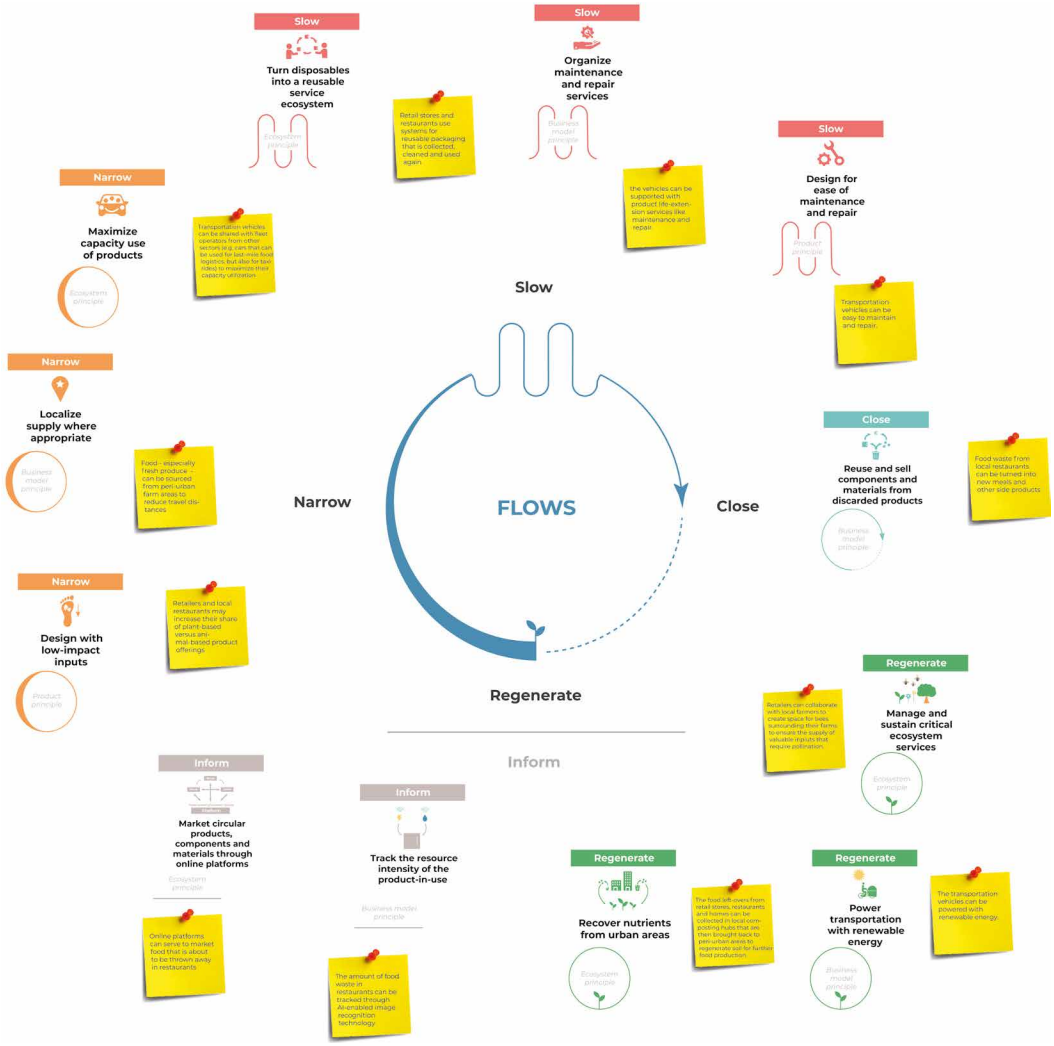


FIG. 3.5 Analyzing and developing the circularity potential of a hypothetical circular food ecosystem

TOC

Retailers and local restaurants may increase their share of plant-based versus animal-based product offerings. This example applies a product principle for narrowing: 'design with low-impact inputs'. They may start experimenting with systems for reusable packaging that is collected, cleaned and used again, which is an ecosystem principle for slowing: 'turn disposables into a service ecosystem for reuse'. Food – especially fresh produce sold in the supermarkets and through the restaurant dishes – can be sourced, if appropriate, from peri-urban farm areas to reduce travel distances, which is a business model principle for narrowing: 'localize supply where appropriate'. Transportation vehicles can be shared with fleet operators from other sectors (e.g., cars that can be used for last-mile food logistics, but also for taxi rides) to maximize their capacity utilization, which is an ecosystem principle for narrowing: 'maximize capacity use'. Transportation vehicles can be easy to maintain and repair, which is a product principle for slowing: 'design for ease of maintenance and repair'. Furthermore, the vehicles can be supported with product life-extension services like maintenance and repair, which applies a business model principle for slowing: 'organize maintenance and repair services'. The transportation vehicles can be powered with renewable energy, applying a business model principle for regenerating: 'power transportation with renewable energy'. The food left-overs from retail stores, restaurants and homes can be collected in local composting hubs that are then brought back to peri-urban areas to regenerate soil for further food production; an ecosystem principle for regenerating: 'recover nutrients from urban areas'. Finally, the food retailers may collaborate with local farmers to create space for bees surrounding their farms to ensure the supply of valuable inputs that require pollination; an ecosystem principle: 'manage and sustain ecosystem services'. The amount of food waste in restaurants can be tracked through AI-enabled image recognition technology to then train staff on how to reduce food waste in the kitchen; a business model principle for informing: 'track the resource intensity of the product-in-use'. Online platforms can serve to market food that is about to be thrown away in restaurants; an ecosystem principle for informing: 'market circular products, components and materials through online platforms'. Figure 3.6 presents a photograph of how the cards have been used in a workshop.

FIG. 3.6 How the Circularity Deck has been used in one of the workshops

Based on the evaluations of the 12 workshops, we propose that a session with the Circularity Deck should take about three hours and is best organized in a group of maximum 12 people. Participants should leave a session with a widened ecosystem perspective on circularity, an understanding of their role within that wider ecosystem, as well as ideas on how they may innovate their ecosystem, and whom they need to engage to get their buy-in and commitment. It is essential to have a trained facilitator to lead a workshop session; that is, someone who is familiar with the circular economy, the four strategies, the principles, the practice examples, and the different innovation perspectives (products, business models, ecosystems). The session then includes the following steps:

1 Present the circular economy framework and the five circular strategies (Figure 3.2). Show Figure 3.1 to explain that there are product, business model and ecosystem principles for each strategy. It is also important to explain how the cards relate to each other. First, some cards are similar to each other. This may be because a principle applies to more than one strategy. For example, the 'slowing' principle for products – 'design for easy dis- and reassembly' – can also be found as a separate 'closing' principle for products as 'design for easy disassembly at the end of the product's life'. Both cards exist, because design for disassembly to enable easy repair may be different from design for easy disassembly to ensure higher recyclability. Both are important to take into account during circular product design. Another example refers to the two 'slowing' principles for business models: 'provide the product as a service' and 'organize maintenance and repair services'. The former relates to the value proposition and the latter to the value creation and delivery of the circular business model. In addition, cards may relate to each other in all kinds of ways. An example is the 'informing' principle for products: 'design connected products'. This principle may be needed to support the 'narrowing' principle 'enable and incentivize users to consume less'. Another example is the 'narrowing' principle for products: 'design light-weight products', which may support the 'slowing' principle 'provide the product as a service'. In general, analyzing and developing circular innovation ecosystems implies that participants identify the relationships among the cards: to realize when one principle enables another one; and how many cards together can enable circularity to emerge as a systemic property in a given innovation ecosystem.

2 Let the participants define a clear problem or challenge that they want to work on during the session. This can be a specific business context or industry, an existing business model or future circular oriented goals that an organization or several organizations want to work towards.

3 Hand out prints (at least A4) of the circular strategies framework (Figure 3.2) and let people brainstorm for about five minutes how they currently use these strategies to address their problem or challenge. This step is to analyze the current status quo. The output can be captured on post-its.

4 Ask the participants to spend five minutes to think about how they can apply the circular strategies in their context. This step makes sure that people can first generate more open ideas about how they could apply the strategies, and prevent that they are influenced by the content of the Circularity Deck. During this step, participants are asked to write on post-its and map them around the circular economy framework.

5 Hand out the Circularity Deck so that the participants can get to know the cards. It might be helpful to pre-select some cards to reduce the overall number of cards that the participants have to go through and to increase the relevance of the cards for a particular context. Not all cards are, for example, relevant to the textile sector.

6 Once they have a basic understanding of the cards, ask participants to analyze if and how the principles can be implemented in their context. The cards can then be put on the table around the framework where each stack of cards belongs. Participants can browse through them and map them around the circular strategies framework, similar to how the cards and post-its are mapped around the framework in Figure 3.2. This exercise results in a circular economy framework that is surrounded by selected cards and post-its. This can then serve to generate and discuss ideas and necessary actions that can lead to higher degrees of circularity.

3.4.3 Evaluation and iterations of the Circularity Deck

Each workshop experience served to evaluate and improve the Circularity Deck, based on the results (Appendix A3) from the feedback forms (Appendix A2). Iterations throughout the six professional workshops with 136 evaluations in different settings give confidence that the tool is useful – for entrepreneurs, innovation managers, business managers and designers – to analyze, ideate and develop the circularity potential of innovation ecosystems (average rating: 4.52/5; standard deviation: 0.56), and that it is easy to use (average rating: 4.42/5; standard deviation: 0.73). Participants noted, for example, that the Circularity Deck can *"reduce complexity"*, provide a *"helicopter view"* and *"a new perspective"*, and *"ensure that many aspects are considered"*. After each workshop, the feedback was used to make the following changes to the Circularity Deck (Table 3.2). A figure with some of the cards from the first version can be found in Appendix A4.

TABLE 3.2 The feedback from the workshops and the changes made

Workshop	Feedback	Changes
1	Clarify principles, add examples	Rewrote principles for more clarity, researched and added examples for each principle
2	Get rid of overlapping principles	Revisited principles for more differentiation
3	Principles and examples may be limiting, lacking connections between the cards, pose principles as questions, improve quality of the cards	10 minutes of brainstorm without the cards, better explanations on the relationships of the cards, better quality prints for cards
4	Address viability of the principles, conceptual overlap among cards	Revisited principles to better differentiate them, improved guidance on how to use the cards
5	Translate cards into Dutch	-
6	Address overlapping cards, clarify relationships between cards	Provide better explanations for the conceptual similarity between cards in the guidance, explain possible relationships in the guidance
7	Add new card on design with renewable materials, make a pre-selection of cards, give clear instructions, add a 'playing board' to the cards, make the ecosystem perspective more clear, change card design, add cards that explain the strategies	Added new card on 'design with renewable materials', added the possibility to preselect cards to the instructions, added instructions on how to allocate the cards around the framework to better explain the ecosystem perspective, changed the card deck design (added a colored top layer) to make it easier to grasp
8/9	-	-
10/11	Include a 'get-to-know the card deck' phase before starting the ideation, give more time for the session	Added a step to the instructions to ensure that the participants have enough time to understand the card deck, changed the proposed time for a workshop from two to three hours.
12	Define a clear problem or challenge at the beginning of the session	Added a step to the instructions that lets participants define a clear problem or challenges that they want to work on during the workshop

The first version was tested in a workshop with a big health technology company. The session showed that not all principles were clear, so we refined them afterwards. In addition, one participant remarked that examples would be helpful to better understand the principles, which we then included. Another participant remarked that more group work would be better. We took this into account for subsequent workshops.

The second workshop was held with twelve 'circular' startups as part of an incubator program at Impact Hub Amsterdam. Following the workshop, one participant remarked that there was too much overlap among the principles. We therefore revisited the principles, merged similar ones and edited others to better distinguish them from each other.

The third workshop was conducted with staff from a mobility design agency. One participant suggested that the principles and examples may limit people to come up with their own ideas. In subsequent workshops, we therefore gave people some time to first generate their own ideas on how to implement the four circular strategies, and only then distributed the cards with our principles and examples. Another remark was that it was difficult to make connections between the cards: how does, for example, the product principle 'design light-weight products' (narrowing) affect the business model principle 'provide the product as a service'? We used the feedback to better highlight the relationships among the different strategies and principles in the guidance on how to use the cards during the workshop. Another idea that resulted from the feedback was to pose the principles as questions. We decided not to do that to save space on the cards and keep the principles short. Following further feedback, we improved the quality of the cards by editing the text on the cards to improve their readability, and developing a professionally printed version.

The fourth workshop was conducted with participants from different small and medium sized enterprises from a province in the North of the Netherlands. One participant noted that the tool missed elements such as cost and performance. We thought about how to integrate a cost perspective to assess the viability of ideas, but decided to leave it out of this tool. This decision was made because the purpose of the tool is to analyze, ideate and develop the circularity potential of ecosystems. Assessing business viability comes later, once maps and ideas are documented. Another participant highlighted conceptual overlaps among the principles. We therefore revisited the consistency of the principles once more. Further remarks related to the need for an online version of the Circularity Deck, and better guidance on how to use the cards. We decided to explore the former suggestion in a later stage of this project. The latter was addressed by providing clearer guidance on how to use the deck.

The fifth workshop was held at a large engineering service company in the Dutch construction sector. One participant suggested to translate the card deck into Dutch. We decided to consider this as an 'extra' that can be explored in the future. Other remarks concerned the 'broad interpretation' of circularity, something we intentionally did to let participants understand the broad nature of changes that are needed to transition towards a circular economy.

The sixth workshop was held as part of an international coaching program for 21 entrepreneurs to develop their circular business models. The participants provided positive feedback. Two issues needed to be addressed: the seeming redundancy of some cards and the relationships between the cards. We decided to enhance the

briefing before using the cards and the description of how to use the cards to provide more clarity (see section 4.2.).

The seventh workshop took place at the Impact Hub in Hamburg, Germany. Based on the feedback, we added one more card to the 'regenerate' strategy: design with renewable materials'. We also added to the instructions that it may help to make a pre-selection of cards based on the context, to reduce the cognitive load of the cards and make them more applicable to a particular context. We also changed the title of the manuscript, to reflect the various purposes the Circularity Deck can serve: to analyze existing ecosystems, as well as ideate and develop the circularity potential of innovation ecosystems. Lastly, the design of the deck was changed to make the strategies more distinguishable. The final version has a colored top layer that indicates the strategy for easy visibility and the possibility to quickly browse through the cards.

The eighth workshop was held during a conference in Riga, Latvia and the ninth workshop with a design agency from Helsinki, Finland. The feedback from the participants of both workshops did not include direct recommendations on how to improve the tool.

The tenth and 11th workshops were held at a university in Espoo, Finland with innovation managers, designers and researchers. One participant suggested to include a step to get to know the cards before the ideation. We included this as a step in the instructions (step 5 in section 4.2). Again, the participants were overwhelmed with the number of cards that they had to read within a short period of time. Next to the possibility to pre-select cards, we extended the proposed time for a workshop from two to three hours.

The 12th workshop took place at a university in Lappeenranta, Finland. At the beginning of the session, we asked the group to split in two and have a challenge owner in each group who explains the challenge to the rest of the group. One group worked on the circular economy of the city of Lappeenranta with the circular economy director of the municipality, the other on the circularity of a welding company whose chairman and environmental manager were present. One participant confirmed in the feedback form that defining a clear problem or challenge is crucial at the beginning of the session. We included this in the instructions (step 2 in section 4.2).

3.5 Discussion

Our study makes two main contributions to the circular economy research and practice. First, as a theoretical contribution, it proposes a novel way to analyze circular strategies and principles to provide an ecosystem perspective on the circular economy. The ecosystem perspective consists of 1) a number of explicit ecosystem principles for narrowing, slowing, closing, regenerating and informing material and energy flows, 2) a number of product, business model and ecosystem principles that – when combined – enable organizations to take an ecosystem perspective on the circular economy and work towards higher circularity. Second, as a practical contribution, our study provides a well-researched and tested tool that can be used to analyze, ideate and develop the circularity potential of innovation ecosystems in a given context. It thereby makes the analysis from the literature and practice review useful for practitioners, which is an important step to close the theory-practice gap of organizational research (Van de Ven, 2007). In the following, we discuss both contributions and their limitations.

As a theoretical contribution, this study adds an ecosystem perspective to the existing tools and approaches that have focused on products and business models (Blomsma et al., 2019; Bocken et al., 2019c; Guzzo et al., 2019; Pieroni et al., 2019). It thereby proposes an analytical approach for organizations to better understand the systemic nature of circularity. In addition, this approach helps to uncover conceptual ambiguities in existing frameworks. Throughout the research for this paper, we noticed that several frameworks used in practice and research are not clear on the type of circular economy strategy that they pursue. This is the case, for example, with the RESOLVE framework proposed by the Ellen MacArthur Foundation (EMF, 2015). It contains principles such as ‘virtualize’, ‘share’, ‘optimize’ and ‘exchange’. They provide a general direction of what to do, but are ambiguous regarding their intended influence on the circularity or sustainability of material and energy flows. ‘Maximize excess capacity’ (‘share’) as a principle, for example, does not have environmental benefits per se. It needs to be supported by other principles like ‘design for easy maintenance and repair’ (product principle for ‘slowing’), ‘organize maintenance and repair services’ (business model principle for ‘slowing’), or ‘power transport with renewable energy’ (business model principle for ‘regenerating’) (Tukker, 2015). This study supports the development of circular ecosystems that do not assume that principles like ‘virtualize’ or ‘share’ are good from an environmental perspective per se. Even though the Circularity Deck aims at ‘better ecosystems’, it is important to assess the environmental impacts of the proposed ideas and actions that result from its use. This assessment is needed to

understand which principles and strategies have the highest potential to decrease environmental impacts in a given context. An assessment is important, because the impact reduction potential of any solution is not obvious. For example, life-cycle assessments of aluminum cans have shown that a higher cradle to cradle certification does not automatically translate to a lower environmental impact (Niero et al., 2016).

As a practical contribution, this study develops the Circularity Deck: a practitioner-focused tool for circular ecosystem innovation. This has led to some findings on how to improve circular oriented innovation tools. Previous research has emphasized, for example, the need to define clear learning outcomes and goals for a tool, define its intended user group, and to incorporate 'circularity checks' (Blomsma et al., 2019; Bocken et al., 2019e). We add three findings to this to provide further guidance for future tool development: 1) clear and concise descriptions and examples can help the participants to understand the tool content and concepts better and faster, 2) participants may benefit from an exercise without a tool, to be free from the possible constraints that it imposes, and to reveal its power once it is used, 3) a tool is most useful when actively facilitated by an expert who is familiar with its background concepts.

It is important to highlight the limitations of this study. First, we neither claim that the underlying review of the Circularity Deck is complete, nor that it captures all relevant principles. Rather, the contribution lies in proposing a framework of circular strategies (narrow, slow, close, regenerate, inform) and innovation perspectives (product, business model and ecosystem) that can be used by future research to edit and extend the set of principles that resulted from the review of this study. Efforts to innovate towards sustainability constantly evolve, and addressing wicked issues like sustainability has no clear starting or end point (Rittel and Webber, 1973). It is therefore important to acknowledge that the research output of this study does not present a fixed result, but rather a starting point, or another research input, for further research in different contexts. Second, it is important to highlight that the tool has been tested in a limited number of contexts. While we are confident about its usefulness and ease-of-use for entrepreneurs, innovation managers, business managers and designers, it is important to acknowledge that the tests were conducted in developed economy contexts, i.e. in the Netherlands, Sweden, Germany, Latvia and Finland. Yet, it should be noted that the participants and facilitators came from diverse backgrounds, also from outside of these countries. Third, it is important to recognize that the tool proposed here does not incorporate social and institutional dimensions of the circular economy. This includes, for example, the need to price carbon emissions or other forms of externalities, as well as the need to explore more participatory and redistributive forms of government

that can safeguard and improve the quality of work and equity within an emerging circular economy (Moreau et al., 2017). We suggest that future research may include a set of social and institutional principles to complement the principles proposed in this study.

3.6 Conclusion

This study proposes the Circularity Deck: a tool and approach to analyze, ideate and develop the circularity potential of innovation ecosystems. The tool is based on a literature and practice review of recent circular economy strategies and principles. The principles are organized according to the perspective that is needed to implement it: a product, business model, or ecosystem perspective. We conclude on the review that an ecosystem perspective on a circular economy is both needed and useful for organizations to capture circularity as a systemic property. The Circularity Deck – a practitioner-focused tool – helped to make the review results useful. The tool has been tested for its 'perceived usefulness' and 'ease of use' in 12 workshops with 136 participants from 62 organizations to ensure that the Circularity Deck has practical value. Based on these iterations and an average rating of 4.52/5 on usefulness and an average rating of 4.42/5, we conclude that the tool is useful and easy to use for entrepreneurs, innovation managers, business managers and designers. Future research is needed to continuously update the tool with new principles examples, and, more generally, to identify more principles to narrow, slow, close, regenerate and inform the material and energy flows that are associated with business activity in the pursuit of an environmentally sustainable circular economy. Furthermore, there is value for future research to use the approach proposed in this study to develop sector-specific versions of the Circularity Deck, most notably for sectors such as mobility, food and construction, due to their high global life-cycle environmental impacts.

4 Circular ecosystem innovation

An initial set of principles

Publication:
Konietzko, J.; Bocken, N.; Hultink, E.J. Circular ecosystem innovation: An initial set of principles. J. Clean. Prod. 2020, 253, 119942.

ABSTRACT A circular economy maximizes the value of material resources and minimizes greenhouse gas emissions, resource use, waste and pollution. We will posit that circularity needs to be understood as a property of a system (e.g., the mobility system of a city), rather than a property of an individual product or service (e.g., a car or a car-sharing service). Hence, there is a need for more knowledge on how to innovate towards 'circular ecosystems'. This study proposes a set of principles for 'circular ecosystem innovation', based on: 1) a concise literature review to retrieve recommended principles on how to successfully innovate in ecosystems, 2) a mobility case of circular ecosystem innovation to investigate how relevant and useful these principles are for circular oriented innovation. The case data include 20 interviews, workshop data and internal background documents. The identified principles can be categorized in three groups: 1) collaboration (i.e., how organizations can interact with other organizations in their ecosystem to innovate towards circularity), 2) experimentation (i.e., how organizations can organize a structured trial-and-error process to implement greater circularity) and 3) platformization (i.e., how organizations can organize social and economic interactions via online platforms to achieve greater circularity). Future research may focus on identifying opportunities and barriers to applying these principles in different contexts than in the one that is investigated in the present study.

KEYWORDS Circular economy, circular business models, innovation ecosystems, service ecosystems, platform ecosystems

4.1 Introduction

A circular economy maximizes the value of material resources and minimizes overall resource use, greenhouse gas emissions, waste and pollution (Geissdoerfer et al., 2017). Circularity – a situation in which this maximizing and minimizing occurs – is a property of a system (e.g., the mobility system of a city), rather than the property of an individual product or service (e.g., a car or a car-sharing service) (Adams et al., 2016; Ceschin and Gaziulusoy, 2016). Transitioning to a circular economy therefore requires product, business model and ecosystem innovation. Product innovation designs, makes and markets new products (Boer and During, 2001). Business model innovation changes the value proposition, value creation and delivery and value capture mechanisms of an organization (Bocken and Short, 2016). Ecosystem innovation changes how a set of actors – producers, suppliers, service providers, end users, regulators, civil society organizations – relate to each other to achieve a collective outcome (based on Jacobides et al., 2018; Talmar et al., 2018). The difference between a business model and an ecosystem perspective is that the latter views the business models of other relevant actors to be as important as the one of a focal organization (Adner, 2016).

Prior research on ecosystems and a circular economy hosts a variety of interpretations of the ecosystem analogy. Some have, for example, used a 'business ecosystem' lens (Moore, 1993) to explore how manufacturing organizations have orchestrated their ecosystems towards circularity (Parida et al., 2019), or how a leading glass-recycling organization in Taiwan has governed its ecosystem over time (Hsieh et al., 2017). Others have built analogies between natural (Holling and Gunderson, 2002) and business ecosystems, to explore possible circular ecosystem roles for organizations (Tate et al., 2019). Yet others have used sectoral or cluster-based analogies of ecosystems. This includes, for instance, research on how the 'ecosystems of repair shops' differ across locations (Türkeli et al., 2019), how innovation ecosystems can support the transition to a circular bio-economy for agricultural systems (Berthet et al., 2018), how a regional innovation ecosystem of relevant design actors can contribute to a circular economy in Scotland (Whicher et al., 2018), or how the aluminum beverage can industry in the UK can explore its circularity potential (Stewart et al., 2018). Another outlet has used a platform ecosystem interpretation (Gawer, 2014) to explore how platform ecosystems can enable smart and circular cities in Indonesia (Mahesa et al., 2019). In this study, we contribute to the business and innovation ecosystem perspectives on a circular economy (Adner, 2016; Hsieh et al., 2017; Jacobides et al., 2018; Parida et al., 2019). To the best of our knowledge, no prior research – using the business and

innovation ecosystem lenses – has explored how organizations can innovate towards circular ecosystems; that is, what principles they might follow to change how a set of actors relate to each other to achieve circularity as a collective outcome.

The goal of the present study is to develop and propose an initial set of principles for circular ecosystem innovation. Our first research question is: *what principles does the (business) literature recommend to successfully innovate in ecosystems?* To develop a first set of principles, we use pattern matching, a qualitative analysis method that compares a predicted theoretical with an observed empirical pattern (Sinkovics, 2018). An initial pattern matching template of recommended principles is derived from a review of the literature on ecosystems – with a focus on the innovation, service and platform ecosystem concepts – to understand what principles it recommends to successfully innovate in ecosystems. Following the review, we match the initial template with case study data to address a second question: *how relevant and useful are these principles for circular oriented innovation?* The case is at the intersection of the mobility, energy and information technology industries; it has set out to develop a *"zero-emissions e-mobility system for cities"* (ACM, 2018). The case study reveals how relevant and useful the recommended principles for circular oriented innovation.

Based on the literature review and the case data, we identify and describe three main groups of principles for circular ecosystem innovation: 1) collaboration (i.e., how organizations can interact with other organizations in their ecosystem to innovate towards circularity), 2) experimentation (i.e., how organizations can organize a structured and action-oriented trial-and-error process to implement greater circularity) and 3) platformization (i.e., how organizations can organize social and economic interactions via online platforms to achieve greater circularity). We describe the principles within each of these groups and highlight if and how the practitioners in the case have used them to implement circularity in their project. The principles proposed in this study need to be further developed and empirically tested through future (action and design) research on circular ecosystem innovation in different contexts.

4.2 Conceptual background

4.2.1 A circular economy and circularity as a systemic property

A circular economy maximizes the value of material resources and minimize greenhouse gas emissions, resource use, waste and pollution (adapted from Geissdoerfer et al. 2017). One of its main assumption is that we currently live in a linear economy: we take resources, make products, use them, and then throw them away (Blomsma and Brennan, 2017; EMF, 2012; Ghisellini et al., 2016). To become 'circular', organizations need to implement new ways of doing business (Linder and Williander, 2015b): they need to narrow (use less material and energy), slow (use products and components longer), close (use products, components and material again) and regenerate (use non-toxic material, renewable energy and regenerate natural ecosystems) their material and energy flows (Figure 4.1) (based on Bocken et al., 2016; EMF, 2015; Geissdoerfer et al., 2017; McDonough & Braungart, 2002).

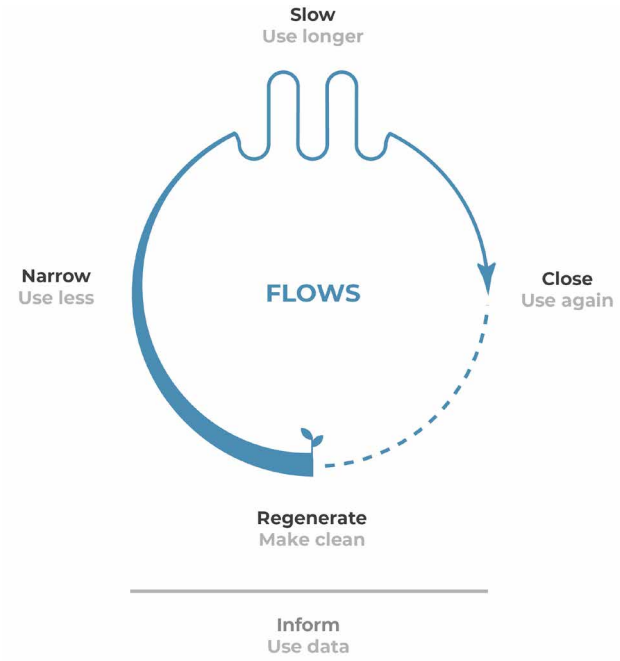


FIG. 4.1 A circular economy: narrow, slow, close and regenerate material and energy flows.

TOC

Innovating towards circularity requires fundamental changes in wide-spread economic structures (Lieder and Rashid, 2016). Circularity therefore needs to be understood as a systemic property (Adams et al., 2016; Ceschin and Gaziulusoy, 2016). For example, the circularity of a new and reusable packaging solution for food delivery services requires that multiple actors change what they do: the service provider needs to convince a critical mass of restaurants to adopt the reusable packaging solution; the food delivery platforms need to offer the solution to their users as an option in the ordering process; users need to be convinced and incentivized to opt for it; someone needs to provide clean delivery solutions to transport the food and packs; another actor needs to collect, wash and re-deliver the packs, and so on. Circular oriented innovation thus widens the innovation perspective to include the ecosystem, next to a product or service and the business model (Figure 4.2).

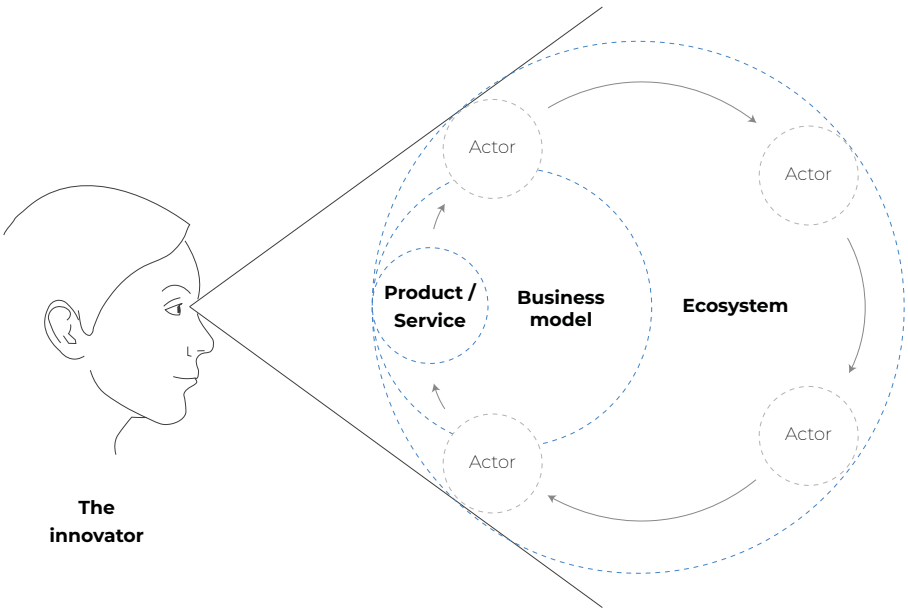


FIG. 4.2 Through an ecosystem perspective, an innovator sees the product or service, the business model and the wider ecosystem.

TOC

4.2.2 Ecosystem innovation

A *business ecosystem* is defined here as a set of actors – producers, suppliers, service providers, end users, regulators, civil society organizations – that contribute to a collective outcome (based on Jacobides et al., 2018; Talmar et al., 2018). We explicitly take business and innovation ecosystem perspectives in this study, which serve to explore the *"cooperative and competitive activities of multiple organizations that belong to different industries"* (Suominen et al., 2019, pp. 336-337). This excludes a review most of the cluster-based or sectoral interpretations of the concept, such as regional or national innovation ecosystems, or value networks (Suominen et al., 2019). This decision is made to avoid conceptual ambiguity, and to have a clear focus on how a focal organization can innovate in and as part of its surrounding ecosystem. From this perspective, *ecosystem innovation* seeks to change how a set of actors collaborate and relate to each other to contribute to a collective outcome (Adner, 2012; Iansiti and Levien, 2004; Jacobides et al., 2018). There are three conceptions of business ecosystems in the literature that may be relevant in a circular economy context: innovation, service and platform ecosystems (Jacobides et al. 2018; Suominen et al. 2019; Vargo et al. 2015).

First, *innovation ecosystems* describe how legally independent actors can jointly create value. The focus of this perspective is on a technology or new value proposition that requires the joint efforts of multiple actors to be successfully implemented (Adner, 2016). Innovation ecosystems may be dominated by one actor, for example, the owner of a platform, or the main provider of collaborative innovation opportunities, sometimes referred to as the 'orchestrator' or 'keystone actor' (Gawer and Cusumano, 2014; Iansiti and Levien, 2004b; Nambisan and Baron, 2013). Innovation ecosystems take into account the involved actors and their business models (their value proposition, value creation and delivery, and value capture mechanisms), the risk that they bring (the risk that an actor will co-innovate and co-adopt what is needed), the dependency among them (how dependent an actor is on another one, and on the whole ecosystem), an ecosystem value proposition (an integrated, end user facing solution) and user segments that are addressed by the ecosystem value proposition (Talmar et al., 2018). An ecosystem lens looks beyond business model innovation: it "*can be thought of as one that takes partner organizations' business model to be as critical to address as the focal firm's"* (Adner, 2016, p.51).

Second, *service ecosystems* are based on the service-dominant logic, which views service as the basis of all social and economic exchange (Vargo and Lusch, 2004). Service-dominant logic is an ontology; i.e., a way of looking at the world, a belief

that humans and other species exist to serve one another[3] (Lusch, 2009). A service ecosystem can be defined as a set of actors that interact with and depend on each other to co-create value (adapted from Vargo & Lusch, 2011). Service ecosystems can be innovated by changing and maintaining institutions – the rules, norms, values and beliefs – that govern social and economic exchange (Koskela-Huotari et al., 2016; Siltaloppi et al., 2016; Vargo and Lusch, 2016). Innovators in service ecosystems face institutional complexity. They need to confront many different, often contradicting norms, values and beliefs about how societal life should be organized. These institutions can be nested in different contexts with distinct perceptions of what is valuable. They may be situated at micro (e.g., an organization), meso (region) or macro (e.g., the national) levels (Chandler and Vargo, 2011; Koskela-Huotari et al., 2016).

Finally, *platform ecosystems* describe how actors organize themselves around common technological and/or market-oriented platforms (Jacobides et al. 2018). Platforms organize data streams, economic interactions and social exchanges across users (based on van Dijck et al. 2018; Konietzko et al. 2019). The platform concept has gradually broadened its scope from internal platforms (that consist of one organization, closed interfaces, sub-units and suppliers), supply-chain platforms (that consist of a focal organization, suppliers and assemblers, selectively open interfaces, contractual relations among actors), to industry platforms (that consist of industry ecosystems, a platform leader, complementors, open interfaces, and an ecosystem governance structure) (Gawer, 2014). Common examples of industry platforms are Google, Facebook, Apple and Amazon. These platforms seek network effects: the more actors join, the more attractive the platform becomes for actors, which in turn attracts more actors (Gawer & Cusumano 2014). Platform ecosystems have an infrastructural core[4] upon which sectoral platforms (e.g., Uber in mobility) build their services (van Dijck et al., 2018). Platforms are useful in facilitating innovation activities (Gomes et al., 2018). They help manage complexity by breaking up a complex system into discrete components, and to encourage division of 'innovation labor' (Gawer and Cusumano, 2014). Platforms may also be seen as multi-sided marketplaces where participants exchange physical products

3 A belief that seems to be shared by, for example, Clayton Christensen (2012), although in a more religious context.

4 The infrastructural core has, until today, been dominated by the four so-called GAFA platforms (Google, Apple, Facebook and Amazon). The core entails *"search engines, browsers, data servers and cloud computing, email and instant messaging, social networking, advertising networks, app stores, pay systems, identification, data analytics, video hosting, geospatial and navigation, and a growing number of other services"* (van Dijck et al. 2018, p. 13).

(e.g., used cars or furniture), build communities around products (e.g., handmade design), match service organizations with users (e.g., local food delivery), exchange online services (e.g., language tutoring), and/or engage in peer-to-peer exchanges of offline services (e.g., ridesharing) (Täuscher and Laudien, 2017).

4.3 Method

This study uses flexible pattern matching to identify and develop principles for circular ecosystem innovation (Sinkovics, 2018). Pattern matching compares a given theoretical pattern with an observed empirical pattern. Flexible pattern matching allows for an open matching of patterns that is suitable for exploratory research, like the one in this study. An initial pattern matching template provides guidance on how to analyze a set of empirical data (ibid.).

The patterns in this study are composed of principles, that is, solution-oriented guidelines for a particular course of action (Romme and Reymen, 2018). Principles can be formalized in terms of the CIMO logic (context, intervention, mechanism, outcome) (Denyer et al., 2008). In this study, the context is circular oriented innovation, and the intervention is circular oriented innovation. Furthermore, principles need to have a clear mechanism, that is, a description of what a principle is supposed to achieve within the given context. They also need to have a defined outcome, that is, a description of the outcome that a principle is supposed to achieve (ibid.). We follow this logic when we describe the principles in the results section.

The method of this study has two main steps (Figure 4.3): 1) the development of an initial pattern matching template of principles derived from a review and analysis of the extant literature on innovation, service and platform ecosystems, 2) a matching of case study data with the initial pattern matching template, to see how relevant and useful the recommended principles are for circular oriented innovation. We also detail how the principles have to be changed, based on the case data, to become more relevant for a circular oriented innovation context. In the following, we describe both steps in more detail.

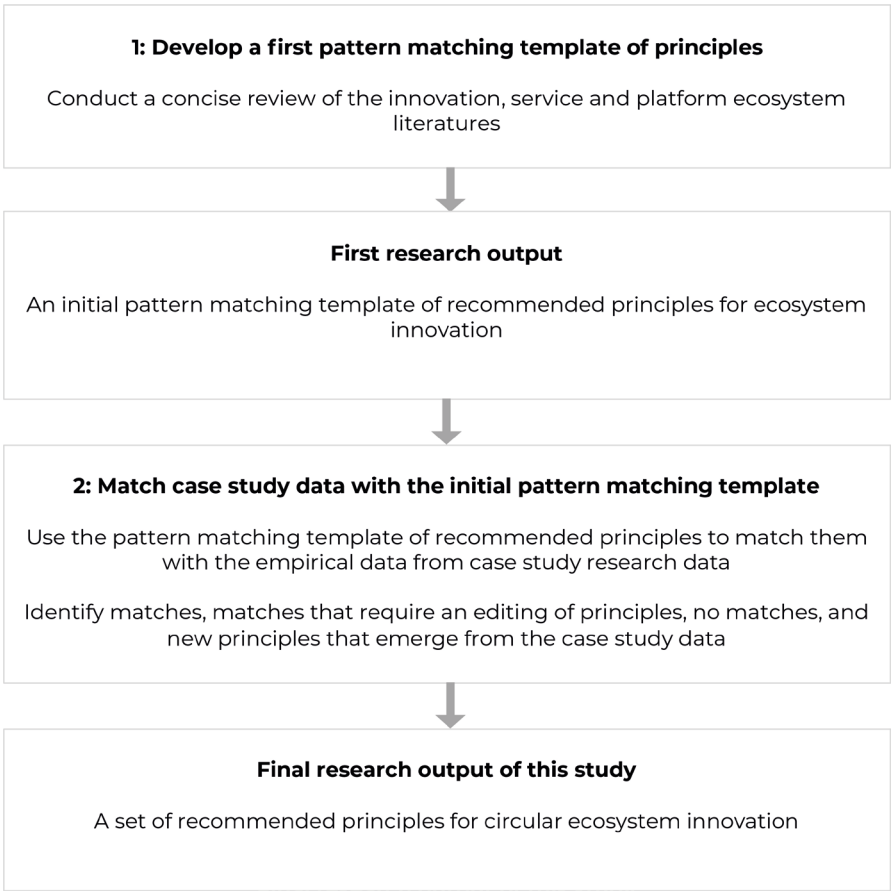


FIG. 4.3 Overview of the method.

4.3.1 Initial pattern matching template

We deduct an initial pattern matching template of recommended principles for designing business ecosystems from a concise literature review. A short literature review serves to *"tackle an emerging issue that would benefit from exposure to potential theoretical foundations"* (Webster & Watson 2002, p.14). Our review consists of a scan of the 'business, management and accounting' literatures (filtered from the academic database SCOPUS) to derive recommended principles for organizations in the innovation, platform and/or service ecosystems literatures. We used a variety of search strings in the database Scopus to identify and select

TOC

a number of articles (further elaborated in Appendix B1). The articles were read and coded to retrieve recommended principles on how to successfully innovate in ecosystems. These principles can be found in at least three ways within the publications. First, they may be found in the 'managerial implications' sections. For example, Koskela-Huotari et al. have translated their findings on service ecosystem innovation into managerial implications: *"[…] including new actors or ways of reframing resources are necessary in order to create something new […]"* (2016, p.2970). Second, the entire publication may address a 'how to' question that develops principles as a main research output. For example, Schreieck et al. describe key constructs for platform ecosystem design and governance. They recommend a clear definition of platform roles, pricing and revenue sharing, boundary resources and the degree of platform openness (2016). Third, recommended principles may be implicit within the articles. For example, Teece in his seminal work on dynamic capabilities, suggests that managers should be capable of identifying, developing and utilizing cospecialized assets (2007). The review leads to the first research output of this study: an initial pattern matching template of recommended principles for ecosystem innovation.

4.3.2 Case study

We then used the initial template of recommended principles from the literature to analyze a circular ecosystem case. This was done by screening the case data to identify if and how the recommended principles have been applied in the case, and how relevant and useful they have been for innovating towards circularity. We chose this case after an extensive search for projects and cases that can be conceptualized as circular ecosystem innovation projects. The case therefore serves as a valuable 'instrument' to learn more about the possible principles for circular ecosystem innovation (Stake, 1994). A single case is justified here because we had unique and rich access (Yin, 2013) to a high-level, multi-actor ecosystem innovation project. For an ecosystem case analysis, it is important to: 1) define clear ecosystem boundaries (in this case the core consortium and some external partners), 2) deal with complexity by focusing on one aspect of a network (in this case a focus on relevant and useful innovation principles), 3) stay flexible regarding unexpected ecosystem changes over time, and 4) accept that findings from ecosystem cases, due to their unique context and historical background, may be difficult to compare with other ecosystem cases later on (Halinen and Törnroos, 2005).

4.3.2.1 Case description

The case is at the intersection of the mobility, energy and information technology industries. It provides a rare example of a cross-industry, multi-actor ecosystem innovation project for a circular economy. The project goal has been to develop a *"zero-emissions e-mobility system for cities"* (ACM, 2018). The case is relevant in this context because the environmental sustainability of inner-city mobility is a key priority area for circular transitions in cities around the world (Tukker et al., 2016). The case study consists of a focal organization ('Adaptive City Mobility'), ten technology organizations (the core consortium) and other actors like the co-funding body (German Ministry of Economic Affairs and Energy), a project monitoring organization (the German Aerospace Center), and the designer of the vehicle (Naumann Design) (Figure 4.4).

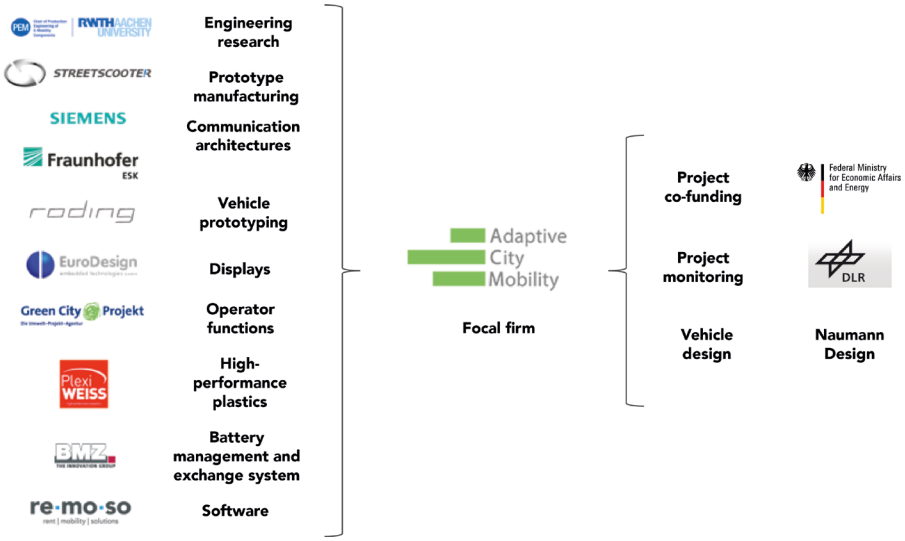


FIG. 4.4 Overview of involved organizations and contributions.

TOC

The project developed a variety of cospecialized technology assets, consisting of three main parts (Figure 4.5):

- *A light-weight vehicle*: the vehicle has the form of a car that has been reduced to its functional essence, with a focus on multi-modal 'sharing'. For example, it is designed to carry both people and goods (the two back seats can be switched for a Euro-pallet). It weighs around 450 kg (excl. batteries).
- *Batteries and a battery management and exchange system*: the batteries (12kg) can be manually exchanged at a battery exchange station. The battery exchange station can be positioned where renewable energy is produced.
- *Software*: Software enables operability of the system. It collects, analyses and feeds back data on the location, condition and usage of the vehicles and batteries. It enables sharing and mode-switching of the vehicle (e.g. from taxi to last-mile logistics).

FIG. 4.5 The adaptable vehicle (e.g. taxi, transport) on the left, the 'operating ecosystem' on the right (figure by ACM).

TOC

The intended circularity of the system emerges from the application of the following circular economy design strategies and principles (Figure 4.6). design light-weight vehicles (the car weighs one third of an average personal car in 2019), design for multiple functions (the vehicle can be used for people and goods transport), maximize use capacity (the vehicle can be shared among end users, ride hailing companies, logistics fleet operators), provide the product as a service (the vehicles are paid on a use basis), repurpose valuable components (repurposed batteries for home heating), design for easy dis- and reassembly (modular vehicle design), and power the use of the product with renewable energy (the batteries can be placed next to facilities for renewable energy production). There was no explicit intention in the project on the recovery of materials.

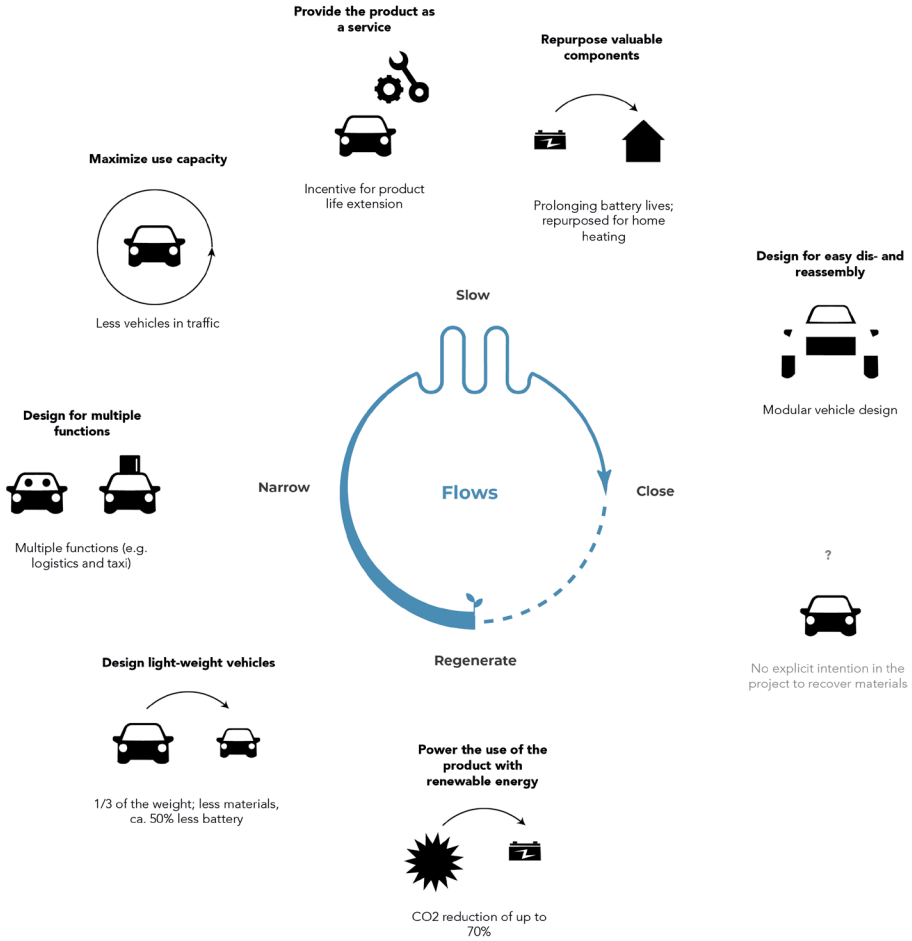


FIG. 4.6 The intended circularity of the project.

TOC

4.3.2.2 Case data

We conducted 20 interviews with eleven key individuals over the course of 15 months, made observations and notes during a workshop with all consortium partners, and accessed several internal background documents (e.g., market studies and project sketches and proposals) and online information (e.g., project website, partner websites, website of the funding body) (see Appendix B2 for an overview of all interview data). Interview questions focused on, for example, what participants have done (activities), how they have done it, and how they worked together with other organizations in the project. Appendix B3 provides a list of the main questions asked during the semi-structured interviews.

4.3.2.3 Case data analysis

The interview data were transcribed and then coded together with additional text documents (e.g., market studies, project proposals) using the coding software NVivo. We took a deductive approach and screened the case data to analyze if and how project participants (the observed empirical pattern) have made use of the recommended ecosystem innovation principles (expected theoretical pattern). For example, one principle for service ecosystem innovation is to 'reframe what resources mean'. We found that this principles matches with the case study data. The resource 'car', for example, has been reframed: from a big, feature-rich and powerful personal car, to a small, sufficiency-based, friendly, shareable and multi-purpose vehicle. This reframing is thus a relevant and useful principle for circular ecosystem innovation.

4.4 Findings

This study proposes three main groups of principles for circular ecosystem innovation: collaboration, experimentation and platformization. Collaboration refers to how organizations can interact with other organizations in their ecosystem to innovate towards circularity. This group of principles has by far the most sources and references from the case data, indicating its importance for circular ecosystem innovation. Experimentation refers to how organizations can organize a structured trial-and-error process to implement greater circularity. Similar to collaboration, the experimental nature of the case project and the many ways in which organizations have prototyped cospecialized assets and 'tried things out' reveals the importance of experimentation as a group of principles for circular ecosystem innovation. Finally, platformization refers to how organizations can organize social and economic interactions via online platforms to achieve greater circularity. This group of principles has also been important in the case project, due to the focus on the connectivity within the ecosystem.

Table 4.1 contains all principles, organized into each of the three groups of principles. It contains two columns per group: the left column with the initial template of principles that were derived from the literature and the right column with the final template of principles. In the right column for each group, we also indicate if we found a match between the principle from the literature and the case study data (match), whether we changed the principle from the literature to match with the case study data (edited match), whether there was no match (no match) and whether we found a pattern in the case study data that we did not find in the literature (new principle). Following the table, we describe each principle and, based on the case data, detail the relevance of each principle for circular ecosystem innovation.

TABLE 4.1 The initial and the final template of principles for collaboration, experimentation and platformization

Collaboration		Experimentation		Platformization	
Initial template of principles	Final template of principles	Initial template of principles	Final template of principles	Initial template of principles	Final template of principles
(including literature stream and source)	(match / edited match / no match / new principle)	(including literature stream and source)	(match / edited match / no match / new principle)	(including literature stream and source)	(match / edited match / no match / new principle)
Define a partner selection process Innovation ecosystems (Traitler et al., 2011; Wong et al., 2016)	Define a partner selection process (match)	Design an ecosystem value proposition Innovation ecosystems (Talmar et al., 2018)	Design a circular ecosystem value proposition (edited match)	Create a modular technological architecture with open interfaces Platform ecosystems (Gawer and Cusumano, 2014; Parker et al., 2016; Schreieck et al., 2016)	Create a modular technological architecture with open interfaces (match)
Involve new actors Innovation ecosystems (Guerrero et al., 2016; Rohrbeck et al., 2009; Russell and Smorodinskaya, 2018; Scuotto et al., 2016) Service ecosystems (Koskela-Huotari et al., 2016)	Involve new actors from different industries and sectors (edited match)	Reframe the meaning of resources Service ecosystems (Koskela-Huotari et al., 2016)	Reframe the meaning of resources (match)	Enable others to build and innovate on top of the platform Platform ecosystems (Baldwin and Clark, 2000; Ceccagnoli et al., 2012; Gawer and Cusumano, 2014; Huang et al., 2018; Parker et al., 2016; Scholten and Scholten, 2012; Schreieck et al., 2016)	Enable others to build and innovate on top of the platform (no match)
Establish and maintain trust Innovation ecosystems (Davis, 2016; Ritala et al., 2013; Russell and Smorodinskaya, 2018; Traitler et al., 2011)	Establish and maintain trust (match)	Map a minimum viable ecosystem Innovation ecosystems (Adner, 2012; Talmar et al., 2018)	Map a local minimum viable ecosystem (edited match)	Define platform openness Platform ecosystems (Boudreau, 2010; Parker and Van Alstyne, 2008; Schreieck et al., 2016; Zhong and Nieminen, 2015a)	Define platform openness (match)

>>>

TABLE 4.1 The initial and the final template of principles for collaboration, experimentation and platformization

Collaboration		Experimentation		Platformization	
Initial template of principles	Final template of principles	Initial template of principles	Final template of principles	Initial template of principles	Final template of principles
Get commitment and buy-in Innovation ecosystems (Adner, 2016; Nambisan and Baron, 2013; Sarasvathy, 2008)	Get commitment and buy-in (match)	Prototype and test the required cospecialized ecosystem assets Innovation ecosystems (Adner, 2012; Talmar et al., 2018)	Prototype the circular ecosystem assets (edited match)	Specify key boundary resources Platform ecosystems (Schreieck et al., 2016)	Specify key boundary resources (match)
Align individual and shared interests Innovation ecosystems (Emerson et al., 2011; Gottschalg and Zollo, 2007; Ritala et al., 2013; Russell and Smorodinskaya, 2018; Teece, 2007)	Align individual and shared interests (match)		Test the minimum viable ecosystem in a local experimentation space (new principle)	Decide upon pricing structures and platform control mechanisms Platform ecosystems (Gawer, 2014; Gawer and Cusumano, 2014; Scholten and Scholten, 2012; Schreieck et al., 2016)	Decide upon pricing structures and platform control mechanisms (no match)
Re-define actor roles and responsibilities Innovation ecosystems (Davis, 2016; Valkokari et al., 2016) Service ecosystems (Lusch & Nambisan 2017)	Re-define actor roles and responsibilities (match)		Get commitment from real customers early on (new principle)	Govern and manage data flows Platform ecosystems (Abella et al., 2017; Eckhardt et al., 2018; Scholten and Scholten, 2012; Zygiaris, 2013)	Govern and manage data flows (match)
Develop a decentralized and collaborative governance structure Innovation ecosystems (Emerson et al., 2011; Teece, 2007)	Develop a decentralized and collaborative governance structure (match)				

>>>

TOC

TABLE 4.1 The initial and the final template of principles for collaboration, experimentation and platformization

Collaboration		Experimentation		Platformization	
Initial template of principles	Final template of principles	Initial template of principles	Final template of principles	Initial template of principles	Final template of principles
Develop joint strategies and goals Innovation ecosystems (Emerson et al., 2011; Ritala et al., 2013; Russell and Smorodinskaya, 2018)	Develop joint strategies and goals (match)				
Ensure fair value capture among involved actors Innovation ecosystems (Leten et al., 2013; Ritala et al., 2013; Traitler et al., 2011) Platform ecosystems (Ceccagnoli et al., 2012)	Ensure fair value capture among involved actors (match)				

4.4.1 Circular ecosystem collaboration

4.4.1.1 Define a partner selection process

A partner selection process refers to how and how many partners can participate in a common project. Potential participants can be involved based on, for example, their stake in the project, existing relationships, proven R&D capabilities, unique technologies and solutions, cultural fit and similar values. Having a partner selection process ensures that there is a fit among the partners, which in turn ensures that the collaboration can function well over time. Partners in the case study were mostly selected based on existing networks and required technology capabilities. There is no evidence of partner selection criteria for cultural fit and similar values. As one interviewee states: *"I didn't know the partner's perspectives or interests. Whether there was a fit or not was a bit of a gamble."* The case data show a number of conflicts and disagreements due to different interests and values. This reinforces how important it is to secure a cultural fit and similar values in the partner selection process. Similar values appear to be especially important for a normative goal like a circular ecosystem.

4.4.1.2 Involve new actors from different industries and sectors

Ecosystem innovation can be initiated by bringing together new and previously unconnected actors, from business, research, policy and civil society. Involving new actors stimulates 'out-of-the-box' thinking and ensures that the participants approach a problem from multiple and un- recognized angles. In the case study, ten technology organizations have formed a consortium to jointly engage in circular ecosystem innovation. Many of these organizations have previously not worked together. The partners came from business, research and policy. Especially the involvement of policy and research organizations appears to be important for circular ecosystem innovation. While ecosystem innovation may be driven by organizations only, circular ecosystem innovation may often require a push from policy organizations, in this case trough financing mechanisms and the ability to involve and align different actors who would have otherwise not aligned their efforts. As one interviewee emphasized: *"if there was not this initial push and support from the government, these organizations would have never found and collaborated with each other.*

4.4.1.3 Establish and maintain trust

Trust is essential to foster inter-organizational collaboration. Inter- personal trust has at least three components: fulfilling obligations, be- having according to expectations, acting fairly. Establishing and maintaining trust is important to keep project partners motivated over time, and to ensure that they pursue similar strategies and goals. Some project participants expressed their perceived mistrust due to unfulfilled obligations, unexpected behavior and unfair treatment. This led to delays in delivering the expected contributions. However, it was also recognized that all participants eventually delivered their contributions, and that no partner left the consortium early. As one interviewee stated: *"in the end, everyone showed professionalism and a willingness to overcome conflicts and disagreements".* A main lesson here is that conflicts and disagreements are natural to the process, and that they need to be carefully resolved. Establishing and maintaining trust among partners is thus an important principle for circular ecosystem innovation.

4.4.1.4 Get commitment and buy-in

Getting commitment and buy-in from potential partners is important to ensure that initial project proposals receive enough back up to be pursued further. The initial commitment and buy-in in the case study was organized by the project founder who had a rough first idea and presented initial concepts to potential partners in the automotive industry and the financing body. Together with a first set of activated partners, the project founder drafted a joint project proposal. The financing body then agreed to make the funding available for the project. Getting the early commitment and buy-in from relevant actors is therefore an important principle for circular ecosystem innovation.

4.4.1.5 Align individual and shared interests

Aligning individual and shared interests ensures that the partners in a project work towards the same goals. Individual and shared interests in the case study were revealed through several conflicts. This slowed the progress and led to a partial unwillingness of some partners to stay engaged. One interviewee expressed his frustration about this: *"if everyone had stuck to what we agreed, then we wouldn't be discussing this anymore. If we acted as a team and presented us this way, then we would al- ready be much further."* Part of the misalignment between individual

and shared interests may have been due to the lack of a clear and shared vision for the project. Although the goal of the overall project was clear to everyone, there was no organized process to create a shared vision for the project. Being open about individual interests, and aligning them to- wards a shared vision is thus an important principle for circular ecosystem innovation.

4.4.1.6 Re-define actor roles and responsibilities

Roles refer to the activities and interactions performed to achieve an objective. They may overlap or conflict. There is a need to make sure that the participants understand and clarify their roles in a circular ecosystem innovation project. Clear roles can prevent misplaced expectations. They may change and therefore may need to be continuously re-defined. Roles relate to responsibilities, i.e. to what actors are expected to do and deliver as part of their role. There were several incidences of re-defined actor roles in the case study. The battery manufacturer, for example, changed its role from a seller of batteries to the co-developer and provider of an integrated battery management and ex- change system. Circular ecosystem innovation requires that the participants are willing and able to re-define their roles. Some interviewees expressed frustration over a lack of clarified responsibilities. Some partners had to take on activities that were previously not part of their role definition. As one interviewee reflected: *"some people assumed that someone else would do this."* Another stated that, *"because nobody wanted to do this, we had to do it."* The case confirmed that roles may change over time and therefore need to be continuously re-defined. Unexpected changes in the project process require that the participants reflect on their roles and that they are open to adapt them if needed. This appears to be especially important when the project has 'higher-order' goals like circularity, where it is not clear from the beginning how circularity will be achieved, and therefore what each actor will need to contribute, and what role each one will be able and willing to take on.

4.4.1.7 Develop a decentralized and collaborative governance structure

Decentralized decision-making structures bring practitioners closer to new technologies, the customer, and the market. This may refer to procedural decisions (e.g., defining work packages) and/or more substantive issues such as procedures for reaching agreements on the overall project direction. Several interviewees expressed that partners need to be viewed as 'equals' who contribute cospecialized assets, and that they *"cannot discipline each other"*. A partner constellation

therefore requires a clear governance structure. Most decisions were made in sub-working groups that reported back to the whole group during general assemblies of the consortium. Some interviewees missed an 'ecosystem coordinator', i.e. someone who oversees 'the big picture', both from a technology and a business model perspective. Such a coordinating role may come from inside or outside of the core project consortium, and may include tasks like mediating, coaching, moderating, motivating partners, and managing the combined work packages.

4.4.1.8 Develop joint circular strategies and goals

Developing joint strategies and goals is important to provide direction for the project that every partner agrees and can identify with. This requires an organized and co-creative process. Part of this process is about building shared meaning and a shared understanding of the higher-order, systemic problem and solution space. Shared meaning can be built, for example, by developing a common language. In the case study, the project goals and strategies were developed by the founder in correspondence with the financing body and some of the partners. One interviewee expressed this in terms of a metaphor: *"the deal is that we bake a cake together, and that every partner contributes some ingredients."* In the course of the project, it became clear that not every partner agreed with and/or identified with these joint strategies and goals. This led to a partial mis-alignment between the strategies of some organizations and those of the project. For example, one of the organizations wanted to leave the project, because its top management had decided to change its R&D direction. One interviewee observed *"very different interests and goals"* among some of the partners. Developing joint strategies and goals is therefore an important principle for circular ecosystem innovation. One interviewee put this in his words: *"it's really not about the technology, but a higher-order consciousness of participants that we can only do this together".* Realizing that circular strategies and goals can only be developed and achieved through joint activities is an important condition for this principle.

4.4.1.9 Ensure fair value capture among involved actors

Fair value capture is important to ensure that partners in a project stay committed and deliver the expected contributions on time. This can be assured through, for example, contractual agreements to define the value capture mechanisms of participating actors (i.e., which intellectual property and project results can be

owned and used by whom and how). It is also important to ensure 'early wins' can be achieved, to maintain commitment and trust. The project documents reveal detailed contractual agreements to ensure fair value capture among the actors. The documents clearly define the value capture mechanisms for the project deliverables. The deal among the partners was that everyone contributes a defined cospecialized technology asset, and that upon negotiation among all partners, every partner is legally allowed to make use of and market the entire system, under the condition that the terms are re-negotiated. Making clear how partners will benefit from a joint project, and establishing clear legal frameworks for value capture are thus important principles for circular ecosystem innovation.

4.4.2 Circular ecosystem experimentation

4.4.2.1 Design a circular ecosystem value proposition

An ecosystem value proposition describes the intended system-level value and customer-facing solution that arises from the joint contributions of multiple involved actors. Designing a circular ecosystem value proposition serves to communicate the goals of the project and the value that the project intends to create. For circular ecosystem innovation, this value proposition revolves around a system-level goal to decarbonize, dematerialize and regenerate a given ecosystem. The project has been developed around the ecosystem value proposition to develop *"a zero-emissions e-mobility system for cities"*, i.e. an ecosystem value proposition with a system-level goal related to environmental sustainability. While ecosystem innovation may propose any integrated customer facing solution, circular ecosystem innovation thus requires the designing of an ecosystem value proposition that integrates system-level goals for environmental sustainability.

4.4.2.2 Reframe the meaning of resources

Resources have an attached meaning. Ecosystem innovation may experiment with the reframing of what resources mean, and thereby open new possibilities for how to handle them. It is important to both break existing institutions (i.e. established norms about how something is framed), make new ones (new frames of how something could be seen), as well as maintain existing institutions, to make 'the

new' feel familiar and make it more acceptable. Experimenting with different ways of reframing resources is an important principle for circular ecosystem innovation. For example, the designer experimented with different ways of reframing the meaning of a car, from a big, feature-rich and powerful personal car, to a small, sufficiency-based, friendly, shareable and multi-purpose vehicle. This has not been an easy task and involved a compromise between the existing frame and the new one: *"the challenge is to both stick to the design brief, which focuses on saving resources wherever possible, and convince those partners who are fans of big and luxurious cars".*

4.4.2.3 Map a local minimum viable circular ecosystem

A minimum viable circular ecosystem is the smallest and most simple structure that can be formed to create and test an initial circular ecosystem value proposition. Mapping and analyzing different possible ecosystems has become an important principle to strategically manage innovation ecosystems. It provides an overview of the intended circular ecosystem value proposition, relevant actors and their business models, as well as actor risks and dependencies. The project participants have not mapped possible minimum viable ecosystems at the beginning of the project. This principle has also only recently been proposed in the literature. Future circular ecosystem projects can benefit from several initial mapping exercises to get an overview of possible minimum viable ecosystem constellations. The case study shows that it is useful to focus the mapping on a particular location or region where a minimum viable ecosystem can be tested later on. In the case study, the city of Munich served as such a location.

4.4.2.4 Prototype the circular ecosystem assets

An ecosystem prototype consists of cospecialized assets, that is, assets that maximize their value in combination with other assets (from other organizations and organizations). The assets in the case were co-designed towards an ecosystem prototype, according to several circular economy principles, like sufficiency *("what do we really need?"*), maximized use capacity (e.g., taxi during the day, postal service during the night), and the reusability of valuable components (2nd life for car batteries in households). Circular ecosystem innovation thus requires that assets are purposely designed according to these and other circularity principles. The case exemplifies how co-specialization of assets can enable circularity. For example,

having a vehicle with manual battery exchange only functions in conjunction with a battery exchange station and the software that predicts battery capacity and the fastest route to the next exchange station. This example supports the initial argument of this study: that circularity is a property of a system of actors and different contributions; it is an interplay of different elements that together lead a maximizing of resource efficiency and a minimizing of resource use, emissions, waste and pollution.

4.4.2.5 Test the minimum viable circular ecosystem in a local experimentation space

The case has shown that the minimum viable circular ecosystem can ideally be tested in a 'safe space', in which participants can experiment with different ecosystem configurations. The city of Munich collaborated with one project partner to loosen local regulation to provide a more flexible space for experimentation. Having these more open and free 'experimentation zones' appears to be an important condition for the successful testing of a minimum viable circular ecosystem. It can bring important insights for how the different cospecialized assets fit together and how they can be provided and used by different actors in the ecosystem.

4.4.2.6 Get commitment from real customers early on

Getting commitment from real customers early on is a crucial principle to ensure that the developed circular ecosystem value proposition is viable. Several interviewees expressed how important it would have been to involve customers early on and to develop the business next to the technology. While the participants conducted a market study at the beginning of the project, and tested several evolving versions of prototypes over time with different user groups, no real customer committed to it initially. For example, the system was intended for fleet operators, but no fleet operator was involved in the project. Whether fleet operators would really be willing to adopt this system was not tested. This was because there was no budget allocated to early customer development. This, in turn, had to with constraints of the co-financing governmental institution, which can legally support *"pre-competitive technology development"*, but is limited in its ability to directly intervene in markets.

4.4.3 Circular ecosystem platformization

4.4.3.1 Create a modular technological architecture with open interfaces

A modular technological architecture provides the basic structure of an online platform. It may contain virtual markets with editable and crowd-sourced software elements, as well as physical assets that form part of the offerings on a platform (e.g., cars for ride hailing services). Open interfaces refer to accessible and usable information to build, test and offer products and services that are complementary with a given platform. The case contains a technological architecture that enables the communication and connectivity among the mobility providers, operators, users, ad providers, cars, batteries, and battery exchange stations. It consists of an online platform for users and providers of mobility services. Users can book a car and providers can offer rides via a common platform. The 'backend' architecture enables operators to manage a car fleet and to share cars with other operators, depending on the excess capacity of the fleet outside of peak hours. Cars have 'multi-mode' functionality, e.g., they can be used as a taxi or as a logistics vehicle. The technological architecture enables this 'mode-switching' and thereby contributes to a decrease in the excess capacity of assets. For circular ecosystem innovation, the modular technological architecture can thus be designed in a way that contributes to higher usage rates of assets, and thereby potentially decrease the overall number of assets that is needed to 'do the job'.

4.4.3.2 Enable others to build and innovate on top of the platform

Complementors and/or end users need to be able to build, innovate and offer products and services on top of a platform. In a strict sense, the platform design in the case does not enable others to build and innovate on top of its core architecture. The platform serves to offer ride services, but not to build additional products and services on top of the platform. In that sense, one can argue that it is not a platform ecosystem, but a platform. Moving from a platform to a platform ecosystem would require the architecture to be designed in a way that the contributions of others increase platform value, which in turn increases platform usage. For example, opening the platform to other types of circular and resource-efficient mobility assets that can be contributed by complementors. Enabling others to build on top of the platform is thus a potentially relevant principle for circular ecosystem innovation, but was not realized in the project.

4.4.3.3 Define platform openness

Platform openness refers to how easy it is for external parties to use, develop and commercialize a technology. Platforms can be opened by granting access to and giving up control over technology development. The more open the platform, the more innovation. But more openness may also lead to more competition and fewer possibilities for platform owners to appropriate rents. Platform openness is related to the previous principle (4.3.2.). In the case, the technology development, for example, was closed and not open to external and potential complementors. This was on purpose because of the clear design goal to have a set of cospecialized ecosystem assets that can provide mobility services with maximized resource efficiency and minimized excess capacity. The case does not allow conclusions about how platform openness influences the circularity potential.

4.4.3.4 Specify key boundary resources

Boundary resources may refer to tools, information, tutorials or rules that specify and govern how others can build and innovate on top of a platform. Examples include software tools (e.g., Application Programming Interfaces), documentation, or types of data. The platform developers developed an API that can let other mobility assets connect to the platform (e.g. bikes), but this has not been part of the core platform architecture of the project. Boundary resources have also included hardware assets (e.g. the battery exchange station, energy production assets, and vehicles), that let other actors contribute services (e.g. battery management, energy provision, mode switching). Specifying key boundary resources is thus an important principle for circular ecosystem innovation.

4.4.3.5 Decide upon pricing structures and platform control mechanisms

Fair pricing structures incentivize complementors to innovate for the platform, rather than against it. Control mechanisms may refer to market-based (e.g. reputation systems), co-regulatory (proprietary tools and interfaces with fixed development guidelines), restrictive (e.g. automated entrance assessment methods), sanctioning (e.g. removal of an offering if it does not comply with the rules), motivational (e.g. development support) and informative control (e.g. shared information on user behavior). This has not been raised or addressed in the case because of the early

stage of the project. The case data thus do not provide enough information to make a statement about the relevance of this principle for circular ecosystem innovation. However, we posit that a careful design of pricing structures can incentivize sustainable behavior change, for example through price differentiation based on the environmental impact of a choice on a platform. This makes this principle relevant for circular ecosystem innovation.

4.4.3.6 Govern and manage data flows

Data can be used to enable participation and value co-creation among complementors and users. Governing and managing data flows is an important principle for platform design. It can ensure that the collected data can be analyzed to create value and maximize the use capacity of circulating assets. Ideally, data can be - upon careful ethical reflection - automatically collected, analyzed and used to inform better decision-making. Inter-organizational data flows and overall system connectivity have been a core part of the case, i.e. how and what kind of data is supposed to flow, for example, across the vehicles, battery systems, battery exchange stations and energy production plants. Data flows enable better information access on the use, condition and location of the ecosystem assets and thus contribute to a more efficient management of their usage and circularity. Governing and managing data flows is therefore an important principle for circular ecosystem innovation.

4.5 Discussion and conclusion

This study proposes a set of principles for circular ecosystem innovation. This is motivated by the need for more systemic innovation approaches for a circular economy, and the fact that business and innovation ecosystems have rarely been framed around circular economy or sustainability issues. Based on a matching of principles for ecosystem innovation from the literature with data from a circular ecosystem case study, we have developed an initial set of principles for circular ecosystem innovation. The case study served to understand the relevance of the principles we found from the literature for circular oriented innovation, and helped to identify three important groups of principles: collaboration, experimentation

and platformization. With this research, we thus add an ecosystem lens to existing circular product (e.g., Bakker et al., 2014) and circular business model design perspectives (e.g., Lewandowski, 2016; Linder and Williander, 2015), and move the ecosystem discourse from the business and management literature (e.g. Jacobides et al., 2018) to other relevant fields like circular oriented innovation. This is an important step to enable organizations to move beyond a traditional 'modus operandi' that is used to develop *one* product, *one* service, within the boundaries of *one* organization or in dyadic relationships between organizations and suppliers or organizations and customers (R. Adams et al., 2016; Ceschin and Gaziulusoy, 2016).

We purposely focused the research output of this study on relevant principles, i.e. solution-oriented guidelines (Romme and Reymen, 2018) that are actionable in practice. This choice was made because sustainable innovation research needs more attention on the implementation of more sustainable and circular solutions (Bocken et al., 2012; Rashid et al., 2008). To the emerging literature on circular business experimentation (see for example Antikainen et al., 2017; Bocken et al., 2018; Evans et al., 2017), we contribute and establish the relevance of ecosystem experimentation principles that so far have been 'hidden behind the doors' of undiscovered literature streams. For example, a review of the literature on service ecosystems has revealed that organizations can experiment with the reframing of resources (Koskela-Huotari et al., 2016). Through the case study research, we have shown that these and other principles from the literature are relevant and useful for innovating towards circularity. Furthermore, to the emerging literature on collaboration in a circular economy (see for example Brown et al., 2019; Ghisellini et al., 2016; Kraaijenhagen et al., 2016), we add a set of recommended principles from the ecosystem literatures and validate their usefulness for circular oriented innovation. Regarding platformization, we add a distinct set of principles that focus on 'how to' design platforms that contribute to circularity. While previous research has investigated the potential positive (e.g., increased shared use of assets) and negative (e.g., increased trade volumes and power-consuming data centers) aspects of sharing platforms (e.g., Boons and Bocken, 2017; Frenken and Schor, 2017), prescriptive knowledge on how to approach sustainable and circular platform innovation have so far been lacking, except for a few initial attempts (see for example Konietzko et al., 2019).

The findings from this study provide a research agenda for action research to test and develop success factors for the recommended principles in different contexts than in the one that is investigated in this study. Further research may re-organize and re-name the principles, and complement them with more and other types. In that sense, circular ecosystem innovation principles are 'moving targets'. In addition, the principles proposed in this study are limited by their clear focus on a

defined and relevant literature base (business ecosystem literatures) and a single circular ecosystem case. We are aware that there are many other literature streams that contain potentially useful principles, and encourage future research to build on and complement the proposed principles by contributing reviews and empirical investigations from, for example, other collaborative innovation literatures like open innovation in the context of a circular economy. The circular economy has the potential to mitigate climate change and resource scarcity. Due to the urgency to act, it is important to focus further research efforts on an equitable and just implementation process for circular strategies. The present study is intended to contribute to this endeavor.

5 Circular business model experimentation

Demystifying assumptions

Publication:
Konietzko, J.; Baldassarre, B.; Brown, P.; Bocken, N.; Hultink, E.J. Circular business model experimentation: demystifying assumptions. J. Clean. Prod. 2020

ABSTRACT Circular business model experiments may help organizations transition towards a circular economy. Little is known about how the participants of experimentation – entrepreneurs, intrapreneurs, innovation managers – develop and test their assumptions during the experimentation process to achieve more circular outcomes. Using a design-science approach, we investigate this process and develop principles to improve it. This is done during three workshops in different contexts: an innovation festival with 14 early-stage circular startups, a workshop with a health technology incumbent, and a workshop with six growth-oriented startups. We find that analyzing their available means – what they find important and prefer to happen (part of their identity), what they know (their skills and knowledge), and whom they know (their social network) – helps to understand how the participants develop and test their assumptions. We show how the mindset and awareness of the participants impact how much attention they pay to the circularity potential of their envisioned circular business models. Based on these insights, we propose a set of principles to prepare the innovation participants for experimentation, and to increase their ability to reflect on their circularity assumptions. Future research is needed to further grow our understanding of the types of principles that can guide meaningful experimentations towards a circular economy.

KEYWORDS Business model, Business model innovation, Circular economy, Lean Startup, Effectuation, Experimentation, Sustainability

5.1 Introduction

Organizations are in need of methods and approaches to innovate their business models towards a circular economy (Blomsma and Brennan, 2017). In a circular economy, organizations maximize the value of the material resources and minimize the overall resource use, waste, pollution and emissions that are associated with their business activities (Geissdoerfer et al., 2017). Designing and conducting business model experiments – small-scale and cost-effective ways to test the underlying theories and hypotheses about new business models – has become a promising approach to innovate towards a circular economy (Antikainen et al., 2017a; Bocken et al., 2019; Weissbrod and Bocken, 2017).

Most existing research on circular business model experimentation has used approaches that operationalize the 'The Lean Startup' (Ries, 2011), a popular approach in entrepreneurship practice (Antikainen et al., 2017a; Bocken et al., 2019; Bocken et al., 2017; Bocken et al., 2018; Weissbrod and Bocken, 2017). This research has shown that experimentation can help speed up action and decision-making towards sustainability in organizations. It has also revealed that the decision-making process during experimentation may be more opportunistic and messy than originally intended (Bocken et al., 2017). Participants often make intuitive judgements and decisions (Foss et al., 2019), rather than rely on the decision criteria of the experiment designs (Bocken et al., 2019). It also appears that the term experimentation may lead participants to adopt a more 'scientific' language, but not necessarily a more rigorous approach to innovation (Weissbrod and Bocken, 2017). In addition, collecting and analyzing data during experimentation may result in unexpected events and surprises that require fast changes of the experiment designs (Antikainen et al., 2017b). Some have suggested that approaches like The Lean Startup fail to guide how the participants can develop and test their hypotheses; that is, how they develop the underlying theory of value about their proposed business models (Felin et al., 2019). Moreover, it appears that there is a gap between the intended formality of experimentation approaches like The Lean Startup (Ries, 2011), and the opportunistic and intuitive nature of how decisions are made during experimentation (Felin et al., 2019; Foss et al., 2019; Sarasvathy, 2001).

The goal of this study is two-fold: first, we aim to better understand how the participants develop and test their assumptions during circular business model experimentation; second, we use this understanding to propose a set of principles that can help improve the process. This is guided by two research questions: *How do the participants develop and test their assumptions during circular business model*

experimentation? How can a better understanding of this help improve the process? Through a design-science approach for entrepreneurship research (Romme and Reymen, 2018), we design and validate contexts and principles for circular business model experimentation. This is done in the course of three different workshops: a circular oriented innovation event with 14 novice student entrepreneurs; an incumbent from the health technology sector and nine participants; and six growth-oriented startups as part of a startup program, with twelve participants.

We find that analyzing their available means – what they find important and prefer to happen (part of their identity), what they know (their skills and knowledge), and whom they know (their social network) – helps to understand how the participants develop and test their assumptions during experimentation. These available means (Sarasvathy, 2001) influence what they focus on – whether they focus on, for example, the desirability of a value proposition, or the contribution of an envisioned business model to a circular economy. Based on these insights, we propose a set of principles to improve the process. This includes, for instance, the importance of recognizing the available means of the participants, and to prepare them if these means are not conducive to more circular outcomes. Future research can use and further develop these principles to better understand how to experiment with new business models towards a circular economy.

5.2 Conceptual background

In this section, we introduce the key concepts of this study: the business model, business model experiments, and circular business model experiments. This leads us to identify the research gap and the intended contribution.

5.2.1 Business model

A business model helps to describe, investigate, and design how organizations do business (Baden-Fuller and Morgan, 2010; Magretta, 2002). It contains three essential elements: the value proposition (what an organization offers and to whom), value creation and delivery (how it creates and delivers the offering), and value capture (how it earns money and other forms of value with it) (Bocken and Short,

2016; Richardson, 2008). From a design perspective, these three elements can be desirable, feasible and viable (Brown, 2008; Calabretta et al., 2016). Desirability is a property of the value proposition: how desirable a value proposition is to, for example, intended users, customers or investors. Feasibility is a property of value creation and delivery: how feasible it is to organize the needed activities and resources to create and deliver the value proposition. Viability is a property of value capture: how the business model can generate enough revenue to sustain the cost of creating and delivering the value proposition (Figure 5.1) (based on Richardson 2008; Bocken and Short 2016; Calabretta et al. 2016). We refer to the properties desirability, feasibility and viability because they are useful in the context of experimentation, i.e. they can be tested. For example, you can test the desirability of a value proposition, or the viability of a business model, to inform the right of course of action during the design process (Simon, 1996).

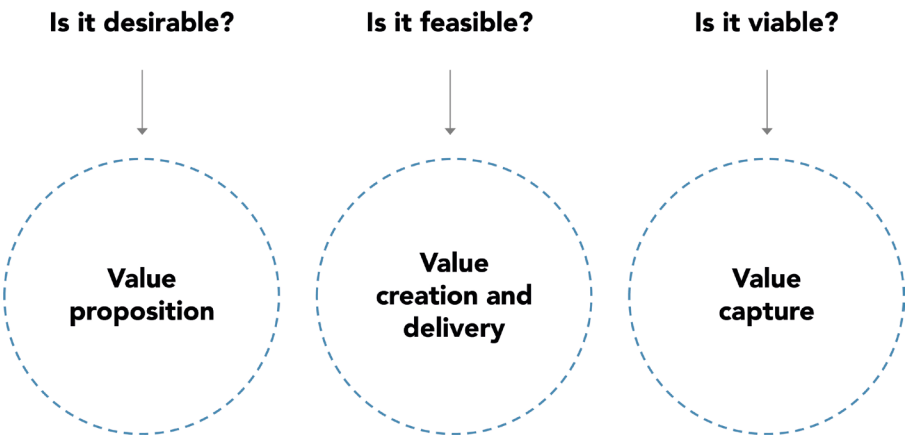


FIG. 5.1 The business model

5.2.2 Business model experiments

Business model experiments can be defined as small-scale and cost-effective ways to test the underlying theories and hypotheses about the desirability, feasibility and viability of a new business model (based on Calabretta et al., 2016; Camuffo et al., 2019; Osterwalder et al., 2014; Ries, 2011). Most business model experiments with start-ups and established business can be characterized as 'quasi-experiments'

(Cook and Campbell, 1979), as they cannot be easily controlled in a business environment (Bocken et al., 2018; Weissbrod & Bocken, 2017). Experiments influence the experience and perception of entrepreneurs and organizations, and help to form more accurate beliefs and expectations about the 'right' course of action (Felin and Zenger, 2009). An experimental approach to business modelling makes it more likely that entrepreneurs scrutinize the profitability of their ideas, that they pivot faster, and that they increase their chances of high returns (Camuffo et al., 2019). Business model experiments are important because from the outset, the probabilities of success are not known (Knight, 1921), and the potential outcome is unclear (Kerr et al., 2014). These conditions characterize business modelling as a highly uncertain process. Investors therefore tend to value experimentation, because they enable them to fund startups and new business models in stages. For each stage, experiments have to reveal new data that inform the quality and likely profitability of the new business model. The benefit of experimentation in a situation of high uncertainty is two-fold: one can assess projects without having to invest large amounts of money upfront, and pursue projects without having to go for an all-or-nothing bet (Kerr et al., 2014).

One of the most popular approaches for business model experimentation is The Lean Startup (Blank, 2013; Felin et al., 2019; Osterwalder et al., 2014; Ries, 2011). This approach proposes a formalized build-measure-learn cycle to conduct business model experiments: *build* a 'minimum viable product', *measure* how interested potential customers are in this product, and use the results to *learn* whether an idea may work or not (Ries, 2011). This is often done by using workshop material like 'experiment cards' that define the hypothesis, the test to verify the hypothesis, the metric to measure success, and the decision criteria to further pursue an idea (Osterwalder et al., 2014). Examples of such experiments include conversational interviews through a quasi-ethnographic approach with a potential partner, or online A/B tests, where two landing pages with different value propositions are tested to understand which element of the value proposition may gain more traction among potential customers (Camuffo et al., 2019; Osterwalder et al., 2014).

A further important design approach to business model experimentation is effectuation (Sarasvathy, 2008). Effectuation is a theory of entrepreneurship that explains how expert entrepreneurs develop successful ventures. According to this theory, entrepreneurs start with a given set of means (what they find important and prefer to happen, what they know, and whom they know) to prototype new business models. These prototypes are shaped through continuous negotiations to get the commitment and buy-in from external parties (Sarasvathy, 2008). Effectuation poses that an expert entrepreneur follows four principles in this process of new venture creation: 1) An entrepreneur only invests what she can afford to lose. This principle

reflects an iterative and step-by-step approach, which is similar to The Lean Startup; 2) she seeks strategic alliances that provide commitment and buy-in for her ideas. This stresses the importance of securing commitment and is also similar to the Lean Startup approach, where direct payments or sign-ups are possible signs of commitment of an experiment; 3) she captures value from unexpected situations. This principle emphasizes the spontaneous and messy nature of the entrepreneurial process; 4) she controls an unpredictable future by building a safe network of supporting stakeholders. This highlights the need for a strong social network to sustain and grow the business (Sarasvathy, 2001). Based on these principles, we pose that effectuation can be seen as an intuitive and less formalized approach to experimentation (Bocken and Antikainen, 2019).

5.2.3 Circular business model experiments and the need for an ecosystem perspective

Business model experiments have been increasingly conducted in the context of a circular economy. Most of the existing research on circular business model experimentation has used The Lean Startup as an underlying approach (see, for example, Antikainen et al., 2017b; Bocken et al., 2018; Weissbrod and Bocken, 2017). A circular economy seeks to maximize the value of products, components and material over time, and minimize the overall resource use, associated emissions, waste and pollution (Geissdoerfer et al., 2017). Organizations can experiment with four inter-related circular strategies (Bocken and Antikainen, 2019): they can narrow (use less material and energy during design, production, use and end-of-life), slow (use products and components longer), close (use wasted products, components and materials again) and regenerate (use non-toxic materials, renewable energy and manage critical ecosystem services) the material and energy flows associated with their business activities (Figure 5.2) (Konietzko et al., 2020a). Organizations can use these strategies to develop new circular business models, and then test how these business models can contribute to circularity – in parallel to how desirable, feasible and viable they are. The goal is to develop new business models that provide superior customer value, and that help to maximize the value of products, components and materials over time, and to minimize the overall associated resource use, waste, emissions and pollution (Bocken and Antikainen, 2019).

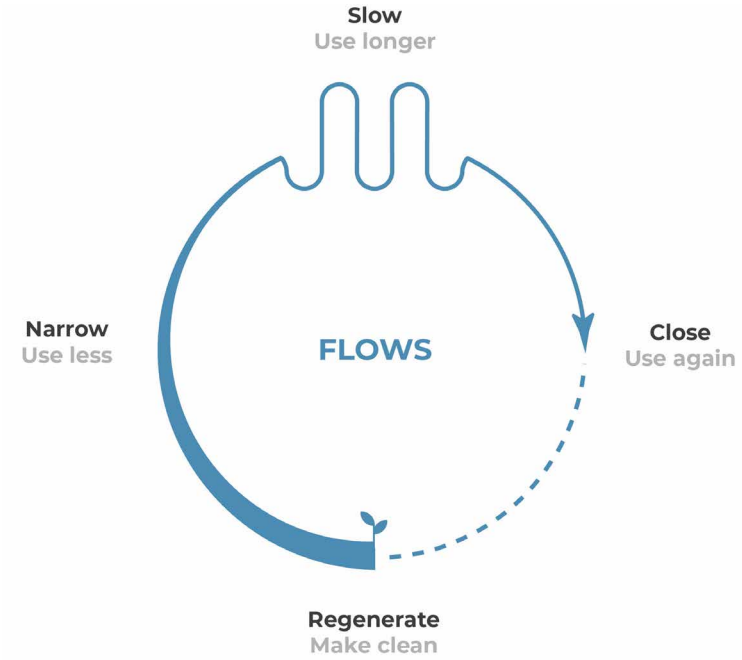


FIG. 5.2 Circular strategies: narrow, slow, close and regenerate material and energy flows

The existing research on this topic has shown that circular business model experimentation can help stimulate innovation and action towards circularity in organizations. It has the potential to promote an iterative 'getting things done' attitude among the participants (Bocken et al., 2017). On a spectrum of what can be done to learn about new business models, experiments are situated between fast learning (e.g., paper sketches, interviews) and slow learning (e.g., business plans, pilots, market studies) (Bocken and Antikainen, 2019). The success of circular business model experiments may depend on the following: a careful selection of the participants (Bocken et al., 2017), internal buy-in from staff and top level management, experimentation capabilities within the organization, as well as commitment from relevant partners who can develop complementary products and services (Antikainen et al., 2017b; Weissbrod and Bocken, 2017). It is also necessary to incorporate 'circularity checks', to make sure that experimentation is geared towards higher circularity (Bocken et al., 2018).

These ‘circularity checks’ are especially important. This is because circularity – a situation in which the value of products, components and materials is maximized, and in which the overall resource use, waste, emissions and pollution are minimized – is a property of a higher-order system, rather than a property of an individual product or business model (Konietzko et al., 2020a). For example, a car may be made lighter and more durable. But if the overall number of cars on the road increases and the cars stand idle 95 % of the time, then the overall resource use, waste and emissions are not minimized. Providing a car sharing service, that is, changing the business model, may decrease the overall number of cars on the road. But if the cars are powered with fossil fuels and still have an idle time of 60 %, then the overall resource use, emissions and waste are not minimized. Instead of focusing on products and business models only, circularity thus needs to be approached from an ecosystem perspective.

From a circular ecosystem perspective, an organization can experiment with a set of complementary products, services and business models (Konietzko et al., 2020b). For instance, to maximize the capacity use of cars, a car sharing provider may try and connect business-to-business fleet operators that have previously had their own fleets. The same cars can also be made accessible for end users through a joint car sharing platform, as well as for the staff of the involved companies through a corporate car sharing program. The car sharing provider can then work together with a local energy provider and make sure the cars are fueled with renewable energy. The batteries in these cars, once they are below a certain quality threshold, can then be installed in office spaces to provide heating and thereby prolong their useful lives. As this example illustrates, several different actors need to be activated and aligned to jointly contribute to circularity as a collective outcome.

Due to the complexity of this collaborative and uncertain process, understanding how circularity can be achieved is a major challenge (Brown et al., 2019). It is therefore important that the innovation participants develop accurate assumptions about the circularity potential of their envisioned business models. In other words, they need to develop a critical and reflective mindset, not only with regards to how desirable something is for the user, but also with regards to the circularity of their proposed circular business models. To develop such a mindset, it is first necessary to understand how the participants develop and test their assumptions during experimentation – to then see how this process can be organized to achieve more circular outcomes.

5.2.4 Research gap and contribution

Previous research on circular business model experimentation has found that structured experimentation may often be more messy and opportunistic than originally intended (Bocken et al., 2017). There seems to be a gap between the intended formality of quasi-experimental approaches like The Lean Startup and the intuitive and opportunistic nature of judgements during experimentation (Felin et al., 2019; Foss et al., 2019). In particular, it is not clear how the participants build their hypotheses and underlying theories of value about the possible desirability, viability, feasibility of their envisioned circular business models, as well as their contribution to circularity (Felin et al., 2019). Our study addresses this gap about the process of developing and testing assumptions during circular business model experimentation. It is important to better understand this, because it influences the circularity outcomes of the envisioned business models. In this study, we therefore want to better understand how the participants develop and test their assumptions during circular business model experimentation; and to use this understanding to develop principles that can help improve it.

5.3 Method

This study applies a design science framework for entrepreneurship research (Romme and Reymen, 2018) to research how the participants develop and test their assumptions during circular business model experimentation (Figure 5.3). The purpose of the framework is to develop knowledge that is both theoretically sound and practically useful (Denyer et al., 2008; Van de Ven, 2007). The research output from this study is a better understanding of how the participants develop and test their assumptions during this process, and a set of principles to improve it. The framework serves to specify how to design and validate this research output within a continuous research cycle: how to create and evaluate (together: design), and how to generalize and justify it (together: validation). It is important to note that these four steps are complementary and researchers may jump from one step to another.

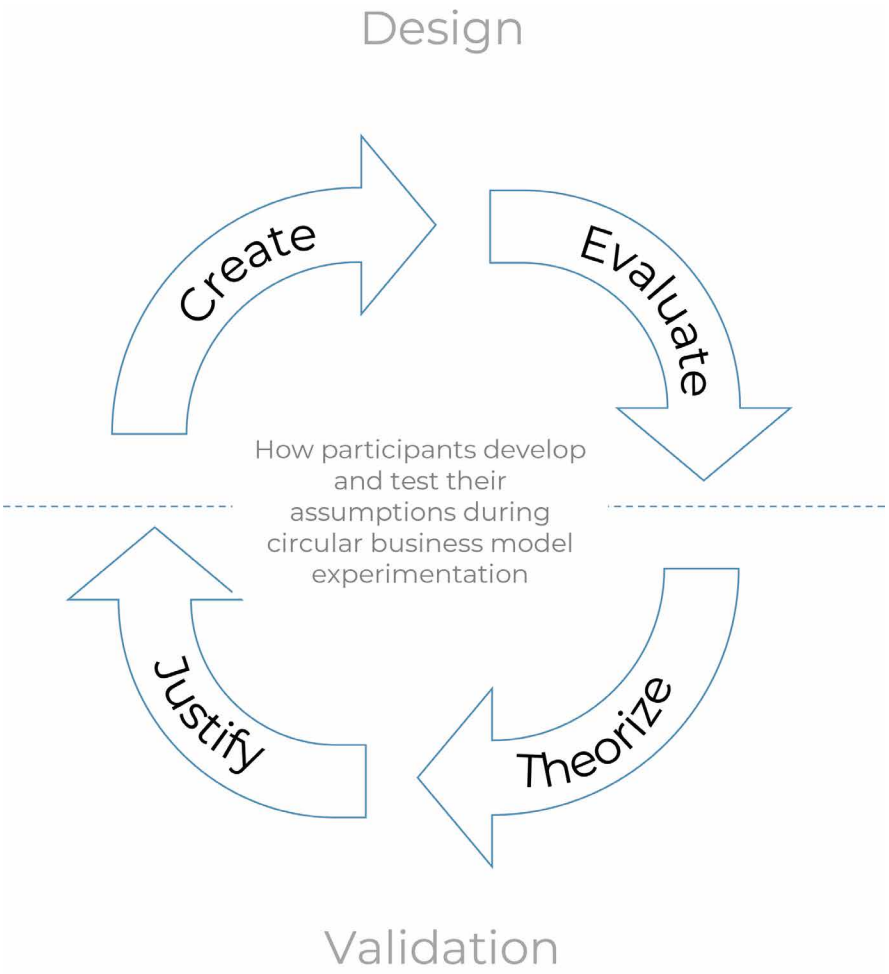


FIG. 5.3 A framework to design and research workshop formats for circular business model experiments (based on Romme and Reymen, 2018)

5.3.1 Design and validate the contexts of experimentation

The first step of the study is to design and validate the contexts of circular business model experimentation. This is done through three workshops. Each workshop represents a different context of experimentation: one with sustainability-minded novice entrepreneurs, one with an incumbent organization that communicates ambitions to innovate towards a circular economy, and one with more experienced and sustainability-minded entrepreneurs. Each one in turn:

TOC

1 The first workshop was created for a ten-day innovation event for the circular economy in the North of The Netherlands (event name: DORP). The event hosted 14 early-stage start-up ideas for a circular economy, posed by novice entrepreneurs, and around 70 participants (most of them master students with design or engineering backgrounds) who formed groups around the 14 ideas. Examples of the startups include two architects who developed a modular furniture set that can be playfully turned into twelve different furniture types (e.g., armchair, coffee table, bench, office table or display); a start-up that has developed packaging material based on wood from certified forests in Sweden; a startup that develops a service model to replace disposable plates and cutlery with reusable ones; an organization that turns old, otherwise wasted bread into beverages.

2 The second workshop was created for nine participants from a Dutch incumbent in the health technology sector. The goal of the company is to become a circular economy pioneer and it has a defined circular economy strategy that needs to be implemented by the different sections of its business portfolio. The participants of the workshop focused on a business section that sought to turn a consumer product from a sales into a product-as-a-service business model.

3 The third workshop was created for 12 participants from six circular oriented startups during an accelerator program of the Impact Hub in Zurich, Switzerland. Examples of these startups include an organization that rescues left-over yields from farm lands and turns them into a vegetable box subscription, an organization that provides baby clothing as a service, and an online platform where users can share everyday goods.

5.3.2 Design and validate principles for experimentation

The first set of principles, applied within a workshop format, was designed for and validated during a ten-day innovation event for the circular economy in the North of The Netherlands. The initial set of principles was derived from the business literature and based on what has been used in earlier research on circular business model experimentation. The principles included: 1) formulate the assumptions you have about how and why an envisioned business model may work in reality (Ries, 2011), 2) test your assumptions early outside of your organization's boundaries, rather than plan thoroughly 'at the desk' (Blank, 2013), 3) iterate fast and several times through the build-measure-learn cycle (Ries, 2011). These principles were instantiated in the form of a list of possible test methods and instructions (Table 5.1) (retrieved from Schuit et al. 2017; Bocken et al. 2018; Ries 2011; Osterwalder et al. 2014), as well as test cards to formulate assumptions and a validation graph to prioritize the tests (Figure 5.4) (based on Osterwalder et al., 2014).

TABLE 5.1 List of possible tests that was available for the first workshop (retrieved from Schuit et al. 2017; Bocken et al. 2018; Ries 2011; Osterwalder et al. 2014)

Method	Instruction
Brainstorming	Get a multi-disciplinary team and perspectives from outside the company and sit together to brainstorm about the assumption
Conversational interview	Interview the person of interest to learn from them
Online A/B test; split-test experiments	Get budget for ad-campaign and a content-writer for ads, write ads and launch them on e.g. Facebook, Google, etc. Make different versions to test different assumptions
Booklet interview	Make a product/service booklet and hand it to a potential customer to get feedback
Ethnographic observation	Get into the field where your customer/user/partner is and observe what they do and how they do things
Creative session with users	Invite users/customers/partners who are able and willing to discuss openly to have a creative session about the problem/potential solution
Moderated online discussion with community members	Find an online forum about your problem and learn from posts, start a discussion about the learning you are trying to gain
Co-create session with stakeholders	Find a location and schedule a meet-up with relevant stakeholders to co-create a solution
Rapid service prototyping/ minimum viable product	Make a first physical and/or digital prototype (e.g. paper mock-up, web landing page, cardboard mock-up), get in front of customers and learn from their reactions
Landing page with Video + option to sign up	Make a short video where you pitch your idea and create a landing page with a call to action (e.g. sign up for the newsletter, early ordering option for product, etc.)
Concierge MVP: "fake it until you make it"	Try to fake the product/service through human actions, help the customer out right away without having any product, improvise
Field experiment	Find a test ground (e.g. a festival), user group, and create an experiment set-up
Wizard of Oz testing	Take humans who can provide the service that you want to provide instead of machines to gain learning

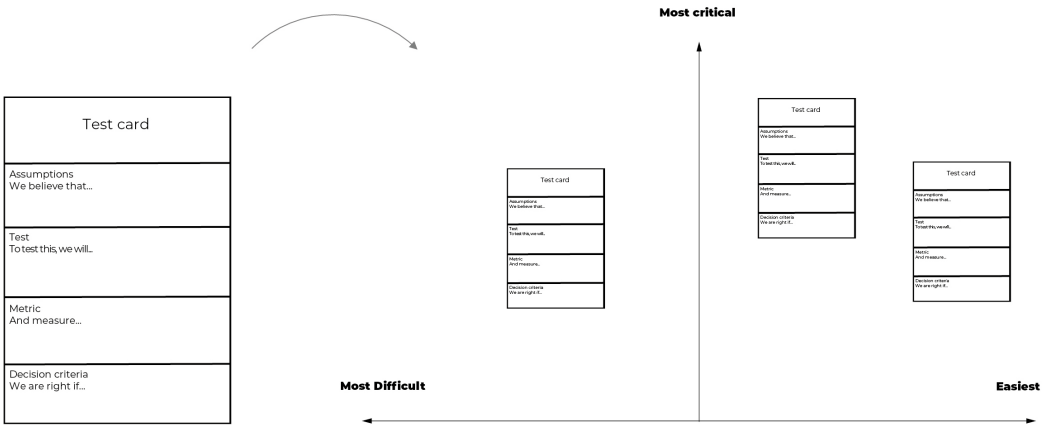


FIG. 5.4 Initial test cards and the validation graph. Based on Osterwalder et al. (2014)

TOC

During the event, the principles were presented in 30 minutes to the participants. The presentation triggered the group to discuss and reflect on their envisioned business models in terms of assumptions. Questions we discussed included: *"what would need to be true for your ideas to work in reality?"; "What are your assumptions?"* We then went through the test cards and explained how the participants could use them to develop and test their assumptions and define tests, metrics and decision criteria. We also introduced the list of tests they could do and discussed some examples. The validation graph was presented as a way to plot and prioritize the test cards according to what they would perceive as easiest and most critical to test. After the presentation, they spread out into groups to use the provided material in a two-hour workshop session.

5.3.2.1 Data collection

In the course of the three workshops, we collected different types of data. During the first workshop, we conducted semi-structured interviews (see Appendix C1 for an overview of the interview questions we asked) (Patton, 2002), made notes to capture observations about the use of the workshop material, made photos of the filled material and followed up with some of the participants later on to see what experiments the participants eventually ran, and what they learned from them. In the second and third workshops, we made notes during the workshops, took photos of the filled-in material and content from post-its, documented discussions among the researchers about the workshop afterwards, and for the third workshop collected a filled-in survey half a year later about the progress and activities since the workshop. Furthermore, each workshop was evaluated by collecting and analyzing data on its user acceptance. This was measured in terms of its ease-of-use and perceived usefulness (Davis, 1989). The participants filled in feedback forms after each session (Appendix C2). The form stated the intended purpose of the workshop (first version: *"understand the assumptions underlying a business idea, and to decide how to test them, and what to test first"*) and then posed two statements: *"The material is useful to address the stated purpose above."* and *"The material is easy to use."* Each statement could be rated with a Likert scale from 1 to 7 (1= fully disagree, 7=fully agree, after the first round we adapted this to 1-5). We also encouraged the participants to explain their rating through written feedback. The results were used to validate the ease-of-use and usefulness of the principles that we proposed for the workshops. Table 5.2 provides an overview of the collected data during each of the three workshops.

TABLE 5.2 List of collected data from the three workshops

Collected data	Total length/amount of data
First workshop	
Feedback forms	35 filled in forms
Audio/video recorded session	115 minutes
Observations from researchers	145 minutes/4 pages
One interview after session about how easy to use the session materials were (10 minutes each)	60 minutes
Discussions among researchers about the session	60 minutes/two pages
Filled-in test cards	8 test cards
One interview during the testing	55 minutes
Observations from researcher during testing	120 minutes/4 pages
One interview after the testing per group	40 minutes
Second workshop	
Feedback forms	9 filled in forms
Photos from post-its and generated ideas and strategies	22 photos
Observations from researchers in the form of notes	180 minutes, one page summary
Discussions among researchers about the session	30 minutes, one page summary
Filled-in workshop material	9 filled in templates
Third workshop	
Feedback forms	6 filled in forms
Observations from researcher in the form of notes	180 minutes, one page summary
Filled-in workshop material	6 filled in templates
Company survey after half a year	6 filled in surveys

5.3.2.2 Data analysis

The data was coded using a mix of descriptive (describe what is being said), In Vivo (which uses the actual language used by participants and reflects the emotionality of the situation) and process coding (observing actions performed by the participants) (Saldaña, 2013). We coded the data according to the three available means of an effectual decision-making logic (Sarasvathy, 2001): what they find important (part of their identity), what they know (their skills and knowledge), and whom they know (their social network). The codes were developed through an iterative coding process that revealed how these available means influenced how the participants developed and tested their assumptions. For example, one important code for the category 'what they find important' is 'the business model property', sub-divided into the codes desirability, viability and feasibility. This coding enabled us to analyze what

business model property the participants found important to investigate. Figure 5.5 shows the coding structure that resulted from the data analysis. The identified codes within the three categories are not meant to be exhaustive. Rather, they show important elements that had an influence on how the participants developed and tested their assumptions throughout the three workshops. The resulting coding structure informs the theoretical research output of this study, which is detailed in the results section 4.1.

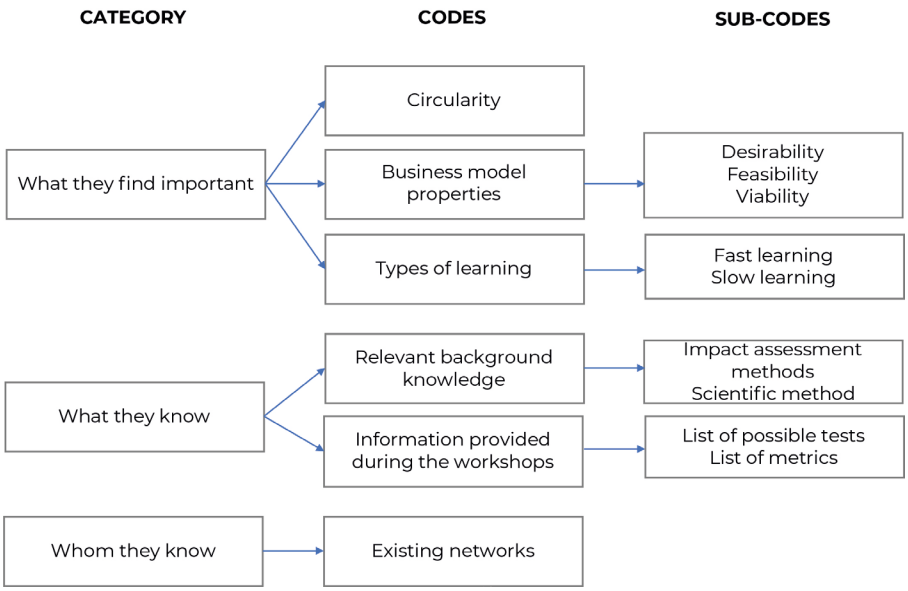


FIG. 5.5 The resulting coding structure from the data analysis

In addition to the coding structure, each workshop was evaluated through the feedback forms. We did this to ensure the practical relevance of the principles that we applied throughout this research. The feedback form gave us insights on the usefulness and ease of use of the proposed principles, and served to develop an evaluated set of principles as a practical research output of this study. This output is detailed in the results sections 4.2.

TOC

5.4 Results

We present the results in terms of theoretical and practical relevance. The first section (4.1.) presents the theoretical results that address the first research question: how the participants develop and test their assumptions during circular business model experimentation. The second section (4.2.) presents the practical outcomes, in the form of principles, that address the second question: how a better understanding of this can help improve the process.

5.4.1 How the participants develop and test their assumptions

We find that the participants develop and test their assumptions in terms of what they need to find out about their envisioned business models, and how they can find it out. The decision-making logic that underlies this process is influenced by their available means: what they find important (part of their identity), what they know (their skills and knowledge), and whom they know (their social network).

5.4.1.1 What they find important

The participants decided what they needed to find out and how they could find it out based on what they found important. This related to, for example, if they found *circularity* important to investigate, the *business model property* (desirability, feasibility, viability), or if they prefer *fast and/or slow learning*.

Circularity: Across all three workshops, experimenting with and investigating circularity was not considered most important. This was in spite of the fact that the workshops were about developing business models for a circular economy. In the first workshop, when prompted, the participants found it difficult to pinpoint which sustainability problem they were trying to address. They stated: *"We are assuming it is more sustainable than current offers"; "it's not crucial right now"*. In the second workshop, circularity was defined by the whole organization under the term 'circular revenues'. A product-as-a-service model, for example, would count as 'circular revenues'. When asked to reflect on why product-as-a-service models were circular, the participants noted down: *"subscription enables refurbishment, personalized offering (buy only what you need), access over ownership"*; *"obvious"*;

"first step to service concept, investigate need for update and refurbishment"; *"we remain the owner, closed loop logistics, reusing basic materials, owning materials"*; *"service model, we own the product".* Only one participant, who had previously worked with environmental life cycle assessments, questioned: *"Is refurbishing more circular and better for the environment?"* In the third workshop, one participant investigated the circularity potential of their idea by asking how many use cycles they could achieve with their baby clothing-as-a-service model, compared to the current average number of cycles. Apart from that, most of the participants assumed that their solutions are 'better' for the environment compared to existing offerings, and did not find it important to better investigate this assumption. They only seriously investigated and documented their assumed circularity or environmental improvements when they had to fill in a dossier for a startup award. These findings show that 'circularity checks' are influenced by whether participants find circularity relevant and important to their process.

The business model properties: The most important business model properties are desirability, feasibility and viability. Most participants in the first workshop focused on the desirability of their envisioned business models. They paid a lot of attention on how they could sell their products and services, and what value they would provide for their customers. The other two workshops were more mixed, with attention on several business model properties and no clear preference for either of them. For example, in the second workshop, one participant with a user-centered approach was interested in the desirability of a refurbished product. Another participant wanted to investigate how feasible their idea was in terms of the hygiene of returned products. Yet another was curious to investigate if the lower price point would get a customer to buy a refurbished product. In the third context, most of the participants considered it important to focus their experiments on the desirability and viability. Table 5.3 contains a selection of quotes that show which business model properties the participants found important to investigate. They illustrate which business model property the participants found important.

TABLE 5.3 Questions that the participants in the three workshops found important to investigate

	Workshop 1	Workshop 2	Workshop 3
Desirability	"Are they potentially interested?" "Will they understand our story?" "Will they like our product?" "How to make the product more appealing for potential customers?" "How can we turn our service into an experience for the customer?" "What is a good name for this product?"	"What drives the consumer? What do they want in refurbished products?" "How many of these products does an average customer buy in a lifetime?" "What is the customer perception of refurbished products?" "What is our target group?"	"How many of our customers are willing to pay for this offering?" "How many will sign up if we advertise this service?"
Viability	"What are people willing to pay?"	"Does the price drive the decision to buy a refurbished product?"	"What are our costs?" "How can we price our service?" "Is this financially viable?"
Feasibility	"Does the service model work?" "What are the challenges of delivering this service?"	"Will reused products be bio-contaminated?" "Can the product be fully modular?" "Does refurbishment affect product safety?" "Will the customers clean the product themselves?"	"How can we get our users to act autonomously?"

Fast and/or slow learning: Fast learning during business model innovation can be gained, for example, via paper sketches, quick interviews or try-outs. Slow learning happens through, for instance, business plans, market studies or pilots. In the first context, most participants found fast learning more important than slow learning. This is likely related to the context of the workshop: an innovation festival in the summer with prototyping facilities and a near-by music festival to test the prototypes. The founder of a service model for reusable plates, for example, noted that they were *"just trying stuff quickly"* to see what worked and what did not. Another participant noted during the testing: *"you just change things quickly and see what happens"*. In the second and third workshops, participants had mixed preferences for both fast and slow learning. In the second one, some participants were eager to act and organize a fast experiment and interviews with some of their employees in their office building. Another participant preferred to conduct a life cycle assessment on the possible environmental impacts of selling refurbished products. In the third workshop, some found it important to make an elaborate cost calculation to design and plan an experiment. Another participant decided to focus on quick changes to the website design, search engine optimization and customer journey optimization. These examples illustrate that whether the participants prefer fast and/or slow learning influences what they want to test and how.

5.4.1.2 What they know

The participants determined what they had to find out and how based on what they knew. This related to, for example, their *relevant background knowledge* or the *provided information during the workshops*.

Relevant background knowledge: Relevant background knowledge refers to the skills and knowledge that the participants bring into the experimentation process. In the first workshop, most of the participants did not follow the suggested quasi-experiment approach and rigorously collected data, but instead wanted to learn by doing. For example, the leader of a startup that offered multifunctional furniture noted that there is *"no need to be too rigid about things"*. The team was simply looking to get customers to sign up. This can be partly explained by a lack of background knowledge of and experience in experiment design. A team member from the service model for reusable plates concluded from the testing that the service model did not really work, because the plates did not meet the aesthetic requirements of their client. Again, this was not based on a carefully designed experiment, but came from the direct, intuitive experience. In the second workshop, the participant who had previously worked with Life Cycle Assessments suggested to conduct such an assessment for the envisioned business model around refurbished products. Another participant with a design background focused on the user-centered methods for value proposition design. In the third workshop, some participants with a mechanics background focused on the feasibility of repairing a certain number of products as part of their envisioned business model. Others with a marketing background focused on how they could optimize their online channels to attract more customers. As these examples show, the background knowledge has an influence on what the participants want to test and how they want to test it.

Provided information during the workshops: This refers to the information that the participants receive during the experimentation, for example in the form of concepts and methods that they can use. In the first workshop, the list with available testing methods contributed to the participant knowledge about how to test their assumptions. During the testing, they used methods such as conversational interviews to understand how much potential customers were willing to pay, how well they understood the story, ethnographic observations to see how users interacted with their prototypes, A/B tests to understand preferences, competitor comparisons, and 'Wizard-of-Oz' testing (*"fake it until you make it")*. In the second workshop, the participants used the provided information to formulate why customers would be interested in their proposed solutions, or what they could do to test their assumptions. In the third workshop, participants were triggered to select a concrete metric that they wanted to improve through their experiments. They used this

information to concretize their ideas for experiments. For example, one startup that wanted to monetize left-over yields from farm lands decided to measure buy-in from a potential retail partner through an experiment to launch a weekly veggie box subscription (*"Will they accept the price offering?"*). Another startup that provided baby clothing as a service defined the circularity metric 'number of use cycles' to measure its comparative impact in the baby clothing market (where there is generally one use cycle). This shows that the available information during experimentation influences what the participants want to test and how.

5.4.1.3 Whom they know

The participants decided what they had to find out and how based on whom they knew. This related to, for example, their *existing network.*

Existing network: This refers to how the social network of the participants can help support the experimentation process. In the first workshop, the existing network had an influence on how the participants prioritized what assumptions to test. For example, the founder of one startup noted that she could *"easily take this one to our partner and discuss"*. Towards the end of the workshop session, another participant noted that *"it is interesting that a lot if this really boils down to the network"*. Whom they knew had an influence on how they prioritized what assumptions to test first. One participant noted that *"there is actually someone here we can ask about this"*. The founder of the startup that offered multifunctional furniture noted that it was easy to find out how their furniture adds value to the brand experience of their potential clients: she already had a client who used their furniture for this purpose, and could go and ask them for more details about how the furniture added value. The existing network also helped get further contacts and buy-in from external parties. For example, the startup with the service model for reusable plates got buy-in to conduct a full experiment at the festival from the event organizers, because they believed in the idea. They also helped to connect the startup to the food providers on the festival to co-organize the experiment. In the second workshop, existing retail partners were mentioned as potential places to conduct an experiment to try and offer a product-as-a-service model. Also internal staff was mentioned as a potential test group to conduct some early experiments around user acceptance for a refurbished product. Similarly, in the third workshop, participants designed experiments together with existing retail, distribution or promotion partners. It appears that the network determines which assumptions the participants prioritize, because tapping into the existing network is immediately actionable. It requires comparatively low efforts to set up experiments and to get the needed information.

This shows that the existing network can influence how participants want to test their assumptions during circular business model experimentation.

5.4.2 Principles to help improve circular business model experimentation

We have shown how analyzing their available means – what they find important, what they know and whom they know – can help to better understand how the participants develop and test their assumptions during circular business model experimentation. Based on this better understanding, we propose a set of principles for *before* experimentation, and a set of principles for *during* experimentation.

5.4.2.1 Before experimentation

Recognize what the participants find important: to ensure that circular business model experiments aim at higher circularity (or lower environmental impact), it is important to involve participants who care about circularity and the minimizing of environmental impact. The more the participants think it is important to ensure that their envisioned business models reduce environmental impact and resource use, the more likely they are to be critical and scrutinize their assumptions about the circularity of the proposed ideas. If some of the participants do not think that circularity is relevant and important, then they need to be supported in developing a stronger awareness about it.

Recognize what the participants know: to ensure that circular business model experiments aim at higher circularity, it is important to involve participants who know about the environmental impacts of their business activities, and how this impact – and the potential impact of the proposed business model changes – can be measured using concrete metrics. In addition, the more the participants know how to apply the principles of the experimental method (how to formulate a hypothesis or theory, and how to test it rigorously), the more likely they are to avoid false negatives: where they disconfirm the potential of an opportunity where there is one; and false positives: where they confirm an opportunity where there is none.

Recognize who the participants know: to ensure that circular business model experiments aim at higher circularity (or lower environmental impact), it is important that the participants explore and develop a supportive network that can help inform

and conduct the experiments. A supportive network can, for example, make the experiments more actionable (partners can provide space to experiment), more collaborative (partners can co-develop complementary products and services), more cost-effective to organize (known partners mean lower transaction cost because of existing ties), and more meaningful (knowledge partners can, for example, help assess the circularity of the experiments).

5.4.2.2 During experimentation

Formulate assumptions in terms of what you need to find out: in the first workshop, we proposed test cards and a validation graph to the participants as a way to develop and test their assumptions. The average rating of perceived usefulness was 4.8 (out of 7), and of ease-of-use 5.1 (out of 7). Many who provided a rating indicated that they did not use the methods (25%). The test card's ability to stimulate immediate action was limited. Thinking in terms of assumptions was often not perceived as helpful. As one participant pointed out: *"I feel like we don't end up anywhere if we point out all these assumptions"*. Instead, the participants developed an intuitive alternative to the test cards to formulate their assumptions. They simply asked: *"what do we need to find out to see if this can work?"* In the second workshop, the participants used this technique to post their assumptions on a wall. This was perceived as a useful way to document the things they did not know and that they wanted to find out.

Prioritize assumptions in terms of what you can do right now, with what is available: the participants in the first workshop tried to answer their questions by looking at currently available means. One noted: *"the question is really what we can test here and now"*. Another participant commented that *"it is true that there is a lot that you can do, but it is also about what is it that you can do right now"*. In the second workshop, the prompts to document possible immediate actions (*"what can we do right now to find out?"*) were captured on post-its and collected on a wall. They provided an intuitive and easy-to-use way to generate a concrete action plan for the next experiment.

Define key metrics: in the second workshop, the metric of 'circular revenues' (e.g., revenue from a product-as-a-service model) was defined as a key metric to guide experimentation. In the third workshop, we asked for feedback on the usefulness and ease-of-use of using concrete metrics to guide circular business model experiments. These were perceived as useful (average rating of 4.25 out of 5) and moderately easy to use (3.5 of 5). The moderate rating on ease of use was because one team needed

more time to define meaningful metrics, and another participant who had to leave earlier and could therefore not use the workshop material as intended. The use of circularity metrics prompted the participants to focus on one key metric that can help them specify how each action further grows the business and increases circularity. For example, one startup that developed a baby-clothing-as-a-service model focused on 'number of use cycles' as a circularity metric. They found that the subscription model may lead to six use cycles, compared to one cycle in the sales model. Another startup that developed a sharing platform for everyday goods measured the number of items on its platform and the number of times they have been rented out to make inferences about avoided sales of these items. The participants noted that defining metrics to guide their experiments helped to *"decide what to focus on"* and that *"it was very helpful to decide on goals for the coming time"*.

5.5 Discussion

This study makes two contributions to the existing research and practice of circular business model experimentation. First, to research, it adds an improved understanding of how the innovation participants – entrepreneurs, innovation managers, business managers, designers – develop and test their assumptions during the experimentation process. Second, for practice, it adds a set of principles – based on this improved understanding and the workshop evaluations – that can help to improve the experimentations. We discuss both contributions and the limitations of this study in the following sections.

5.5.1 Contribution to circular business model experimentation research

The findings from circular business model experimentation research show that the experimentation reality is less formal than what may be desirable according to The Lean Startup (Ries, 2011), confirming earlier findings on the application of Lean startup in the circular economy context (Bocken et al., 2017). In general, approaches like The Lean Startup lack an understanding of, and guidance on how the participants – entrepreneurs, innovation managers, business managers, designers – develop an underlying theory of value about their envisioned business models

(Felin et al., 2019). In this study, we seek to contribute to a better understanding of this process. In particular, we show that their available means influence how the participants move through the experimentation process. Decisions on what to test, how to test it, and what to conclude from the tests are influenced by an effectual logic and behavior: what they find important (part of their identity), what they know (their skills and knowledge) and whom they know (their social network) (Sarasvathy, 2008). This supports the findings from the circular business model experimentation literature (Bocken et al., 2017). It also fits with the understanding that the innovation process is often driven by subjective and intuitive judgements (Foss et al., 2019). It is therefore important to recognize this underlying process of developing and testing assumptions, to make the participants aware of it, and in turn to develop a more reflective and rigorous process.

It is important to highlight that these findings do not intend to discredit the merits of a more formalized approach to entrepreneurship. We are aware of earlier research that has demonstrated the potential positive influence of a more formal approach to business venturing (Camuffo et al., 2019). Rather, we argue that a better understanding of the subjective nature of decision-making during experimentation can help to make the process more rigorous. With regards to circularity, this relates to making sure that the participants have strong sustainability and circularity aspirations; that they have the skills and knowledge that are necessary to experiment towards circularity; and that they have a supportive network to achieve their aspirations. This adds to previous findings about the importance of carefully selecting the participants who join the efforts (Bocken et al., 2017). It is important to understand that they never enter into the process with a blank slate. Rather, they have a set of predetermined means – their identity, their skills and knowledge, and their social network – that influence it. We argue that recognizing and leveraging these means can help improve the process.

5.5.2 Contribution to circular business model experimentation practice

The practical research output of this study is a set of principles that can help improve circular business model experimentation. The first three principles relate to the effectual logic and behavior of the participants before the process: what they find important, what they know and whom they know. Recognizing these elements can be used to compose stronger teams for experimentation. In particular, it can be used to identify participant profiles with useful capabilities, for example: a strong personal drive to innovate towards sustainability and a circular economy, good knowledge of

the scientific method, an understanding of environmental impact assessments, and a network of supportive actors that can be used to support and widen the perspective of the process.

We also propose a set of principles for during experimentation. During experimentation, the participants can formulate their assumptions in terms of what they think they need to find out about their ideas. They can prioritize which assumptions to test by looking at what they can do right now, and whom they know who can support or who is needed for the inquiry process. The participants benefit from defining concrete metrics to guide their search process. This is to ensure an element of rigor and goal orientation within a largely effectual process. We provide an example set of metrics (Appendix C3) that can be used as inspiration to find an appropriate metric. The search for an appropriate metric can be guided by questions such as: *how do we know if we are on the right track? What do we want to achieve? How do we measure progress?* We learned throughout the three workshops that defining a key metric for each experiment helps to focus the efforts, and that it helps to be clear about the intended outcome of an experiment. This is in line with earlier propositions for a metric-based approach to business model experimentation (Croll and Yoskovitz, 2013; Heikkilä et al., 2016). It is important to highlight that metrics do not have to be quantitative. Sometimes, qualitative metrics are more meaningful, especially when a business model is new and has no prior history (M. Antikainen et al., 2017b). These principles need further research to understand when and how they can be used to experiment more successfully.

5.5.3 Limitations of this study

We highlight several limitations of this study. First, It is important to note that we conducted three workshops: two in the Netherlands and one in Switzerland; one with novice entrepreneurs, one with an incumbent and one with growth-oriented and more experienced entrepreneurs. This provides a solid data foundation, but is limited in terms of organizational (no mid-sized company, for example) and cultural richness (no emerging or developing country context). Second, there are potentially other ways to explain and describe the decision-making logic during business model experimentation. We found an effectual logic and behavior to be useful in this context. This does not mean that other theoretical frameworks may not also shed light on the underlying logic of how the participants form a theory of value about their envisioned business models. Third, the proposed principles need further testing and refining, especially with regards to the metrics. Previous research has collected a set of metrics to guide business model experimentation (Croll and Yoskovitz, 2013;

Heikkilä et al., 2016). It is important to better understand how metrics can be used during circular business model experimentation, especially how they can help to conduct 'circularity checks' (Bocken et al., 2018).

5.6 Conclusion

This study has shown that analyzing their available means – what they find important, what they know, and whom they know – can help to better understand how the participants develop and test their assumptions during circular business model experimentation. We also showed how a better understanding of this underlying process can help improve it. In particular, *before* experimentation, it can help to form a strong circular oriented team with participants who care about circularity, know about it, and have a network of supporting stakeholders to explore circularity from an ecosystem perspective. Moreover, *during* experimentation, we propose that the participants can formulate their assumptions in terms of what they need to find out about their ideas, that they can prioritize what to test based on what they can do right now with what is available, and that they benefit from defining concrete metrics to guide their search process. Future research is needed to further increase our understanding of the experimentation process. In particular, it is important to further investigate, for example, how to compose effective experimentation teams, how to choose an appropriate metric for an experiment, and how to organize more inter-organizational business model experimentations for ecosystem level change towards sustainability and a circular economy.

6 Discussion and conclusion of this thesis

This thesis has proposed that organizations need to take an ecosystem perspective to innovate towards a circular economy. The main argument is that an ecosystem perspective is necessary because circularity is a collective outcome, and not the outcome of how one organization does business. To understand how resources flow through social environments – and how organizations can narrow, slow, close, regenerate and inform them – therefore requires a broader perspective. In the following, I discuss the contributions of this thesis (6.1), its implications for industry and innovation management (6.2), the challenges of putting an ecosystem perspective into practice (6.3), the implications of this thesis for design and engineering (6.3), design education (6.4), and its limitations (6.5). I will finish with some concluding remarks (6.6).

6.1 Contributions of this thesis and future research

This thesis provides a starting point to shift the attention of circular oriented innovation to an ecosystem perspective – and to understand how this perspective can be put into action. It thereby contributes to the circular business model literature, because it emphasizes multiple business models – and how they work together – to jointly enable circularity. Earlier work has recognized the systemic nature of circular business models (Lüdeke-Freund et al., 2019). An ecosystem perspective adds distinct attention to the collective outcome and the interactions among many business models, to materialize a circular and end user facing

ecosystem value proposition (Talmar et al., 2018). There is an opportunity for future research to better explore these value propositions: how can they be designed, how can actors align on a joint and overarching ecosystem value proposition? Prior research has shown that this is a dynamic process with high uncertainty. The focal actor does not necessarily have a clear vision and a clear idea of who the actors are that are needed to deliver an ecosystem value proposition (Dattée et al., 2018). This is likely also the case for circular oriented innovation. The design of a circular ecosystem value proposition – and the accompanying minimum viable ecosystem of actors needed to deliver it – is an interesting area for further research.

The thesis also adds to the ecosystem literature, with its focus on circularity and 'circular complementarity': the types of products and services that need to be combined to keep product, component and material value high over time (Shaw and Allen, 2018). With the Circularity Deck, practitioners have now a tool that can help them to identify these circular complementarities (Konietzko et al., 2020a). Further research can build on this and identify the specific types of complementary products and services needed to deliver circularity in particular sectors. This can then inform the forming of consortia around these needed complementarities.

Another contribution is the identification of the main areas of action to drive ecosystem innovation: collaboration, experimentation and platformization (Konietzko et al., 2020b). This thesis is just a starting point to see how these areas can be combined in practice. For example, an interesting question is how companies can experiment in ecosystems. While this thesis provides a first start, a lot is unknown about what constitutes an ecosystem experiment, and how it is different from, or how it might overlap with other notions of experimentation from domains like business models (Weissbrod and Bocken, 2017), or transition studies (Sengers et al., 2016). Exploring the intersections between ecosystem innovation and transitions management is a fruitful topic for future research.

Another important field for future research is impact assessment. An ecosystem perspective moves beyond product-based approaches for environmental impact assessments, like LCA (Scheepens et al., 2016). It focuses on the complex interactions among several actors in a given ecosystem – and how these interactions lead to better or worse environmental outcomes. While some have started, there are still a lot of unknowns about how to assess these dynamic interactions (Boons and Bocken, 2017). Often this is a question of data: how to collect and analyze the cross-organizational data on the overall environmental performance in an ecosystem, like a mobility system in a city? Future research is needed to develop appropriate methods, and test their usability in practice contexts. An ecosystem perspective will be needed to account for complex rebound effects that might result from circular business models (Zink and Geyer, 2017).

6.2 Implications for industry and innovation management

An ecosystem perspective can seem complicated and abstract. Here I want to argue that 1) any organization can take an ecosystem perspective, 2) every organization should care to take an ecosystem perspective, and 3) how an organization can get started.

6.2.1 Any organization can take an ecosystem perspective

The outcome of chapter three, the Circularity Deck, has shown that circular ecosystem innovation can be approached on three levels: product/service, business model and ecosystem. On which level an organization innovates for circularity depends on the context and the ambition. An ice cream store, to take a simple example, can first prioritize the product level to achieve environmental impact reductions: it can, for instance, make the ice cream from more plant-based sources (to narrow their resource intensity), or collaborate with local farmers to narrow the transportation intensity of the ice cream ingredients. But maybe the ice cream store wants to implement a system for reusable cups, to reduce their packaging waste. This is an ecosystem problem: the store needs to collaborate with other stores to jointly propose and organize a system for reusable ice cream cups. They could engage a service provider to pick up, clean and re-deliver the cups to the stores. As this example illustrates, any organization can approach sustainability problems from an ecosystem perspective.

6.2.2 Organizations should care to take an ecosystem perspective

The main reason why an organization should care to take an ecosystem perspective is that we are entering an age of resource scarcity and environmental constraints (Heuer, 2011). The Corona Pandemic has already shown how vulnerable global supply systems are to environmental shocks. Future environmental shocks – like heat waves and droughts, collapsing natural ecosystems, flooding, strong rain fall and storms – will have an impact on many businesses. An ecosystem perspective helps to change not only the product, the business model, or the supply chain structure, but the wider structure of how business is organized, to adapt to a world full of people that is increasingly shaped by environmental constraints.

Take the fashion industry. The business model of fashion still largely depends on the continuous extraction of natural resources. Investments in take-back systems and recycling of materials like cotton might seem unprofitable in the short term. But severe droughts may affect cotton supply, which requires a lot of water. In such a scenario, the ability to maintain and recover the value embedded within clothing items becomes a competitive advantage. The challenge is when to do it. Circular ecosystem structures require time and effort to build, which is why it is important to start building new structures now. Early movers can have an ecosystem advantage, in case resource scarcity and other environmental constraints accelerate as a result of climate heating (Lenton et al., 2019). But more importantly, an ecosystem perspective can help to mitigate the environmental impacts of production and consumption (Adams et al., 2016; Ceschin and Gaziulusoy, 2016; Tukker, 2004).

6.2.3 How organizations can start taking an ecosystem perspective

This thesis has shown that it makes sense to start by focusing on a particular city and its surrounding region. Cities have clear geographic boundaries and are dominant loci of resource consumption. Around 80 % of the global population will live in cities by 2050 (Pickett et al., 2013). Any organization that operates within, or whose products are used and deployed in a city, can analyze how its resources (in the form of products, components or materials) flow through a city over time. In mobility, this can be the mobility system of a city – how people and goods move around, and how the providers of the different modes of transportation address different user groups that use them. In construction, this can be all the activities and interactions in a given city that deal with construction and demolition. For food, this could include, for example, food producers at a city's periphery, retailers, private households, and local restaurants.

A focus on a city makes circular ecosystem innovation concrete. Ideally, an organization starts experimenting and working towards a pilot in a relevant city in which it operates that has ambitious plans for the circular transition. A city with ambitious plans provides a favorable institutional environment, like local innovation hubs, engaged citizens, access to finance, regulatory support, or networks of like-minded organizations and motivated individuals. An example is Amsterdam, which wants to be a circular city by 2030 and has built a vibrant innovation community around the circular economy (Circle Economy, 2015). But it is also important to acknowledge that most urban growth will happen in developing countries, mostly in Asia and Africa (Pickett et al., 2013). The European Union is challenged to reorganize the resource flows in and out of cities to ensure high human development while

radically reducing net resource consumption. In Africa and Asia, the challenge is to build new city structures now that support human development, and that facilitate leap-frogging and direct implementation of more sustainable solutions.

When an organization starts its innovation process, it is important that it maps its own position and function and the ones of other relevant actors within the current, and the future circular ecosystem. Is it a complementor who occupies a specialized niche, or an orchestrator who can shape the co-evolution of an ecosystem? The position influences the ability of an organization to drive change (Parida et al., 2019). A complementor who occupies a specific niche can drive ecosystem change by, for example, partnering with a larger organization that shares a similar vision about the future. It can also develop higher degrees of complementarity to better fit within emerging ecosystem structures.

Take Lancey, a French energy storage company that has partnered with e-bike providers in the city of Paris to reuse the old batteries from the bikes in their home heating systems (Lancey, 2020). Imagine that Lancey reaches out to the company that manufactures the batteries, to explore how data about the second life of the batteries can be used to capture value from the batteries over a longer period of time. It can even go a step further – mindful of other essential circular ecosystem functions – and explore different end-of-life scenarios for the batteries. Lancey, a niche player, can thereby try and influence the battery manufacturer to make the batteries compatible for reuse and end-of-life: to provide a better fit and easier deployment in the home heating systems, and to ensure their recyclability to capture valuable raw materials for new batteries. This way, Lancey could explore additional business opportunities to resell the batteries back to the manufacturer. The manufacturer, in turn, has found a partner to organize efficient take-back mechanisms and to get access to valuable raw materials.

An important aspect of circular ecosystem innovation is to envision and form a ‘minimum viable ecosystem’: the smallest alignment structure to materialize a circular ecosystem value proposition. Take the example of Unwaste (Unwaste, 2020). This Amsterdam-based startup has created an ecosystem that collects coffee ground and orange peel waste from office buildings, turns them into new products, and returns the products to the same offices. They propose to ‘unwaste’ big office spaces. To enable this value proposition and circular flow of resources, Unwaste had to first find a pilot office space in Amsterdam as a launching customer, and partner with two local waste managers, a processing plant, a manufacturing plant and a logistics company to deliver the ecosystem value proposition. Each of these actors had to change what they do. For example, people in the office had to start separating the coffee and orange peel waste from the other waste, and the waste management

firms had to collect them separately. I met with the project team several times and noticed that they had mapped their business model, but that they paid less attention to actor alignment, co-innovation and co-adoption risk – all crucial elements of forming a minimum viable ecosystem (Adner, 2012; Talmar et al., 2018).

Governments play an important role during circular ecosystem innovation, as they can provide funding, facilitate new interactions and exchange, enable shared visioning, and provide regulatory support (Konietzko et al., 2020b). There are several consortia that are supported by the government to tackle the more systemic elements of resource efficiency and circular oriented innovation. Examples include Adaptive City Mobility, a consortium of ten technology organizations (see chapter three), or BAMB2020, a consortium of 15 organizations that aim at developing buildings as material banks (BAMB, 2020). Next to funding and enabling networks, governments can also support emerging ecosystems by changing regulatory frameworks. In the case of Adaptive City Mobility, the municipality of Munich has allowed for softened regulations in a dedicated district, to test the systemic prototypes that came out of the project. In the previously mentioned example of Lancey, regulators could provide additional incentives for the circular ecosystem of batteries, for example in terms of strictly enforced extended producer responsibility, or requirements for the recyclability of batteries.

6.2.4 Challenges of taking an ecosystem perspective

An ecosystem perspective has its challenges, four of which I want to discuss here: 1) an ecosystem perspective requires a different mindset and new capabilities; 2) it is difficult but important to be clear on the business case of an ecosystem value proposition; 3) it creates higher complexity of contractual agreements and questions of liability; 4) and collaboration agreements within ecosystems might lock parties into undesirable ecosystem structures over time.

First, an ecosystem perspective requires a different mindset and new capabilities. Innovators need to learn how to see the big picture, and then zoom into their context. They need to be able to reflect and engage in generative thinking. This implies a shift from reactive problem-solving to co-creating the future in inter-organizational constellations (Senge et al., 2015). People will be needed who are able to work in inter-organizational and collaborative innovation projects. Once a minimum viable ecosystem is forming – that is, the smallest alignment structure that is needed to deliver an ecosystem value proposition – the different partners need to build trust, continuously negotiate, and be open about their interests. Negotiating

fair value capture, based on the inputs from each partner, is a major challenge. Many collaborations fail because the participants of the process do not spend enough time and energy on developing trusting relationships (Brown et al., 2019; Emerson et al., 2011).

A second challenge is to be clear on the business case of an ecosystem value proposition. I argue that an ecosystem perspective can be an attractive business proposition. Ensuring a favorable alignment structure – and the needed co-innovations and co-adoptions of actors within the ecosystem – make good business sense (Adner, 2012). Adaptive City Mobility, for example, achieves up to 70 % emission reductions, more than 50 % raw material reduction, up to 35 % cost reduction per kilometer and up to 50 % higher utilization, because they focus on actor alignment and collaborative ecosystems for mobility (ACM, 2018). But to sell these systemic benefits can be difficult. One of the managers from Adaptive City Mobility mentioned that it was hard to explain the systemic character of the project to investors. Investors think in products, not in ecosystems. A clear and simple ecosystem value proposition is therefore crucial to get supportive investors on board.

A third challenge is the increasing complexity of contractual agreements and questions of liability. When several organizations co-create an ecosystem value proposition, who is liable for the result? What kinds of agreements need to be crafted among the contributors to ensure simplified contractual agreements? In the case of Adaptive City Mobility, the participants tried to simplify the agreements by finding one ecosystem operator per city (Konietzko et al., 2020b). Another possibility to overcome this is online platforms, where platform control mechanisms and clear governance structures can simplify actor coordination (Konietzko et al., 2019). Blockchain technology can also help to simplify contractual agreements, by tokenizing transactions and automating the allocation of revenue to different parties (Narayan and Tidström, 2020).

A last challenge I want to mention is that collaboration agreements within ecosystems might lock parties into undesirable ecosystem structures over time. What can seem like a great idea in the beginning, may turn out to be undesirable in the mid to long term. The question here is how to design open collaboration structures and ensure that contributors can secure 'quick-wins' on a regular basis, that keep them engaged, and how to make it possible for partners to come and go. The field of open innovation can help explore these questions in the future (Chesbrough and Appleyard, 2007). An ecosystem perspective requires flexible inter-organizational structures with clear complementarities and an openness for actors to complement to, or leave a given ecosystem.

6.3 Implications for design and engineering

An ecosystem perspective has implications for design and engineering. It adds to the strategic aspect of the design process, that is, the experimentation with the desirability, feasibility and viability of proposed design concepts (Brown, 2008; Calabretta et al., 2016). This is normally user-centered. An ecosystem perspective brings this experimentation process into a multi-actor and collaborative context (Baldassarre et al., 2020a). From an ecosystem perspective, user-centered design thus needs to shift towards ecosystem design, which includes users, but also pays attention to the environment in which the user is situated. An employee of a Finish Design agency we worked with called it 'planet-centric design'. It is true that, say, a circular mobility ecosystem will only work if users adopt the new and integrated offerings that are proposed. Yet the main attention should not only be on the user. It should be on the collective outcome. An important question to be answered at the intersection of user-centered design and an ecosystem perspective is how to align the collective outcome with the interests and needs of the intended users. Recent approaches like DesignX (Norman and Stappers, 2015) or Systemic Design (Buchanan, 2019) provide starting points to align an ecosystem perspective with design thinking. These approaches recognize the need to go from design to implementation, a major challenge in sustainable innovation and strategic design for sustainability, because of the complexity of triggering systemic change (Baldassarre et al., 2020b). This thesis, with its attempt to make an ecosystem perspective concrete and actionable, contributes to closing the theory-practice gap of sustainable innovation research.

Another implication for design and engineering is that high uncertainty in the design process and fast changing environments have challenged the classical stage-gate model of product development (Cooper, 1990). Rapid prototyping and experimentation have become more important to innovate under uncertainty, as shown by the prominence of approaches like Design Thinking and the Lean Startup (Brown, 2008; Ries, 2011). An ecosystem perspective changes the character of experimentation and prototyping. Design thinking and the Lean Startup tend to emphasize user desirability. An ecosystem perspective simultaneously looks at the feasibility and viability of integrated solutions. Organizations can experiment in ecosystems by choosing a dedicated physical space, and by prototyping integrated systems that test how the different complementary products and services of an ecosystem work together to materialize an ecosystem value proposition. Ecosystem experimentation is about testing the desirability, viability and feasibility of an ecosystem value proposition, rather than a value proposition that focuses on one user, using one product.

6.4 Implications for design education

After having been a coach and lecturer for the students of the Faculty of Industrial Design Engineering, I want to quickly discuss the implications of an ecosystem perspective for design education. Traditionally focused on product design, our faculty recently integrated business model design for sustainability and a circular economy in the curriculum of design education. This is a great first step to acknowledge the organizational elements of sustainable innovation. In addition, the design education should offer formats for systemic design that move beyond single-firm business models. This should go hand in hand with completely new ways of organizing education around it. The education should involve real world sustainability challenges – based on building integrated systems – that the students can work on across faculties. A good example is the TU Eindhoven Innovation Space, an ecosystem based approach, where students from across faculties can use joint prototyping spaces to engage in challenge-based learning. Such an educational reform is radical, because it would mean that the students spend most of their time outside of the classroom. It also requires higher coordination among faculties, and a different engagement with external partners. But I argue that it is worthwhile to explore how the TU Delft campus, and university education in general, can be designed to facilitate innovation ecosystems towards a circular economy.

6.5 Limitations of this thesis

Each of the chapters and studies have their own limitations, which have been explored in their respective discussion sections. Here, I want to briefly discuss some limitations of the overall thesis. One limitation is that in the literature, many other relevant concepts and perspectives exist that have been omitted from this thesis. Two examples are innovation systems (Anttonen et al., 2018; Oh et al., 2016) and transition theory (Rotmans and Loorbach, 2009).

Innovation systems have explored interdependent and systemic forms of innovation, especially within the so-called regional triple, or quadruple helix of business, university, government, and civil society (Carayannis and Campbell, 2009). This concept has several overlaps with innovation ecosystems, which have been

discussed elsewhere (Oh et al., 2016; Ritala and Almpanopoulou, 2017). Also in the context of a circular economy, innovation systems have been used, to explore in how far university, industry and government Interpretations of a circular economy overlap and can be combined to arrive at new forms of innovation (Anttonen et al., 2018). I reside with the argument that the prefix 'eco' adds an important dynamic and complex adaptive lens to the literature on innovation systems, and that it deals with co-evolution of a defined set of actors (Ritala and Almpanopoulou, 2017). In addition, the ecosystem as a complex adaptive system (Phillips and Ritala, 2019) makes it a suitable concept to be combined with the natural ecosystem 'original' in the future, to explore how social-ecological systems can be influenced and changed through innovation activities (Holling and Gunderson, 2002). Still, omitting the rich tradition of research on innovation systems is a limitation of this thesis, and future research might further investigate how the traditions of innovation systems and the market oriented ecosystem interpretations overlap, and how they can be combined to explore the transition towards a circular economy.

A second omission from this thesis is transition theory. As an important theoretical framework, transition theory explains how transitions come about (Geels, 2002). This is relevant in the context of *transitions* towards a circular economy. There is rich information on how transition experiments – as bottom-up initiatives that can trigger the emergence of new niches that can challenge existing regimes – can be organized to explore new and more sustainable means of provision (Sengers et al., 2016). The reason why I omitted this concept in this thesis is its lacking focus on business organizations. Transition experiments are mostly civil society and policy driven, and have under-appreciated the role of business organizations, except for some recent research (Sarasini and Linder, 2017). A case in point is the lacking attention to the financial viability of transition experiments as part of a proposed evaluation scheme (Luederitz et al., 2017). Nonetheless, a lot can be learned from combining transition experiments, business model experiments (Bocken et al., 2018), and ecosystem experimentation in the future, especially when it comes to organizing these experiments in cities to trigger systemic change. Future research may therefore focus on the role of business in wider societal transitions, and how the business case and other strategic aspects can be integrated with prior approaches to transition experiment designs.

6.6 Concluding remarks

This thesis has proposed that organizations need to take an ecosystem perspective when they innovate towards a circular economy. It has reviewed the different ecosystem analogies that are relevant in the context of a circular economy, and how organizations can put them into action (chapter two). This thesis has furthermore shown how organizations can be facilitated to take an ecosystem perspective, through the Circularity Deck – a card deck based tool that has been tested with 136 participants from 62 different organizations (chapter three). A case study has served to investigate the types of principles that can help organizations organize for circular ecosystem innovation (chapter four). Lastly, this thesis has investigated contexts of circular business model experimentation, and found that the practitioners of experimentation – innovation managers, entrepreneurs, and intrapreneurs – tend to overestimate the environmental impact reductions of their proposed solutions. This is because circularity is a collective outcome, and not the outcome of how one organization does business. Only through collective action can organizations tackle wicked problems like waste, pollution and emissions. I sincerely hope that this thesis can make a contribution to advancing systemic business practices that lead to more desirable collective outcomes in the future.

TOC

References

Aarikka-Stenroos, L., Ritala, P., 2017. Network management in the era of ecosystems: Systematic review and management framework. Ind. Mark. Manag. 67, 23–36. https://doi.org/10.1016/j.indmarman.2017.08.010

Abella, A., Ortiz-de-Urbina-Criado, M., De-Pablos-Heredero, C., 2017. A model for the analysis of data-driven innovation and value generation in smart cities' ecosystems. Cities. https://doi.org/10.1016/j.cities.2017.01.011

acatech, 2020. Resource-Efficient Battery Life Cycles –Driving Electric Mobility with the Circular Economy.

ACM, 2018. Adaptive City Mobility Website [WWW Document]. URL http://www.adaptive-city-mobility.de/

Adams, R., Jeanrenaud, S., Bessant, J., Denyer, D., Overy, P., 2016. Sustainability-oriented Innovation: A Systematic Review. Int. J. Manag. Rev. https://doi.org/10.1111/ijmr.12068

Adams, R.J., Smart, P., Huff, A.S., 2016. Shades of Grey: Guidelines for Working with the Grey Literature in Systematic Reviews for Management and Organizational Studies. Int. J. Manag. Rev. https://doi.org/10.1111/ijmr.12102

Adidas, 2019. adidas unlocks a circular future for Sports with Futurecraft.loop: a performance running shoe made to be remade [WWW Document]. URL https://news.adidas.com/running/adidas-unlocks-a-circular-future-for-sports-with-futurecraft.loop--a-performance-running-shoe-made-t/s/c2c22316-0c3e-4e7b-8c32-408ad3178865 (accessed 8.6.19).

Adner, R., 2016. Ecosystem as Structure: An Actionable Construct for Strategy. J. Manage. 43, 39–58. https://doi.org/10.1177/0149206316678451

Adner, R., 2012. The Wide Lens, The Wide Lens.

Adner, R., 2006. Match your innovation strategy to your innovation ecosystem. Harv. Bus. Rev.

Adner, R., Kapoor, R., 2016. Innovation ecosystems and the pace of substitution: Re-examining technology S-curves. Strateg. Manag. J. https://doi.org/10.1002/smj.2363

Adner, R., Kapoor, R., 2010. Value creation in innovation ecosystems: How the structure of technological interdependence affects firm performance in new technology generations. Strateg. Manag. J. https://doi.org/10.1002/smj.821

Ahlström, H., Williams, A., Vildåsen, S.S., 2020. Enhancing systems thinking in corporate sustainability through a transdisciplinary research process. J. Clean. Prod. https://doi.org/10.1016/j.jclepro.2020.120691

Alcayaga, A., Wiener, M., Hansen, E.G., 2019. Towards a framework of smart-circular systems: An integrative literature review. J. Clean. Prod. https://doi.org/10.1016/j.jclepro.2019.02.085

Allwood, J.M., 2014. Squaring the Circular Economy: The Role of Recycling within a Hierarchy of Material Management Strategies, in: Handbook of Recycling: State-of-the-Art for Practitioners, Analysts, and Scientists. https://doi.org/10.1016/B978-0-12-396459-5.00030-1

Allwood, J.M., Cullen, J.M., Milford, R.L., 2010. Options for achieving a 50% cut in industrial carbon emissions by 2050. Environ. Sci. Technol. https://doi.org/10.1021/es902909k

Amsterdam, 2020. Amsterdam Circular Strategy 2020-2025.

Anderson, L., Ostrom, A.L., Corus, C., Fisk, R.P., Gallan, A.S., Giraldo, M., Mende, M., Mulder, M., Rayburn, S.W., Rosenbaum, M.S., Shirahada, K., Williams, J.D., 2013. Transformative service research: An agenda for the future. J. Bus. Res. 66, 1203–1210. https://doi.org/10.1016/j.jbusres.2012.08.013

Anderson, P., 1999. Complexity Theory and Organization Science. Organ. Sci. https://doi.org/10.1287/orsc.10.3.216

Antikainen, M., Aminoff, A., Kettunen, O., Sundqvist-Andberg, H., Paloheimo, H., 2017a. Circular economy business model innovation process – Case study, in: Smart Innovation, Systems and Technologies. https://doi.org/10.1007/978-3-319-57078-5_52

Antikainen, M., Aminoff, A., Paloheimo, H., Kettunen, O., 2017b. Designing circular business model experimentation - Case study. ISPIM Innov. Forum 1–14.
Antikainen, M., Valkokari, K., Mcclelland, J., 2016. A Framework for Sustainable Circular Business Model Innovation. Technol. Innov. Manag. Rev. 6, 5–12.
Antikainen, R., Alhola, K., Jääskeläinen, T., 2017. Experiments as a means towards sustainable societies Lessons learnt and future outlooks from a Finnish perspective. J. Clean. Prod. 169, 216224. https://doi.org/10.1016/j.jclepro.2017.06.184
Anttonen, M., Lammi, M., Mykkänen, J., Repo, P., 2018. Circular Economy in the Triple Helix of Innovation Systems. Sustainability 10, 2646. https://doi.org/10.3390/su10082646
Aquafil, 2019. Aquafil - The ECONYL® yarn [WWW Document]. URL https://www.aquafil.com/sustainability/econyl/ (accessed 8.6.19).
Autio, E., Kenney, M., Mustar, P., Siegel, D., Wright, M., 2014. Entrepreneurial innovation: The importance of context. Res. Policy 43, 1097–1108. https://doi.org/10.1016/j.respol.2014.01.015
Baden-Fuller, C., Morgan, M.S., 2010. Business models as models. Long Range Plann. https://doi.org/10.1016/j.lrp.2010.02.005
Bakker, C., Wang, F., Huisman, J., Den Hollander, M., 2014. Products that go round: Exploring product life extension through design. J. Clean. Prod. https://doi.org/10.1016/j.jclepro.2014.01.028
Baldassarre, B., Calabretta, G., Bocken, N.M.P., Jaskiewicz, T., 2017. Bridging sustainable business model innovation and user-driven innovation: A process for sustainable value proposition design. J. Clean. Prod. https://doi.org/10.1016/j.jclepro.2017.01.081
Baldassarre, B., Keskin, D., Diehl, J.C., Bocken, N., Calabretta, G., 2020a. Implementing sustainable design theory in business practice: A call to action. J. Clean. Prod. https://doi.org/10.1016/j.jclepro.2020.123113
Baldassarre, B., Konietzko, J., Brown, P., Calabretta, G., Bocken, N., Karpen, I.O., Hultink, E.J., 2020b. Addressing the design-implementation gap of sustainable business models by prototyping: A tool for planning and executing small-scale pilots. J. Clean. Prod. 255, 120295. https://doi.org/10.1016/j.jclepro.2020.120295
Baldwin, C.Y., Clark, K.B., 2000. Design Rules: The Power of Modularity Volume 1, Academy of Management The Academy of Management Review. https://doi.org/10.1159/000348293
BAMB, 2020. About bamb - BAMB [WWW Document]. URL https://www.bamb2020.eu/about-bamb/ (accessed 8.10.20).
Bansal, P., 2005. Evolving sustainably: A longitudinal study of corporate sustainable development. Strateg. Manag. J. https://doi.org/10.1002/smj.441
Bar-On, Y.M., Phillips, R., Milo, R., 2018. The biomass distribution on Earth. Proc. Natl. Acad. Sci. U. S. A. https://doi.org/10.1073/pnas.1711842115
Barile, S., Lusch, R., Reynoso, J., Saviano, M., Spohrer, J., 2016. Systems, networks, and ecosystems in service research. J. Serv. Manag. 27, 652–674. https://doi.org/10.1108/JOSM-09-2015-0268
Barrett, M., Davidson, E., Prabhu, J., Vargo, S.L., 2015. Service Innovation in the Digital Age: Key Contributions and Future Directions. MIS Q. 39, 135–154. https://doi.org/10.25300/MISQ/2015/39:1.03
Baumann, H., Boons, F., Bragd, A., 2002. Mapping the green product development field: Engineering, policy and business perspectives. J. Clean. Prod. https://doi.org/10.1016/S0959-6526(02)00015-X
Berkel, R., Willems, E., Lafleur, M., 1997. The Relationship between Cleaner Production and Industrial Ecology. J. Ind. Ecol. https://doi.org/10.1162/jiec.1997.1.1.51
Berthet, E.T., Hickey, G.M., Klerkx, L., 2018. Opening design and innovation processes in agriculture: Insights from design and management sciences and future directions. Agric. Syst. https://doi.org/10.1016/j.agsy.2018.06.004
Bijl-Brouwer, M. van der, Malcolm, B., 2020. Systemic Design Principles in Social Innovation: A Study of Expert Practices and Design Rationales. She Ji. https://doi.org/10.1016/j.sheji.2020.06.001
Blank, S., 2013. The four steps to the epiphany, Fifth edit. ed. K&S.
Blomsma, F., Brennan, G., 2017. The Emergence of Circular Economy: A New Framing Around Prolonging Resource Productivity. J. Ind. Ecol. 21, 603–614. https://doi.org/10.1111/jiec.12603

Blomsma, F., Pieroni, M., Kravchenko, M., Pigosso, D.C.A., Hildenbrand, J., Kristinsdottir, A.R., Kristoffersen, E., Shahbazi, S., Nielsen, K.D., Jönbrink, A.-K., Li, J., Wiik, C., McAloone, T.C., 2019. Developing a circular strategies framework for manufacturing companies to support circular economy-oriented innovation. J. Clean. Prod. 241, 118271. https://doi.org/10.1016/J.JCLEPRO.2019.118271

Bocken, N., Boons, F., Baldassarre, B., 2019a. Sustainable business model experimentation by understanding ecologies of business models. J. Clean. Prod. https://doi.org/10.1016/j.jclepro.2018.10.159

Bocken, N., Ingemarsdotter, E., Gonzalez, D., 2019b. Designing Sustainable Business Models: Exploring IoT-Enabled Strategies to Drive Sustainable Consumption, in: Sustainable Business Models. Springer International Publishing, Cham, pp. 61–88. https://doi.org/10.1007/978-3-319-93275-0_3

Bocken, N., Miller, K., Weissbrod, I., Holgado, M., Evans, S., 2019c. Slowing resource loops in the circular economy: An experimentation approach in fashion retail, in: Smart Innovation, Systems and Technologies. https://doi.org/10.1007/978-3-030-04290-5_17

Bocken, N., Schuit, C.S.C., Kraaijenhagen, C., 2018. Experimenting with a circular business model: Lessons from eight cases. Environ. Innov. Soc. Transitions.

Bocken, N., Short, S., Rana, P., Evans, S., 2013. A value mapping tool for sustainable business modelling. Corp. Gov. Int. J. Bus. Soc. 13, 482–497. https://doi.org/10.1108/CG-06-2013-0078

Bocken, N., Strupeit, L., Whalen, K., Nußholz, J., 2019d. A review and evaluation of circular business model innovation tools. Sustain. https://doi.org/10.3390/su11082210

Bocken, N., Strupeit, L., Whalen, K., Nußholz, J., Bocken, N., Strupeit, L., Whalen, K., Nußholz, J., 2019e. A Review and Evaluation of Circular Business Model Innovation Tools. Sustainability 11, 2210. https://doi.org/10.3390/su11082210

Bocken, N.M.P., Allwood, J.M., Willey, A.R., King, J.M.H., 2012. Development of a tool for rapidly assessing the implementation difficulty and emissions benefits of innovations. Technovation. https://doi.org/10.1016/j.technovation.2011.09.005

Bocken, N.M.P., Allwood, J.M., Willey, A.R., King, J.M.H., 2011. Development of an eco-ideation tool to identify stepwise greenhouse gas emissions reduction options for consumer goods. J. Clean. Prod. 19, 1279–1287. https://doi.org/10.1016/j.jclepro.2011.04.009

Bocken, N.M.P., Antikainen, M., 2019. Circular business model experimentation: Concept and approaches, in: Smart Innovation, Systems and Technologies. https://doi.org/10.1007/978-3-030-04290-5_25

Bocken, N.M.P., Bakker, C., Pauw, I. De, 2016. Product design and business model strategies for a circular economy. J. Ind. Prod. Eng. 1015, 20. https://doi.org/10.1080/21681015.2016.1172124

Bocken, N.M.P., Boons, F., Baldassarre, B., 2019. Sustainable business model experimentation by understanding ecologies of business models. J. Clean. Prod. 208C, 1498–1512.

Bocken, N.M.P., Miller, K., Weissbrod, I., Holgado, M., Evans, S., 2017. Business model experimentation for circularity: Driving sustainability in a large international clothing retailer. Econ. Policy Energy Environ. https://doi.org/10.3280/EFE2017-001006

Bocken, Nancy M.P., Mugge, R., Bom, C.A., Lemstra, H.J., 2018. Pay-per-use business models as a driver for sustainable consumption: Evidence from the case of HOMIE. J. Clean. Prod. https://doi.org/10.1016/j.jclepro.2018.07.043

Bocken, N. M.P., Schuit, C.S.C., Kraaijenhagen, C., 2018. Experimenting with a circular business model: Lessons from eight cases. Environ. Innov. Soc. Transitions. https://doi.org/10.1016/j.eist.2018.02.001

Bocken, N.M.P., Short, S., Rana, P., Evans, S., 2013. A value mapping tool for sustainable business modelling. Corp. Gov. Int. J. Bus. Soc. 13, 482–497. https://doi.org/10.1108/CG-06-2013-0078

Bocken, N.M.P., Short, S.W., 2016. Towards a sufficiency-driven business model: Experiences and opportunities. Environ. Innov. Soc. Transitions 18, 41–61. https://doi.org/10.1016/j.eist.2015.07.010

Bocken, N.M.P., Short, S.W., Rana, P., Evans, S., 2014. A literature and practice review to develop sustainable business model archetypes. J. Clean. Prod. https://doi.org/10.1016/j.jclepro.2013.11.039

Boer, H., During, W.E., 2001. Innovation, what innovation? a comparison between product, process and organizational innovation. Int. J. Technol. Manag.

Bolton, R.N., 2020. Commentary: future directions of the service discipline. J. Serv. Mark. ahead-of-print. https://doi.org/10.1108/jsm-02-2020-0067

Boons, F., Bocken, N., 2017. Assessing the sharing economy: analyzing ecologies of business models, in: Product Lifetimes And e Environment 2017 - Conference Proceedings. pp. 46–50.

Bosch-Sijtsema, P.M., Bosch, J., 2014. Aligning innovation ecosystem strategies with internal R&D, in: 2014 IEEE International Conference on Management of Innovation and Technology. IEEE, pp. 424–430. https://doi.org/10.1109/ICMIT.2014.6942464
Bosch, T., Verploegen, K., Grösser, S.N., van Rhijn, G., 2017. Sustainable furniture that grows with end-users, in: Dynamics of Long-Life Assets: From Technology Adaptation to Upgrading the Business Model. https://doi.org/10.1007/978-3-319-45438-2_16
Boudreau, K., 2010. Open Platform Strategies and Innovation: Granting Access vs. Devolving Control. Manage. Sci. https://doi.org/10.1287/mnsc.1100.1215
Brown, P., Bocken, N., Balkenende, R., Brown, P., Bocken, N., Balkenende, R., 2019. Why Do Companies Pursue Collaborative Circular Oriented Innovation? Sustainability 11, 635. https://doi.org/10.3390/su11030635
Brown, R., Mason, C., 2017. Looking inside the spiky bits: a critical review and conceptualisation of entrepreneurial ecosystems. Small Bus. Econ. 49, 11–30. https://doi.org/10.1007/s11187-017-9865-7
Brown, T., 2008. Design thinking. Harv. Bus. Rev. 86. https://doi.org/10.1145/2535915
Buchanan, R., 2019. Systems Thinking and Design Thinking: The Search for Principles in the World We Are Making. She Ji. https://doi.org/10.1016/j.sheji.2019.04.001
Byggeth, S., Broman, G., Robèrt, K.H., 2007. A method for sustainable product development based on a modular system of guiding questions. J. Clean. Prod. https://doi.org/10.1016/j.jclepro.2006.02.007
Calabretta, G., Gemser, G., Karpen, I., 2016. Strategic Design: 8 Essential Practices Every Strategic Designer Must Master. BIS Publishers.
Camuffo, A., Cordova, A., Gambardella, A., Spina, C., 2019. A Scientific Approach to Entrepreneurial Decision Making: Evidence from a Randomized Control Trial. Manage. Sci. https://doi.org/10.1287/mnsc.2018.3249
Cao, Z., Shi, X., 2020. A systematic literature review of entrepreneurial ecosystems in advanced and emerging economies. Small Bus. Econ. 1–36. https://doi.org/10.1007/s11187-020-00326-y
Carayannis, E.G., Campbell, D.F.J., 2009. "Mode 3" and "Quadruple Helix": toward a 21st century fractal innovation ecosystem. Int. J. Technol. Manag. https://doi.org/10.1504/ijtm.2009.023374
Cardoso, A.C., Free, G., Nõges, P., Kaste, Ø., Poikane, S., Solheim, A.L., 2009. Lake Management, Criteria, in: Encyclopedia of Inland Waters. https://doi.org/http://dx.doi.org/10.1016/B978-012370626-3.00244-1
Carter, C.R., Rogers, D.S., Choi, T.Y., 2015. Toward the theory of the supply chain. J. Supply Chain Manag. https://doi.org/10.1111/jscm.12073
Ceccagnoli, Forman, Huang, Wu, 2012. Cocreation of Value in a Platform Ecosystem! The Case of Enterprise Software. MIS Q. 36, 263. https://doi.org/10.2307/41410417
Ceschin, F., Gaziulusoy, I., 2016. Evolution of design for sustainability: From product design to design for system innovations and transitions. Des. Stud. 47, 118–163. https://doi.org/10.1016/j.destud.2016.09.002
Chandler, J.D., Danatzis, I., Wernicke, C., Akaka, M.A., Reynolds, D., 2019. How Does Innovation Emerge in a Service Ecosystem? J. Serv. Res. 22, 75–89. https://doi.org/10.1177/1094670518797479
Chandler, J.D., Vargo, S.L., 2011. Contextualization and value-in-context: How context frames exchange. Mark. Theory. https://doi.org/10.1177/1470593110393713
Chesbrough, H., 2010. Business model innovation: Opportunities and barriers. Long Range Plann. 43, 354–363. https://doi.org/10.1016/j.lrp.2009.07.010
Chesbrough, H., Kim, S., Agogino, A., 2014. Chez Panisse: Building an Open Innovation Ecosystem. Calif. Manage. Rev. 56, 144–171. https://doi.org/10.1525/cmr.2014.56.4.144
Chesbrough, H.W., Appleyard, M.M., 2007. Open Innovation and Strategy. Calif. Manage. Rev. 50, 57–76. https://doi.org/10.2307/41166416
Chierici, E., Copani, G., 2016. Remanufacturing with Upgrade PSS for New Sustainable Business Models, in: Procedia CIRP. https://doi.org/10.1016/j.procir.2016.03.055
China, EU, 2018. Memorandum of Understanding between the European Commission and the National Development and Reform Commission of the People's Republic of China.
Christensen, C., 2012. How Will You Measure Your Life? Clay Christensen at TEDxBoston - YouTube [WWW Document]. URL https://www.youtube.com/watch?v=tvos4nORf_Y (accessed 2.20.19).
Circle Economy, 2015. Amsterdam circular - a vision and roadmap for the city and region. Amsterdam.

Clarysse, B., Wright, M., Bruneel, J., Mahajan, A., 2014. Creating value in ecosystems: Crossing the chasm between knowledge and business ecosystems. Res. Policy. https://doi.org/10.1016/j.respol.2014.04.014
Closing the Loop, 2019. Closed loop solutions for mobile phones | Closing the Loop [WWW Document]. URL http://www.closingtheloop.eu/ (accessed 8.6.19).
Cohen, B., 2006. Sustainable valley entrepreneurial ecosystems. Bus. Strateg. Environ. 15, 1–14. https://doi.org/10.1002/bse.428
Cook, T., Campbell, D., 1979. Quasi-Experimentation: Design and Analysis Issues for Field Settings. Houghton Mifflin Company, Boston.
Cooper, D.R., Skelton, A.C.H., Moynihan, M.C., Allwood, J.M., 2014. Component level strategies for exploiting the lifespan of steel in products. Resour. Conserv. Recycl. https://doi.org/10.1016/j.resconrec.2013.11.014
Cooper, R.G., 1990. Stage-gate systems: A new tool for managing new products. Bus. Horiz. 33, 44–54. https://doi.org/10.1016/0007-6813(90)90040-I
Côté, R., Hall, J., 1995. Industrial parks as ecosystems. J. Clean. Prod. https://doi.org/10.1016/0959-6526(95)00041-C
Côté, R.P., Cohen-Rosenthal, E., 1998. Designing eco-industrial parks: A synthesis of some experiences. J. Clean. Prod. 6, 181–188. https://doi.org/10.1016/s0959-6526(98)00029-8
Cradle to Cradle, 2019. Resources - Cradle to Cradle Products Innovation Institute [WWW Document]. URL https://www.c2ccertified.org/resources/detail/cradle-to-cradle-certified-banned-list-of-chemicals (accessed 8.6.19).
Croll, A., Yoskovitz, B., 2013. Lean Analytics. O'Reilly Media Inc., Sebastopol.
Currie, W.S., 2011. Units of nature or processes across scales? The ecosystem concept at age 75. New Phytol. 190, 21–34. https://doi.org/10.1111/j.1469-8137.2011.03646.x
Darn Tough Vermont, 2019. Darn Tough Vermont - Premium Merino Wool Socks, for more than hiking [WWW Document]. URL https://darntough.com/ (accessed 8.6.19).
Davis, F.D., 1989. Perceived Usefulness, Perceived Ease Of Use, And User Acceptance of Information Technology. MIS Q. 13, 319–40.
Davis, J.P., 2016. The Group Dynamics of Interorganizational Relationships: Collaborating with Multiple Partners in Innovation Ecosystems. Adm. Sci. Q. https://doi.org/10.1177/0001839216649350
De Bernardi, P., Azucar, D., 2020. Innovation and entrepreneurial ecosystems: Structure, boundaries, and dynamics, in: Contributions to Management Science. https://doi.org/10.1007/978-3-030-33502-1_3
De los Rios, I.C., Charnley, F.J.S., 2017. Skills and capabilities for a sustainable and circular economy: The changing role of design. J. Clean. Prod. 160, 109–122. https://doi.org/10.1016/j.jclepro.2016.10.130
den Hollander, M.C., Bakker, C.A., Hultink, E.J., 2017. Product Design in a Circular Economy: Development of a Typology of Key Concepts and Terms. J. Ind. Ecol. 21, 517–525. https://doi.org/10.1111/jiec.12610
Denyer, D., Tranfield, D., Van Aken, J.E., 2008. Developing design propositions through research synthesis. Organ. Stud. https://doi.org/10.1177/0170840607088020
Despeisse, M., Ball, P.D., Evans, S., Levers, A., 2012. Industrial ecology at factory level - A conceptual model. J. Clean. Prod. 31, 30–39. https://doi.org/10.1016/j.jclepro.2012.02.027
Dig Inn, 2019. Dig Inn [WWW Document]. URL https://www.diginn.com/ (accessed 8.27.19).
Eckhardt, J.T., Ciuchta, M.P., Carpenter, M., 2018. Open innovation, information, and entrepreneurship within platform ecosystems. Strateg. Entrep. J. 12, 369–391. https://doi.org/10.1002/sej.1298
Ecovative, 2019. Ecovative Design [WWW Document]. URL https://ecovativedesign.com/ (accessed 12.8.19).
Ehrenfeld, J., 2019. Flourishing: Designing a Brave New World. She Ji 5, 105–116. https://doi.org/10.1016/j.sheji.2019.03.001
Elia, G., Margherita, A., Petti, C., 2020. Building responses to sustainable development challenges: A multistakeholder collaboration framework and application to climate change. Bus. Strateg. Environ. bse.2514. https://doi.org/10.1002/bse.2514
Elia, V., Gnoni, M.G., Tornese, F., 2016. Measuring circular economy strategies through index methods: A critical analysis. J. Clean. Prod. https://doi.org/10.1016/j.jclepro.2016.10.196
Ellen Macarthur Foundation, 2019. Kaer Air conditioning as a service reduces building carbon emissions [WWW Document]. URL https://www.ellenmacarthurfoundation.org/case-studies/air-conditioning-as-a-service-reduces-building-carbon-emissions (accessed 8.27.19).
Ellen MacArthur Foundation, 2019a. Artificial Intelligence and the Circular Economy.

TOC

Ellen MacArthur Foundation, 2019b. Reuse – Rethinking Packaging.
Ellen MacArthur Foundation, 2019c. Case studies - Teemill [WWW Document]. URL https://www.ellenmacarthurfoundation.org/case-studies/an-open-access-circular-supply-chain-for-fashion (accessed 8.21.19).
Ellen MacArthur Foundation, 2019d. Case studies [WWW Document]. URL https://www.ellenmacarthurfoundation.org/case-studies/remanufacturing-at-scale (accessed 8.7.19).
Ellen MacArthur Foundation, 2018. Cities and circular economy for food. Ellen Macarthur Found.
Elmqvist, T., Setälä, H., Handel, S.N., van der Ploeg, S., Aronson, J., Blignaut, J.N., Gómez-Baggethun, E., Nowak, D.J., Kronenberg, J., de Groot, R., 2015. Benefits of restoring ecosystem services in urban areas. Curr. Opin. Environ. Sustain. https://doi.org/10.1016/j.cosust.2015.05.001
Emerson, K., Nabatchi, T., Balogh, S., 2011. An Integrative Framework for Collaborative Governance. J. Public Adm. Res. Theory 22, 1–29. https://doi.org/10.1093/jopart/mur011
EMF, 2017. Cities in the Circular Economy: An initial Exploration.
EMF, 2015. Growth within: a circular economy vision for a competitive europe. Ellen MacArthur Found. 100. https://doi.org/Article
EMF, 2012. Towards a Circular Economy - Economic and Business Rationale for an Accelerated Transition. Greener Manag. Int. 97. https://doi.org/2012-04-03
EU, 2016. Closing the loop New circular economy package.
European Commission, 2019. Accelerated Metallurgy Project Website [WWW Document].
Evans, S., Vladimirova, D., Holgado, M., Van Fossen, K., Yang, M., Silva, E.A., Barlow, C.Y., 2017. Business Model Innovation for Sustainability: Towards a Unified Perspective for Creation of Sustainable Business Models. Bus. Strateg. Environ. https://doi.org/10.1002/bse.1939
Fairphone, 2019. Fairphone [WWW Document]. URL https://www.fairphone.com/en/ (accessed 8.21.19).
Felin, T., Gambardella, A., Stern, S., Zenger, T., 2019. Lean startup and the business model: Experimentation revisited. Long Range Plann. https://doi.org/10.1016/j.lrp.2019.06.002
Felin, T., Zenger, T.R., 2009. Entrepreneurs as theorists: on the origins of collective beliefs and novel strategies. Strateg. Entrep. J. https://doi.org/10.1002/sej.67
Filho, W.L., Barbir, J., Nagy, G.J., Sima, M., Kalbus, A., Paletta, A., Villamizar, A., Martinez, R., Azeiteiro, U.M., Pereira, M.J., Mussetta, P.C., Ivars, J.D., Salgueirinho Osório de Andrade Guerra, J.B., de Silva Neiva, S., Moncada, S., Galdies, C., Klavins, M., Nikolova, M., Gogu, R.C., Babatunde Balogun, A.-L., Bouredji, A., Bonoli, A., 2020. Reviewing the role of ecosystems services in the sustainability of the urban environment: A multi-country analysis. J. Clean. Prod. https://doi.org/10.1016/j.jclepro.2020.121338
Flood, R.L., 2010. The Relationship of 'Systems Thinking' to Action Research. Syst. Pract. Action Res. 23, 269–284. https://doi.org/10.1007/s11213-010-9169-1
Folke, C., 2006. Resilience: The emergence of a perspective for social–ecological systems analyses. Glob. Environ. Chang. 16, 253–267. https://doi.org/10.1016/j.gloenvcha.2006.04.002
Foodlogica, 2019. FOODLOGICA - DUURZAME LOGISTIEK VOOR LOKALE MERKEN EN HORECA [WWW Document]. URL https://foodlogica.com/ (accessed 8.6.19).
Forister, M.L., Pelton, E.M., Black, S.H., 2019. Declines in insect abundance and diversity: We know enough to act now. Conserv. Sci. Pract. https://doi.org/10.1111/csp2.80
Foss, N.J., Klein, P.G., Bjørnskov, C., 2019. The Context of Entrepreneurial Judgment: Organizations, Markets, and Institutions. J. Manag. Stud. https://doi.org/10.1111/joms.12428
Främling, K., Holmström, J., Loukkola, J., Nyman, J., Kaustell, A., 2013. Sustainable PLM through Intelligent Products. Eng. Appl. Artif. Intell. 26, 789–799. https://doi.org/10.1016/J.ENGAPPAI.2012.08.012
Frenken, K., Schor, J., 2017. Putting the sharing economy into perspective. Environ. Innov. Soc. Transitions 23, 3–10. https://doi.org/10.1016/j.eist.2017.01.003
Freudenreich, B., Lüdeke-Freund, F., Schaltegger, S., 2020. A Stakeholder Theory Perspective on Business Models: Value Creation for Sustainability. J. Bus. Ethics. https://doi.org/10.1007/s10551-019-04112-z
Friedman, B., Hendry, D.G., 2012. The envisioning cards: A toolkit for catalyzing humanistic and technical imaginations. Proc. 2012 ACM Annu. Conf. Hum. Factors Comput. Syst. - CHI '12. https://doi.org/10.1145/2207676.2208562
Frosch, R.A., Gallopoulos, N.E., 1989. Strategies for Manufacturing. Sci. Am. https://doi.org/10.1038/scientificamerican0989-144
Fuller, J., Jacobides, M.G., Reeves, M., 2019. The Myths and Realities of Business Ecosystems. MIT Sloan Manag. Rev.

Gawer, A., 2014. Bridging differing perspectives on technological platforms: Toward an integrative framework. Res. Policy. https://doi.org/10.1016/j.respol.2014.03.006
Gawer, A., Cusumano, M.A., 2014. Industry platforms and ecosystem innovation. J. Prod. Innov. Manag. 31, 417–433. https://doi.org/10.1111/jpim.12105
Ge, X., Jackson, J., 2014. The Big Data Application Strategy for Cost Reduction in Automotive Industry. SAE Int. J. Commer. Veh. https://doi.org/10.4271/2014-01-2410
Geels, F.W., 2002. Technological transitions as evolutionary reconfiguration processes: A multi-level perspective and a case-study. Res. Policy. https://doi.org/10.1016/S0048-7333(02)00062-8
Geissdoerfer, M., Bocken, N., Hultink, E.J., 2016. Design Thinking to Enhance the Sustainable Business Modelling Process.
Geissdoerfer, M., Savaget, P., Bocken, N.M.P., Hultink, E.J., 2017. The Circular Economy – A new sustainability paradigm? J. Clean. Prod. 143, 757–768. https://doi.org/10.1016/j.jclepro.2016.12.048
George, G., Merrill, R.K., Schillebeeckx, S.J.D., 2020. Digital Sustainability and Entrepreneurship: How Digital Innovations Are Helping Tackle Climate Change and Sustainable Development. Entrep. Theory Pract. 104225871989942. https://doi.org/10.1177/1042258719899425
Ghisellini, P., Cialani, C., Ulgiati, S., 2016. A review on circular economy: The expected transition to a balanced interplay of environmental and economic systems. J. Clean. Prod. https://doi.org/10.1016/j.jclepro.2015.09.007
Gispen, 2019. Remade by Gispen | Circular Economy | About Remade | Gispen [WWW Document]. URL https://www.gispen.com/en/circular-economy/repurpose-remade-by-gispen (accessed 8.19.19).
Golembewski, M., Selby, M., 2010. Ideation Decks: A Card Based Ideation Tool, in: DIS '10: Proceedings of the 8th ACM Conference on Designing Interactive Systems.
Gomes, L.A. de V., Facin, A.L.F., Salerno, M.S., Ikenami, R.K., 2018. Unpacking the innovation ecosystem construct: Evolution, gaps and trends. Technol. Forecast. Soc. Change. https://doi.org/10.1016/j.techfore.2016.11.009
Gomez-Carrasco, P., Michelon, G., 2017. The Power of Stakeholders' Voice: The Effects of Social Media Activism on Stock Markets. Bus. Strateg. Environ. 26, 855–872. https://doi.org/10.1002/bse.1973
Gottschalg, O., Zollo, M., 2007. Interest alignment and competitive advantage. Acad. Manag. Rev. https://doi.org/10.5465/AMR.2007.24351356
Govindan, K., Jafarian, A., Khodaverdi, R., Devika, K., 2014. Two-echelon multiple-vehicle location-routing problem with time windows for optimization of sustainable supply chain network of perishable food. Int. J. Prod. Econ. https://doi.org/10.1016/j.ijpe.2013.12.028
Guedes, G.B., Paganin, L.B.Z., Borsato, M., 2018. Bibliometric and Systemic Analysis on Material Flow Mapping and Industrial Ecosystems. J. Ind. Integr. Manag. 03, 1850001. https://doi.org/10.1142/s242486221850001x
Guerrero, M., Urbano, D., Fayolle, A., Klofsten, M., Mian, S., 2016. Entrepreneurial universities: emerging models in the new social and economic landscape. Small Bus. Econ. https://doi.org/10.1007/s11187-016-9755-4
Guide Jr, V.D.R., Van Wassenhove, L.N., 2009. OR FORUM-the evolution of closed-loop supply chain research. Oper. Res. 57, 10–18. https://doi.org/10.1287/opre.1080.0628
Guldmann, E., Bocken, N.M.P., Brezet, H., 2019. A Design Thinking Framework for Circular Business Model Innovation. J. Bus. Model. 7, 39–70. https://doi.org/10.5278/ojs.jbm.v7i1.2122
Gupta, S., Chen, H., Hazen, B.T., Kaur, S., Santibañez Gonzalez, E.D.R., 2019. Circular economy and big data analytics: A stakeholder perspective. Technol. Forecast. Soc. Change. https://doi.org/10.1016/j.techfore.2018.06.030
Guzzo, D., Trevisan, A.H., Echeveste, M., Costa, J.M.H., 2019. Circular Innovation Framework: Verifying Conceptual to Practical Decisions in Sustainability-Oriented Product-Service System Cases. Sustainability 11, 3248. https://doi.org/10.3390/su11123248
Häagen-Dazs, 2019. Häagen-Dazs® Loves Honey Bees | Häagen-Dazs® [WWW Document]. URL https://www.haagendazs.us/about/news/haagen-dazsr-loves-honey-bees (accessed 8.6.19).
Haffmans, S., Gelder, M. van, Hinte, E. van, Zijlstra, Y., n.d. Products that flow : circular business models and design strategies for fast-moving consumer goods.
Haines-Gadd, M., Chapman, J., Lloyd, P., Mason, J., Aliakseyeu, D., 2018. Emotional durability design Nine-A tool for product longevity. Sustain. https://doi.org/10.3390/su10061948

TOC

Hakala, H., O'Shea, G., Farny, S., Luoto, S., 2020. Re-storying the Business, Innovation and Entrepreneurial Ecosystem Concepts: The Model-Narrative Review Method. Int. J. Manag. Rev. 22, 10–32. https://doi.org/10.1111/ijmr.12212
Halinen, A., Törnroos, J.Å., 2005. Using case methods in the study of contemporary business networks. J. Bus. Res. 58, 1285–1297. https://doi.org/10.1016/j.jbusres.2004.02.001
Harper, E.M., Graedel, T.E., 2004. Industrial ecology: A teenager's progress. Technol. Soc. 26, 433–445. https://doi.org/10.1016/j.techsoc.2004.01.013
Hayter, C.S., 2016. A trajectory of early-stage spinoff success: the role of knowledge intermediaries within an entrepreneurial university ecosystem. Small Bus. Econ. https://doi.org/10.1007/s11187-016-9756-3
Heikkilä, M., Bouwman, H., Heikkilä, J., Solaimani, S., Janssen, W., 2016. Business model metrics: an open repository. Inf. Syst. E-bus. Manag. https://doi.org/10.1007/s10257-015-0286-3
Hein, A., Scheiber, M., Böhm, M., Weking, J., 2018. Towards a Design Framework for Service Platform Ecosystems. Res. Pap.
Hellström, M., Tsvetkova, A., Gustafsson, M., Wikström, K., 2015. Collaboration mechanisms for business models in distributed energy ecosystems. J. Clean. Prod. 102, 226–236. https://doi.org/10.1016/j.jclepro.2015.04.128
Henry, M., Bauwens, T., Hekkert, M., Kirchherr, J., 2020. A typology of circular start-ups: Analysis of 128 circular business models. J. Clean. Prod. https://doi.org/10.1016/j.jclepro.2019.118528
Hens, L., Block, C., Cabello-Eras, J.J., Sagastume-Gutierez, A., Garcia-Lorenzo, D., Chamorro, C., Herrera Mendoza, K., Haeseldonckx, D., Vandecasteele, C., 2018. On the evolution of "Cleaner Production" as a concept and a practice. J. Clean. Prod. https://doi.org/10.1016/j.jclepro.2017.11.082
Herczeg, G., Akkerman, R., Hauschild, M.Z., 2018. Supply chain collaboration in industrial symbiosis networks. J. Clean. Prod. https://doi.org/10.1016/j.jclepro.2017.10.046
Heuer, M., 2011. Ecosystem cross-sector collaboration: conceptualizing an adaptive approach to sustainability governance. Bus. Strateg. Environ. 20, 211–221. https://doi.org/10.1002/bse.673
Heyes, G., Sharmina, M., Mendoza, J.M.F., Gallego-Schmid, A., Azapagic, A., 2018. Developing and implementing circular economy business models in service-oriented technology companies. J. Clean. Prod. https://doi.org/10.1016/j.jclepro.2017.12.168
Holling, C.S., Gunderson, L.H., 2002. Resilience and adaptive cycles. Panarchy Underst. Transform. Hum. Nat. Syst. 25–62. https://doi.org/10.1016/j.ecolecon.2004.01.010
Holmqvist, J., Diaz Ruiz, C., 2017. Service ecosystems, markets and business networks: What is the difference? A horizontal literature review. TQM J. 29, 800–810. https://doi.org/10.1108/TQM-03-2017-0028
Hopper, J.R., Nielsen, J.M., 1991. Recycling as altruistic behavior: Normative and Behavioral Strategies to Expand Participation in a Community Recycling Program. Environ. Behav. https://doi.org/10.1177/0013916591232004
Hribernik, K. a, Ghrairi, Z., Hans, C., Thoben, K., 2011. Co-creating the Internet of Things - First Experiences in the Participatory Design of Intelligent Products with Arduino. Concurr. Enterprising (ICE), 2011 17th Int. Conf. 1–9.
Hsieh, Y.C., Lin, K.Y., Lu, C., Rong, K., 2017. Governing a sustainable business ecosystem in Taiwan's circular economy: The story of spring pool glass. Sustain. https://doi.org/10.3390/su9061068
Huang, P., Mithas, S., Tafti, A., 2018. Platform Sponsor Investments and User Contributions in Knowledge Communities: The Role of Knowledge Seeding. MIS Q. https://doi.org/10.25300/misq/2018/13490
Iansiti, M., Levien, R., 2004a. The keystone advantage. Networks 1.
Iansiti, M., Levien, R., 2004b. Strategy as Ecology. Harv. Bus. Rev. https://doi.org/10.1108/eb025570
IDEO, 2019. The Circular Design Guide [WWW Document]. URL https://www.circulardesignguide.com/ (accessed 9.19.19).
Impossible Foods, 2019. Home - Impossible Foods [WWW Document]. URL https://impossiblefoods.com/ (accessed 8.6.19).
IPCC, 2018. Special Report on Global Warming of 1.5°C.
IRP, 2019. Global Resources Outlook 2019: Natural Resources for the Future We Want. Nairobi, Kenya.
Järvi, K., Almpanopoulou, A., Ritala, P., 2018. Organization of knowledge ecosystems: Prefigurative and partial forms. Res. Policy. https://doi.org/10.1016/j.respol.2018.05.007

Jabbour, C.J.C., Jabbour, A.B.L. de S., Sarkis, J., Filho, M.G., 2019. Unlocking the circular economy through new business models based on large-scale data: An integrative framework and research agenda. Technol. Forecast. Soc. Change. https://doi.org/10.1016/j.techfore.2017.09.010

Jacobides, M G, Cennamo, C., Gawer, A., 2018. TOWARDS A THEORY OF ECOSYSTEMS Michael. J. Strateg. Manag. 804–828. https://doi.org/10.1002/smj.2

Jacobides, Michael G., Cennamo, C., Gawer, A., 2018. Towards a theory of ecosystems. Strateg. Manag. J. https://doi.org/10.1002/smj.2904

Jacobsen, N.B., 2006. Industrial symbiosis in Kalundborg, Denmark: A quantitative assessment of economic and environmental aspects. J. Ind. Ecol. https://doi.org/10.1162/108819806775545411

Jarzabkowski, P., Kaplan, S., 2015. Strategy tools-in-use: A framework for understanding "technologies of rationality" in practice. Strateg. Manag. J. https://doi.org/10.1002/smj.2270

Jelinski, L.W., Graedel, T.E., Laudise, R.A., McCall, D.W., Patel, C.K.N., 1992. Industrial ecology: Concepts and approaches, in: Proceedings of the National Academy of Sciences of the United States of America. https://doi.org/10.1073/pnas.89.3.793

Joyce, A., Paquin, R.L., 2016. The triple layered business model canvas: A tool to design more sustainable business models. J. Clean. Prod. https://doi.org/10.1016/j.jclepro.2016.06.067

Kania, J., Hanleybrown, F., Juster, J.S., 2014. Essential Mindset Shifts for Collective Impact. Stanford Soc. Innov. Rev.

Kent, R., Kent, R., 2016. Design quality management. Qual. Manag. Plast. Process. 227–262. https://doi.org/10.1016/B978-0-08-102082-1.50008-3

Kerin, M., Pham, D.T., 2019. A review of emerging industry 4.0 technologies in remanufacturing. J. Clean. Prod. 237, 117805. https://doi.org/10.1016/J.JCLEPRO.2019.117805

Kerr, W.R., Nanda, R., Rhodes-Kropf, M., 2014. Entrepreneurship as experimentation. J. Econ. Perspect. https://doi.org/10.1257/jep.28.3.25

Keskin, D., 2015. Product Innovation in Sustainability-Oriented New Ventures: A Process Perspective.

Khan, M.A., Mittal, S., West, S., Wuest, T., 2018. Review on upgradability – A product lifetime extension strategy in the context of product service systems. J. Clean. Prod. https://doi.org/10.1016/j.jclepro.2018.08.329

Khavul, S., Bruton, G.D., 2013. Harnessing Innovation for Change: Sustainability and Poverty in Developing Countries. J. Manag. Stud. 50, 285–306. https://doi.org/10.1111/j.1467-6486.2012.01067.x

Kjaer, L.L., Pigosso, D.C.A., Niero, M., Bech, N.M., McAloone, T.C., 2019. Product/Service-Systems for a Circular Economy: The Route to Decoupling Economic Growth from Resource Consumption? J. Ind. Ecol. https://doi.org/10.1111/jiec.12747

Knight, F.H., 1921. Risk, Uncertainty, and Profit. Houghton Mifflin, Boston.

Konietzko, J., Bocken, N., Hultink, E.J., 2020a. A Tool to Analyze, Ideate and Develop Circular Innovation Ecosystems. Sustainability 12, 417. https://doi.org/10.3390/su12010417

Konietzko, J., Bocken, N., Hultink, E.J., 2020b. Circular ecosystem innovation: An initial set of principles. J. Clean. Prod. 253, 119942. https://doi.org/10.1016/j.jclepro.2019.119942

Konietzko, J., Bocken, N., Hultink, E.J., 2019. ONLINE PLATFORMS AND THE CIRCULAR ECONOMY, in: Bocken, N., Ritala, P., Albareda, L., Verburg, R. (Eds.), Innovation for Sustainability - Business Transformations towards a Better World. Palgrave.

Korhonen, J., 2007. Environmental planning vs. systems analysis: Four prescriptive principles vs. four descriptive indicators. J. Environ. Manage. 82, 51–59. https://doi.org/10.1016/j.jenvman.2005.12.003

Korhonen, J., 2004. Industrial ecology in the strategic sustainable development model: Strategic applications of industrial ecology. J. Clean. Prod. 12, 809–823. https://doi.org/10.1016/j.jclepro.2004.02.026

Korhonen, J., 2001. Four ecosystem principles for an industrial ecosystem. J. Clean. Prod. 9, 253–259. https://doi.org/10.1016/S0959-6526(00)00058-5

Korhonen, J., von Malmborg, F., Strachan, P.A., Ehrenfeld, J.R., 2004. Management and policy aspects of industrial ecology: an emerging research agenda. Bus. Strateg. Environ. 13, 289–305. https://doi.org/10.1002/bse.415

Koskela-Huotari, K., Edvardsson, B., Jonas, J.M., Sörhammar, D., Witell, L., 2016. Innovation in service ecosystems-Breaking, making, and maintaining institutionalized rules of resource integration. J. Bus. Res. 69, 2964–2971. https://doi.org/10.1016/j.jbusres.2016.02.029

Kraaijenhagen, C., van Oppen, C., Bocken, N., 2016. Circular Business - Collaborate and Circulate. Circular Collaboration.

Krikke, H., Le Blanc, I., Van De Velde, S., 2004. Product modularity and the design of closed-loop supply chains. Calif. Manage. Rev. https://doi.org/10.2307/41166208
Kumar, H., Singh, M.K., Gupta, M.P., Madaan, J., 2020. Moving towards smart cities: Solutions that lead to the Smart City Transformation Framework. Technol. Forecast. Soc. Change. https://doi.org/10.1016/j.techfore.2018.04.024
Laasch, O., 2018. Beyond the purely commercial business model: Organizational value logics and the heterogeneity of sustainability business models. Long Range Plann. https://doi.org/10.1016/j.lrp.2017.09.002
Lacy, P., Keeble, J., McNamara, R., Rutqvist, J., Haglund, T., Cui, M., Cooper, A., Pettersson, C., Eckerle, K., Buddemeier, P., Sharma, A., Senior, T., 2014. Circular Advantage: Innovative Business Models and Technologies to Create Value in a World without Limits to Growth, Accenture Strategy.
Lancey, 2020. Lancey Energy Storage [WWW Document]. URL https://www.lancey.fr/en/ (accessed 8.6.20).
Launchforth, 2019. launchforth Website [WWW Document]. URL https://launchforth.io/ (accessed 9.26.19).
Leduc, W.R.W.A., Van Kann, F.M.G., 2013. Spatial planning based on urban energy harvesting toward productive urban regions. J. Clean. Prod. 39, 180–190. https://doi.org/10.1016/j.jclepro.2012.09.014
Leising, E., Quist, J., Bocken, N., 2018. Circular Economy in the building sector: Three cases and a collaboration tool. J. Clean. Prod. 176, 976–989. https://doi.org/10.1016/j.jclepro.2017.12.010
Lenton, T.M., Rockström, J., Gaffney, O., Rahmstorf, S., Richardson, K., Steffen, W., Schellnhuber, H.J., 2019. Climate tipping points — too risky to bet against. Nature 575, 592–595. https://doi.org/10.1038/d41586-019-03595-0
Leten, B., Vanhaverbeke, W., Roijakkers, N., Clerix, A., Helleputte, J. Van, 2013. IP Models to Orchestrate Innovation Ecosystems: IMEC, A PUBLIC RESEARCH INSTITUTE IN NANO-ELECTRONICS. Calif. Manage. Rev. https://doi.org/10.1525/cmr.2013.55.4.51
Levin, S.A., 1998. Ecosystems and the biosphere as complex adaptive systems. Ecosystems 1, 431–436. https://doi.org/10.1007/s100219900037
Lewandowski, M., 2016. Designing the business models for circular economy-towards the conceptual framework. Sustain. https://doi.org/10.3390/su8010043
Li, F., Liu, X., Zhang, X., Zhao, D., Liu, H., Zhou, C., Wang, R., 2017. Urban ecological infrastructure: an integrated network for ecosystem services and sustainable urban systems. J. Clean. Prod. 163, S12–S18. https://doi.org/10.1016/j.jclepro.2016.02.079
Lieder, M., Rashid, A., 2016. Towards circular economy implementation: a comprehensive review in context of manufacturing industry. J. Clean. Prod. 115, 36–51. https://doi.org/10.1016/j.jclepro.2015.12.042
Linder, M., Sarasini, S., van Loon, P., 2017. A Metric for Quantifying Product-Level Circularity. J. Ind. Ecol. https://doi.org/10.1111/jiec.12552
Linder, M., Williander, M., 2015a. Circular Business Model Innovation: Inherent Uncertainties. Bus. Strateg. Environ. n/a--n/a. https://doi.org/10.1002/bse.1906
Linder, M., Williander, M., 2015b. Circular Business Model Innovation: Inherent Uncertainties. Bus. Strateg. Environ. n/a-n/a. https://doi.org/10.1002/bse.1906
Loop, 2019. Loop US [WWW Document]. URL https://loopstore.com/ (accessed 8.6.19).
Lopes de Sousa Jabbour, A.B., Jabbour, C.J.C., Godinho Filho, M., Roubaud, D., 2018. Industry 4.0 and the circular economy: a proposed research agenda and original roadmap for sustainable operations. Ann. Oper. Res. 270, 273–286. https://doi.org/10.1007/s10479-018-2772-8
Luederitz, C., Schäpke, N., Wiek, A., Lang, D.J., Bergmann, M., Bos, J.J., Burch, S., Davies, A., Evans, J., König, A., Farrelly, M.A., Forrest, N., Frantzeskaki, N., Gibson, R.B., Kay, B., Loorbach, D., McCormick, K., Parodi, O., Rauschmayer, F., Schneidewind, U., Stauffacher, M., Stelzer, F., Trencher, G., Venjakob, J., Vergragt, P.J., von Wehrden, H., Westley, F.R., 2017. Learning through evaluation — A tentative evaluative scheme for sustainability transition experiments. J. Clean. Prod. 169, 61–76. https://doi.org/10.1016/j.jclepro.2016.09.005
Lüdeke-Freund, F., Gold, S., Bocken, N.M.P., 2019. A Review and Typology of Circular Economy Business Model Patterns. J. Ind. Ecol. 23, 36–61. https://doi.org/10.1111/jiec.12763
Lusch, R., 2009. Robert Lusch on Service-Dominant Logic. Part 1/3 - YouTube.
Lusch, R.F., 2011. Reframing supply chain management: A service-dominant logic perspective. J. Supply Chain Manag. https://doi.org/10.1111/j.1745-493X.2010.03211.x
Lusch, R.F., Nambisan, S., 2017. Service Innovation: A Service-Dominant Logic Perspective. MIS Q. https://doi.org/10.25300/misq/2015/39.1.07

Luscuere, L., 2016. Materials Passports : Providing Insights in the Circularity of Materials , Products and Systems - Lars Luscuere, in: Sustainable Innovation. pp. 176–179.
Luttropp, C., Lagerstedt, J., 2006. EcoDesign and The Ten Golden Rules: generic advice for merging environmental aspects into product development. J. Clean. Prod. https://doi.org/10.1016/j.jclepro.2005.11.022
Lystek, 2019. Lystek: Leaders in Biosolids and Organics Management | Lystek | Leaders in Biosolids & Organics Management [WWW Document]. URL https://lystek.com/ (accessed 9.30.19).
Ma, Y., Rong, K., Mangalagiu, D., Thornton, T.F., Zhu, D., 2018. Co-evolution between urban sustainability and business ecosystem innovation: Evidence from the sharing mobility sector in Shanghai. J. Clean. Prod. 188, 942–953. https://doi.org/10.1016/j.jclepro.2018.03.323
Macke, J., Casagrande, R.M., Sarate, J.A.R., Silva, K.A., 2018. Smart city and quality of life: Citizens' perception in a Brazilian case study. J. Clean. Prod. 182, 717–726. https://doi.org/10.1016/j.jclepro.2018.02.078
Magnomer, 2019. Magnomer [WWW Document]. URL https://www.magnomer.com/ (accessed 9.26.19).
Magretta, J., 2002. Why Business Models Matter. Harv. Bus. Rev. https://doi.org/10.1016/j.cub.2005.06.028
Mahesa, R., Yudoko, G., Anggoro, Y., 2019. Platform Ecosystems for Indonesia Smart Cities, in: 2018 International Conference on Computer, Control, Informatics and Its Applications: Recent Challenges in Machine Learning for Computing Applications, IC3INA 2018 - Proceeding. https://doi.org/10.1109/IC3INA.2018.8629537
Manninen, K., Koskela, S., Antikainen, R., Bocken, N., Dahlbo, H., Aminoff, A., 2018. Do circular economy business models capture intended environmental value propositions? J. Clean. Prod. https://doi.org/10.1016/j.jclepro.2017.10.003
McDonough, W.; Braungart, M., 2002. Remaking the way we make things: Cradle to cradle, New York: North Point Press. ISBN.
McDonough, W., Braungart, M., 2002. Cradle to Cradle: Remaking the way we make things. Chem. Eng. News 193. https://doi.org/10.1177/0276146704264148
McPhearson, T., Andersson, E., Elmqvist, T., Frantzeskaki, N., 2015. Resilience of and through urban ecosystem services. Ecosyst. Serv. 12, 152–156. https://doi.org/10.1016/j.ecoser.2014.07.012
Meadows, D., 1997. Places to intervene in a system. Whole Earth. https://doi.org/10.1080/02604020600912897
Mont, O., 2008. Innovative approaches to optimising design and use of durable consumer goods. Int. J. Prod. Dev. https://doi.org/10.1504/IJPD.2008.020395
Mont, O., 2002. Clarifying the concept of product – service system. J. Clean. Prod. 10, 237–245. https://doi.org/10.1016/S0959-6526(01)00039-7
Moore, J.F., 1993. Predators and prey: a new ecology of competition. Harv. Bus. Rev.
Moreau, V., Sahakian, M., van Griethuysen, P., Vuille, F., 2017. Coming Full Circle: Why Social and Institutional Dimensions Matter for the Circular Economy. J. Ind. Ecol. 21, 497–506. https://doi.org/10.1111/jiec.12598
Moreno, M., de los Rios, C., Charnley, F., 2016a. Guidelines for Circular Design: A Conceptual Framework. Sustainability 8, 1–13. https://doi.org/10.3390/su8090937
Moreno, M., De los Rios, C., Rowe, Z., Charnley, F., 2016b. A conceptual framework for circular design. Sustain. https://doi.org/10.3390/su8090937
Morlet, A., Blériot, J., Opsomer, R., Linder, M., Henggeler, A., Bluhm, A., Carrera, A., 2016. Intelligent Assets: Unlocking the Circular Economy Potential. Ellen MacArthur Found. 1–25.
Morris, Z., Weissburg, M., Bras, B., 2018. Towards a Biologically-inspired Urban-industrial Ecosystem, in: Procedia CIRP. Elsevier B.V., pp. 861–866. https://doi.org/10.1016/j.procir.2017.11.055
Mukhopadhyay, S., Bouwman, H., 2019. Orchestration and governance in digital platform ecosystems: a literature review and trends. Digit. Policy, Regul. Gov. . https://doi.org/10.1108/DPRG-11-2018-0067
Nambisan, S., Baron, R.A., 2013. Entrepreneurship in innovation ecosystems: Entrepreneurs' self-regulatory processes and their implications for new venture success. Entrep. Theory Pract. https://doi.org/10.1111/j.1540-6520.2012.00519.x
Narayan, R., Tidström, A., 2020. Tokenizing coopetition in a blockchain for a transition to circular economy. J. Clean. Prod. 263, 121437. https://doi.org/10.1016/j.jclepro.2020.121437

Nascimento, D.L.M., Alencastro, V., Quelhas, O.L.G., Caiado, R.G.G., Garza-Reyes, J.A., Lona, L.R., Tortorella, G., 2019. Exploring Industry 4.0 technologies to enable circular economy practices in a manufacturing context: A business model proposal. J. Manuf. Technol. Manag. https://doi.org/10.1108/JMTM-03-2018-0071

Newbold, T., Hudson, L.N., Arnell, A.P., Contu, S., De Palma, A., Ferrier, S., Hill, S.L.L., Hoskins, A.J., Lysenko, I., Phillips, H.R.P., Burton, V.J., Chng, C.W.T., Emerson, S., Gao, D., Hale, G.P., Hutton, J., Jung, M., Sanchez-Ortiz, K., Simmons, B.I., Whitmee, S., Zhang, H., Scharlemann, J.P.W., Purvis, A., 2016. Has land use pushed terrestrial biodiversity beyond the planetary boundary? A global assessment. Science (80-.). https://doi.org/10.1126/science.aaf2201

Nielsen, S.N., 2007. What has modern ecosystem theory to offer to cleaner production, industrial ecology and society? The views of an ecologist. J. Clean. Prod. 15, 1639–1653. https://doi.org/10.1016/j.jclepro.2006.08.008

Niero, M., Negrelli, A.J., Hoffmeyer, S.B., Olsen, S.I., Birkved, M., 2016. Closing the loop for aluminum cans: Life Cycle Assessment of progression in Cradle-to-Cradle certification levels, in: Journal of Cleaner Production. https://doi.org/10.1016/j.jclepro.2016.02.122

Nissen, U., 1995. A methodology for the development of cleaner products. The ideal-eco-product approach. J. Clean. Prod. https://doi.org/10.1016/0959-6526(95)98166-L

Nižetić, S., Djilali, N., Papadopoulos, A., Rodrigues, J.J.P.C., 2019. Smart technologies for promotion of energy efficiency, utilization of sustainable resources and waste management. J. Clean. Prod. https://doi.org/10.1016/j.jclepro.2019.04.397

Nobre, G.C., Tavares, E., 2017. Scientific literature analysis on big data and internet of things applications on circular economy: a bibliometric study. Scientometrics. https://doi.org/10.1007/s11192-017-2281-6

Norman, D.A., Stappers, P.J., 2015. DesignX: Complex Sociotechnical Systems. She Ji 1, 83–106. https://doi.org/10.1016/j.sheji.2016.01.002

Nudie Jeans, 2019. Free repairs for life - Nudie Jeans [WWW Document]. URL https://www.nudiejeans.com/page/free-repairs-for-life (accessed 9.26.19).

Nußholz, J.L.K., 2018. A circular business model mapping tool for creating value from prolonged product lifetime and closed material loops. J. Clean. Prod. https://doi.org/10.1016/j.jclepro.2018.06.112

OECD, 2012. Greenhouse gas emissions and the potential for mitigation from materials management within OECD countries.

Oh, D.S., Phillips, F., Park, S., Lee, E., 2016. Innovation ecosystems: A critical examination, in: Technovation. https://doi.org/10.1016/j.technovation.2016.02.004

Ojaghi, H., Mohammadi, M., Yazdani, H.R., 2019. A synthesized framework for the formation of startups' innovation ecosystem: A systematic literature review. J. Sci. Technol. Policy Manag. https://doi.org/10.1108/JSTPM-07-2018-0071

Ooms, W., Caniëls, M.C.J., Roijakkers, N., Cobben, D., 2020. Ecosystems for smart cities: tracing the evolution of governance structures in a dutch smart city initiative. Int. Entrep. Manag. J. 1–34. https://doi.org/10.1007/s11365-020-00640-7

Oskam, I., Bossink, B., de Man, A.-P., 2020. Valuing Value in Innovation Ecosystems: How Cross-Sector Actors Overcome Tensions in Collaborative Sustainable Business Model Development. Bus. Soc. 000765032090714. https://doi.org/10.1177/0007650320907145

Osterwalder, A., Pigneur, Y., Bernarda, G., Smith, A., 2014. Value proposition design, Strategyzer series. https://doi.org/10.1017/CBO9781107415324.004

Pagoropoulos, A., 2017. The Emergent Role of Digital Technologies in the Circular Economy: A Review. Procedia CIRP 64, 19–24. https://doi.org/10.1016/J.PROCIR.2017.02.047

Parida, V., Burström, T., Visnjic, I., Wincent, J., 2019. Orchestrating industrial ecosystem in circular economy: A two-stage transformation model for large manufacturing companies. J. Bus. Res. https://doi.org/10.1016/j.jbusres.2019.01.006

Parker, G., Van Alstyne, M.W., 2008. Innovation, Openness, and Platform Control, SSRN. https://doi.org/10.2139/ssrn.1079712

Parker, G., Van Alstyne, M.W., Jiang, X., 2016. Platform Ecosystems: How Developers Invert the Firm, SSRN. https://doi.org/10.2139/ssrn.2861574

Patala, S., Jalkala, A., Keränen, J., Väisänen, S., Tuominen, V., Soukka, R., 2016. Sustainable value propositions: Framework and implications for technology suppliers. Ind. Mark. Manag. https://doi.org/10.1016/j.indmarman.2016.03.001

Patton, M.Q., 2002. Qualitative Research & evaluation methodos. SAGE Publ. https://doi.org/10.1037/a0033788
Peerby [WWW Document], n.d. URL https://www.peerby.com/beta-dashboard (accessed 11.10.19).
Peffers, K., Tuunanen, T., Rothenberger, M.A., Chatterjee, S., 2007. A Design Science Research Methodology for Information Systems Research. J. Manag. Inf. Syst. 24, 45–77. https://doi.org/10.2753/MIS0742-1222240302
Phillips, M.A., Ritala, P., 2019. A complex adaptive systems agenda for ecosystem research methodology. Technol. Forecast. Soc. Change. https://doi.org/10.1016/j.techfore.2019.119739
Pialot, O., Millet, D., Bisiaux, J., 2017. "Upgradable PSS": Clarifying a new concept of sustainable consumption/production based on upgradablility. J. Clean. Prod. https://doi.org/10.1016/j.jclepro.2016.08.161
Pickett, S.T.A., Boone, C.G., McGrath, B.P., Cadenasso, M.L., Childers, D.L., Ogden, L.A., McHale, M., Grove, J.M., 2013. Ecological science and transformation to the sustainable city. Cities 32, S10–S20. https://doi.org/10.1016/j.cities.2013.02.008
Pieroni, M.P.P., McAloone, T.C., Pigosso, D.C.A., 2019. Business model innovation for circular economy and sustainability: A review of approaches. J. Clean. Prod. https://doi.org/10.1016/j.jclepro.2019.01.036
Pigosso, D.C.A., Zanette, E.T., Filho, A.G., Ometto, A.R., Rozenfeld, H., 2010. Ecodesign methods focused on remanufacturing. J. Clean. Prod. https://doi.org/10.1016/j.jclepro.2009.09.005
Pincetl, S., 2012. Nature, urban development and sustainability - What new elements are needed for a more comprehensive understanding? Cities 29, S32–S37. https://doi.org/10.1016/j.cities.2012.06.009
Planing, P., 2018. Towards a circular economy – How business model innovation will help to make the shift. Int. J. Bus. Glob. https://doi.org/10.1504/IJBG.2018.10009522
Planko, J., Chappin, M.M.H., Cramer, J., Hekkert, M.P., 2019. Coping with coopetition — Facing dilemmas in cooperation for sustainable development: The case of the Dutch smart grid industry. Bus. Strateg. Environ. 28, 665–674. https://doi.org/10.1002/bse.2271
Planko, J., Cramer, J.M., Chappin, M.M.H., Hekkert, M.P., 2016. Strategic collective system building to commercialize sustainability innovations. J. Clean. Prod. https://doi.org/10.1016/j.jclepro.2015.09.108
Rajala, R., Westerlund, M., Lampikoski, T., 2016. Environmental sustainability in industrial manufacturing: Re-examining the greening of Interface's business model. J. Clean. Prod. 115, 52–61. https://doi.org/10.1016/j.jclepro.2015.12.057
Rashid, S.H.A., Evans, S., Longhurst, P., 2008. A comparison of four sustainable manufacturing strategies. Int. J. Sustain. Eng. https://doi.org/10.1080/19397030802513836
ResCom, 2019. ResCoM - Product Lifecycle Management And Design for Multiple Lifecycles [WWW Document]. URL https://www.rescoms.eu/project (accessed 9.19.19).
Rhue, L., 2019. Crowd-based markets: Technical progress, civil and social regression, in: Race in the Marketplace: Crossing Critical Boundaries. Springer International Publishing, pp. 193–210. https://doi.org/10.1007/978-3-030-11711-5_12
Richardson, J., 2008. The business model: an integrative framework for strategy execution. Strateg. Chang. 17, 133–144. https://doi.org/10.1002/jsc.821
Ries, E., 2011. The Lean Startup: How Today's Entrepreneurs Use Continuous Innovation to Create Radically Successful Businesses, Crown Business. https://doi.org/23
Ripple, W.J., Wolf, C., Galetti, M., Newsome, T.M., Alamgir, M., Crist, E., Mahmoud, M.I., Laurance, W.F., 2017. World Scientists' Warning to Humanity: A Second Notice. Bioscience XX, 1–9. https://doi.org/10.1093/biosci/bix125/4605229
Ritala, P., Agouridas, V., Assimakopoulos, D., Gies, O., 2013. Value creation and capture mechanisms in innovation ecosystems: a comparative case study. Int. J. Technol. Manag. https://doi.org/10.1504/ijtm.2013.056900
Ritala, P., Almpanopoulou, A., 2017. In defense of 'eco' in innovation ecosystem. Technovation. https://doi.org/10.1016/j.technovation.2017.01.004
Rittel, H.W.J., Webber, M.M., 1973. Dilemmas in a general theory of planning. Policy Sci. https://doi.org/10.1007/BF01405730
Roetz, 2019. ROETZ - Configure your own unique (e)-bike [WWW Document]. URL https://roetz-bikes.com/ (accessed 8.6.19).

TOC

Rohrbeck, R., Hölzle, K., Gemünden, H.G., 2009. Opening up for competitive advantage - How Deutsche telekom creates an open innovation ecosystem. R D Manag. https://doi.org/10.1111/j.1467-9310.2009.00568.x
Romero, E., Ruiz, M.C., 2013. Framework for Applying a Complex Adaptive System Approach to Model the Operation of Eco-Industrial Parks. J. Ind. Ecol. 17, n/a-n/a. https://doi.org/10.1111/jiec.12032
Romme, A.G.L., Reymen, I.M.M.J., 2018. Entrepreneurship at the interface of design and science: Toward an inclusive framework. J. Bus. Ventur. Insights 10. https://doi.org/10.1016/j.jbvi.2018.e00094
Rossi, M., Germani, M., Zamagni, A., 2016. Review of ecodesign methods and tools. Barriers and strategies for an effective implementation in industrial companies. J. Clean. Prod. https://doi.org/10.1016/j.jclepro.2016.04.051
Rotmans, J., Loorbach, D., 2009. Complexity and transition management. J. Ind. Ecol. https://doi.org/10.1111/j.1530-9290.2009.00116.x
Russell, M.G., Smorodinskaya, N. V., 2018. Leveraging complexity for ecosystemic innovation. Technol. Forecast. Soc. Change 136, 114–131. https://doi.org/10.1016/J.TECHFORE.2017.11.024
Rytle, 2019. RYTLE – the smart move – THE SMART MOVE [WWW Document]. URL https://rytle.de/?lang=en (accessed 9.26.19).
Saldaña, J., 2013. The Coding Manual for Qualitative Researchers, Sage Publication. https://doi.org/10.1109/TEST.2002.1041893
Sandelowski, M., Docherty, S., Emden, C., 1997. Qualitative metasynthesis: Issues and techniques. Res. Nurs. Health. https://doi.org/10.1002/(sici)1098-240x(199708)20:4<365::aid-nur9>3.3.co;2-7
Sarasini, S., Linder, M., 2017. Integrating a business model perspective into transition theory: The example of new mobility services. Environ. Innov. Soc. Transitions. https://doi.org/10.1016/j.eist.2017.09.004
Sarasvathy, S.D., 2008. Effectuation - Elements of Entrepreneurial Expertise. Edward Elgar Publishing Limited.
Sarasvathy, S.D., 2001. Causation and effectuation: Toward a theoretical shift from economic inevitability to entrepreneurial contingency. Acad. Manag. Rev. 26, 243–263. https://doi.org/10.5465/AMR.2001.4378020
Scharmer, O., Yukelson, A., 2015. Theory U: From Ego-system to Eco-system Economies. J. Corp. Citizsh. https://doi.org/10.2307/jcorpciti.58.35
Scheel, C., 2016. Beyond sustainability. Transforming industrial zero-valued residues into increasing economic returns. J. Clean. Prod. 131, 376–386. https://doi.org/10.1016/j.jclepro.2016.05.018
Scheepens, A.E., Vogtländer, J.G., Brezet, J.C., 2016. Two life cycle assessment (LCA) based methods to analyse and design complex (regional) circular economy systems. Case: Making water tourism more sustainable. J. Clean. Prod. 114, 257–268. https://doi.org/10.1016/j.jclepro.2015.05.075
Scholten, S., Scholten, U., 2012. Platform-based Innovation Management: Directing External Innovational Efforts in Platform Ecosystems. J. Knowl. Econ. 3, 164–184. https://doi.org/10.1007/s13132-011-0072-5
Schreieck, M., Wiesche, M., Krcmar, H., 2016. DESIGN AND GOVERNANCE OF PLATFORM ECOSYSTEMS – KEY CONCEPTS AND ISSUES FOR FUTURE RESEARCH. Res. Pap.
Schröder, P., Lemille, A., Desmond, P., 2020. Making the circular economy work for human development. Resour. Conserv. Recycl. 156, 104686. https://doi.org/10.1016/j.resconrec.2020.104686
Schuit, C.S.C., Baldassarre, B., Bocken, N., 2017. Sustainable business model experimentation practices: evidence from three start-ups, in: Bakker, C., Mugge, R. (Eds.), Product Lifetimes and the Environment (PLATE) 2017 - Conference Proceedings. Delft University of Technology and iOS Press, Delft, pp. 370–376.
Scruggs, C.E., 2013. Reducing hazardous chemicals in consumer products: Proactive company strategies. J. Clean. Prod. https://doi.org/10.1016/j.jclepro.2012.12.005
Scuotto, V., Ferraris, A., Bresciani, S., 2016. Internet of Things: Applications and challenges in smart cities: a case study of IBM smart city projects. Bus. Process Manag. J. https://doi.org/10.1108/BPMJ-05-2015-0074
Seebode, D., Jeanrenaud, S., Bessant, J., 2012. Managing innovation for sustainability. R&D Manag. 42, 195–206. https://doi.org/10.1111/j.1467-9310.2012.00678.x
Senge, P., Hamilton, H., Kania, J., 2015. The dawn of system leadership. Stanford Soc. Innov. Rev. https://doi.org/10.1017/CBO9781107415324.004

Senge, P.M., Lichtenstein, B.B., Kaeufer, K., Bradbury, H., Carroll, J., 2007. Collaborating for systemic change. MIT Sloan Manag. Rev.
Sengers, F., Wieczorek, A.J., Raven, R., 2016. Experimenting for sustainability transitions: A systematic literature review. Technol. Forecast. Soc. Change. https://doi.org/10.1016/j.techfore.2016.08.031
Shahbazi, S., Wiktorsson, M., Kurdve, M., Jönsson, C., Bjelkemyr, M., 2016. Material efficiency in manufacturing: swedish evidence on potential, barriers and strategies. J. Clean. Prod. https://doi.org/10.1016/j.jclepro.2016.03.143
Shaw, D.R., Allen, T., 2018. Studying innovation ecosystems using ecology theory. Technol. Forecast. Soc. Change 136, 88–102. https://doi.org/10.1016/J.TECHFORE.2016.11.030
Shipilov, A., Gawer, A., 2020. Integrating research on interorganizational networks and ecosystems. Acad. Manag. Ann. https://doi.org/10.5465/annals.2018.0121
Siltaloppi, J., Koskela-Huotari, K., Vargo, S.L., 2016. Institutional Complexity as a Driver for Innovation in Service Ecosystems. Serv. Sci. 8, 333–343. https://doi.org/10.1287/serv.2016.0151
Simon, H.A., 1996. The sciences of the artificlal. MIT Press.
Sinclair, M., Sheldrick, L., Moreno, M., Dewberry, E., 2018. Consumer intervention mapping-A tool for designing future product strategies within circular product service systems. Sustain. https://doi.org/10.3390/su10062088
Singh, J., Ordoñez, I., 2016. Resource recovery from post-consumer waste: important lessons for the upcoming circular economy. J. Clean. Prod. https://doi.org/10.1016/j.jclepro.2015.12.020
Sinkovics, N., 2018. Pattern Matching in Qualitative Analysis, in: Cassell, C., Cunliffe, A.L., Grandy, G. (Eds.), The SAGE Handbook of Qualitative Business and Management Research Methods: Methods and Challenges. SAGE Publications Ltd, 1 Oliver's Yard, 55 City Road London EC1Y 1SP, pp. 468–484. https://doi.org/10.4135/9781526430236.n28
SolarRoadways, 2019. Home - SolarRoadways [WWW Document]. URL http://www.solarroadways.com/ (accessed 8.6.19).
Sono Motors, 2019. Invest – Sono Motors [WWW Document]. URL https://sonomotors.com/en/invest/? (accessed 9.26.19).
SOOP, 2019. SOOP Website [WWW Document]. URL http://www.aworldofsoop.com/ (accessed 8.28.19).
SPC - Design for Recycled Content Guide [WWW Document], 2019. URL https://recycledcontent.org/ (accessed 9.26.19).
Stahel, W., 2008. The performance economy: business models for the functional service economy, in: Handbook of Performability Engineering. pp. 127–138.
Stake, R.E., 1994. Case Studies, in: Handbook of Qualitative Research. pp. 236–247. https://doi.org/10.1258/096214400320575624
Stead, J.G., Stead, W.E., 2013. The Coevolution of Sustainable Strategic Management in the Global Marketplace. Organ. Environ. 26, 162–183. https://doi.org/10.1177/1086026613489138
Steffen, W., Broadgate, W., Deutsch, L., Gaffney, O., Ludwig, C., 2015. The trajectory of the Anthropocene: The Great Acceleration. Anthr. Rev. 2, 81–98. https://doi.org/10.1177/2053019614564785
Stewart, R., Niero, M., Murdock, K., Olsen, S.I., 2018. Exploring the Implementation of a Circular Economy Strategy: The Case of a Closed-loop Supply of Aluminum Beverage Cans, in: Procedia CIRP. https://doi.org/10.1016/j.procir.2017.11.006
Still, K., Huhtamäki, J., Russell, M.G., Rubens, N., 2014. Insights for orchestrating innovation ecosystems: the case of EIT ICT Labs and data-driven network visualisations. Int. J. Technol. Manag. 66, 243. https://doi.org/10.1504/IJTM.2014.064606
Street, G., 2019. Home - Gerrard Street [WWW Document]. URL https://gerrardstreet.nl/ (accessed 9.26.19).
Stubbs, W., Cocklin, C., 2008. Conceptualizing a "Sustainability Business Model." Organ. Environ. 21, 103–127. https://doi.org/10.1177/1086026608318042
Studio Davero, 2019. Studio Davero | Puzzle Peace [WWW Document]. URL http://studiodavero.nl/portfolio_page/puzzle-peace/ (accessed 8.6.19).
Stuermer, M., Abu-Tayeh, G., Myrach, T., 2017. Digital sustainability: basic conditions for sustainable digital artifacts and their ecosystems. Sustain. Sci. 12, 247–262. https://doi.org/10.1007/s11625-016-0412-2
Sumter, D., de Koning, J., Bakker, C., Balkenende, R., 2020. Circular Economy Competencies for Design. Sustainability 12, 1561. https://doi.org/10.3390/su12041561

TOC

Sun, L., Dong, H., Geng, Y., Li, Z., Liu, Z., Fujita, T., Ohnishi, S., Fujii, M., 2016. Uncovering driving forces on urban metabolism - A case of Shenyang. J. Clean. Prod. 114, 171–179. https://doi.org/10.1016/j.jclepro.2015.05.053

Suominen, A., Seppänen, M., Dedehayir, O., 2019. A bibliometric review on innovation systems and ecosystems: a research agenda. Eur. J. Innov. Manag. 22, 335360. https://doi.org/10.1108/EJIM-12-2017-0188

Swilling, M., Hajer, M., Baynes, T., Bergesen, J., Labbé, F., Musango, J.K., Ramaswami, A., Robinson, B., Salat, S., Suh, S., Currie, P., Fang, A., Hanson, A., Kruit, K., Reiner, M., Smit, S., Tabory, S., 2018. The Weight of Cities: Resource requirements of future urbanization, UN Environment - International Resource Panel.

Talmar, M., Walrave, B., Podoynitsyna, K.S., Holmström, J., Romme, A.G.L., 2018. Mapping, analyzing and designing innovation ecosystems: The Ecosystem Pie Model. Long Range Plann. https://doi.org/10.1016/J.LRP.2018.09.002

Tansley, A.G., 1935. The Use and Abuse of Vegetational Concepts and Terms. Ecology 16, 284–307. https://doi.org/10.2307/1930070

Tate, W.L., Bals, L., Bals, C., Foerstl, K., 2019. Seeing the forest and not the trees: Learning from nature's circular economy. Resour. Conserv. Recycl. 149, 115–129. https://doi.org/10.1016/J.RESCONREC.2019.05.023

Täuscher, K., Laudien, S.M., 2017. Understanding platform business models: a mixed methods study of marketplaces. Eur. Manag. J. J. 1–11. https://doi.org/10.1016/j.emj.2017.06.005

Techcrunch, 2019. Apple leads corporate American solar energy usage | TechCrunch.

Teece, D.J., 2007. Explicating dynamic capabilities: The nature and microfoundations of (sustainable) enterprise performance. Strateg. Manag. J. 28, 1319–1350. https://doi.org/10.1002/smj.640

Tencati, A., Zsolnai, L., 2009. The collaborative enterprise. J. Bus. Ethics 85, 367–376. https://doi.org/10.1007/s10551-008-9775-3

The Ocean Cleanup, 2019. The Ocean Cleanup [WWW Document]. URL https://theoceancleanup.com/ (accessed 8.6.19).

Thomas, L.D.W., Autio, E., Gann, D.M., 2014. Architectural Leverage: Putting Platforms in Context. Acad. Manag. Perspect. 28, 198–219. https://doi.org/10.5465/amp.2011.0105

Traitler, H., Watzke, H.J., Saguy, I.S., 2011. Reinventing R&D in an Open Innovation Ecosystem. J. Food Sci. 76, R62–R68. https://doi.org/10.1111/j.1750-3841.2010.01998.x

Tranfield, D., Denyer, D., Smart, P., 2003. Towards a Methodology for Developing Evidence-Informed Management Knowledge by Means of Systematic Review. Br. J. Manag. 14, 207–222. https://doi.org/10.1111/1467-8551.00375

Trischler, J., Johnson, M., Kristensson, P., 2020. A service ecosystem perspective on the diffusion of sustainability-oriented user innovations. J. Bus. Res. https://doi.org/10.1016/j.jbusres.2020.01.011

Tsvetkova, A., Gustafsson, M., 2012. Business models for industrial ecosystems: A modular approach. J. Clean. Prod. 29–30, 246–254. https://doi.org/10.1016/j.jclepro.2012.01.017

Tukker, A., 2015. Product services for a resource-efficient and circular economy - A review. J. Clean. Prod. 97, 76–91. https://doi.org/10.1016/j.jclepro.2013.11.049

Tukker, A., 2004. Eight types of product–service system: Eight ways to sustainability? Experiences from suspronet. Bus. Strateg. Environ. 13, 246–260. https://doi.org/10.1002/bse.414

Tukker, A., Bulavskaya, T., Giljum, S., de Koning, A., Lutter, S., Simas, M., Stadler, K., Wood, R., 2016. Environmental and resource footprints in a global context: Europe's structural deficit in resource endowments. Glob. Environ. Chang. https://doi.org/10.1016/j.gloenvcha.2016.07.002

Tukker, A., Emmert, S., Charter, M., Vezzoli, C., Sto, E., Munch Andersen, M., Geerken, T., Tischner, U., Lahlou, S., 2008. Fostering change to sustainable consumption and production: an evidence based view. J. Clean. Prod. 16, 1218–1225. https://doi.org/10.1016/j.jclepro.2007.08.015

Türkeli, S., Huang, B., Stasik, A., Kemp, R., 2019. Circular Economy as a Glocal Business Activity: Mobile Phone Repair in the Netherlands, Poland and China. Energies 12, 498. https://doi.org/10.3390/en12030498

Unwaste, 2020. home - unwaste [WWW Document]. URL https://www.unwaste.nl/ (accessed 8.10.20).

Urbinati, A., Chiaroni, D., Chiesa, V., 2017. Towards a new taxonomy of circular economy business models. J. Clean. Prod. https://doi.org/10.1016/j.jclepro.2017.09.047

Valkokari, K., Amitrano, C.C., Bifulco, F., Valjakka, T., 2016. Managing Actors, Resources, and Activities in Innovation Ecosystems – A Design Science Approach. Springer, Cham, pp. 521–530. https://doi.org/10.1007/978-3-319-45390-3_44
Van Aken, J.E., Romme, G., 2009. Reinventing the future: Adding design science to the repertoire of organization and management studies. Organ. Manag. J. 6, 5–12. https://doi.org/10.1057/omj.2009.1
Van Berkel, R., Willems, E., Lafleur, M., 1997. Development of an industrial ecology toolbox for the introduction of industrial ecology in enterprises - I. J. Clean. Prod.
Van de Ven, A.H., 2007. Engaged scholarship: A guide for organizational and social research. Oxford Univ. Press 344. https://doi.org/10.1017/CBO9781107415324.004
van Dijck, J., Poell, T., de Waal, M., 2018. The Platform Society. Oxford University Press.
Vargo, S.L., Lusch, R.F., 2017. Service-dominant logic 2025. Int. J. Res. Mark. 34, 46–67. https://doi.org/10.1016/J.IJRESMAR.2016.11.001
Vargo, S.L., Lusch, R.F., 2016. Institutions and axioms: an extension and update of service-dominant logic. J. Acad. Mark. Sci. https://doi.org/10.1007/s11747-015-0456-3
Vargo, S.L., Lusch, R.F., 2011. It's all B2B...and beyond: Toward a systems perspective of the market. Ind. Mark. Manag. 40, 181–187. https://doi.org/10.1016/j.indmarman.2010.06.026
Vargo, S.L., Lusch, R.F., 2004. Evolving to a New Dominant Logic for Marketing. J. Mark. 68, 1–17. https://doi.org/10.1509/jmkg.68.1.1.24036
Vargo, S.L., Wieland, H., Akaka, M.A., 2015. Innovation through institutionalization: A service ecosystems perspective. Ind. Mark. Manag. 44, 63–72. https://doi.org/10.1016/j.indmarman.2014.10.008
Velte, C.J., Steinhilper, R., 2016. Complexity in a Circular Economy : A Need for Rethinking Complexity Management Strategies. World Congr. Eng. 2016.
Vestaron, 2019. Vestaron Website [WWW Document]. URL https://www.vestaron.com/ (accessed 8.28.19).
Von Bertalanffy, L., 1972. The History and Status of General Systems Theory. Acad. Manag. J. https://doi.org/10.5465/255139
Voytenko, Y., McCormick, K., Evans, J., Schliwa, G., 2016. Urban living labs for sustainability and low carbon cities in Europe: Towards a research agenda. J. Clean. Prod. 123, 45–54. https://doi.org/10.1016/j.jclepro.2015.08.053
Waka Waka, 2019. WakaWaka® - Premium portable solar products, for everyone [WWW Document]. URL https://waka-waka.com/en/ (accessed 9.26.19).
Walls, J.L., Paquin, R.L., 2015. Organizational Perspectives of Industrial Symbiosis: A Review and Synthesis. Organ. Environ. https://doi.org/10.1177/1086026615575333
Walrave, B., Talmar, M., Podoynitsyna, K.S., Romme, A.G.L., Verbong, G.P.J., 2018. A multi-level perspective on innovation ecosystems for path-breaking innovation. Technol. Forecast. Soc. Change 136, 103–113. https://doi.org/10.1016/J.TECHFORE.2017.04.011
Wastling, T., Charnley, F., Moreno, M., 2018. Design for circular behaviour: Considering users in a circular economy. Sustain. https://doi.org/10.3390/su10061743
Webster, J., Watson, R.T., 2002. Analyzing the past fo prepare for the future: writing a literature review. MIS Q. https://doi.org/1210112213
WEF, 2020. Nature Risk Rising: Why the Crisis Engulfing Nature Matters for Business and the Economy.
Wei, F., Feng, N., Yang, S., Zhao, Q., 2020. A conceptual framework of two-stage partner selection in platform-based innovation ecosystems for servitization. J. Clean. Prod. https://doi.org/10.1016/j.jclepro.2020.121431
Weissbrod, I., Bocken, N.M.P., 2017. Developing sustainable business experimentation capability – A case study. J. Clean. Prod. 142, 2663–2676. https://doi.org/10.1016/j.jclepro.2016.11.009
Whicher, A., Harris, C., Beverley, K., Swiatek, P., 2018. Design for circular economy: Developing an action plan for Scotland. J. Clean. Prod. https://doi.org/10.1016/j.jclepro.2017.11.009
Whim, 2019. Whim - All your journeys with bus, tram, taxi, car, bike and more in 1 app. [WWW Document]. URL https://whimapp.com/ (accessed 9.25.19).
Wohlin, C., 2014. Guidelines for snowballing in systematic literature studies and a replication in software engineering, in: ACM International Conference Proceeding Series. Association for Computing Machinery, New York, New York, USA, pp. 1–10. https://doi.org/10.1145/2601248.2601268
Wolf, A., Eklund, M., Söderström, M., 2007. Developing integration in a local industrial ecosystem – an explorative approach. Bus. Strateg. Environ. 16, 442–455. https://doi.org/10.1002/bse.485

Wong, T.Y.T., Peko, G., Sundaram, D., Piramuthu, S., 2016. Mobile environments and innovation co-creation processes & ecosystems. Inf. Manag. https://doi.org/10.1016/j.im.2015.09.005
Xu, G., Wu, Y., Minshall, T., Zhou, Y., 2018. Exploring innovation ecosystems across science, technology, and business: A case of 3D printing in China. Technol. Forecast. Soc. Change. https://doi.org/10.1016/j.techfore.2017.06.030
Xu, M., Cai, H., Liang, S., 2015. Big data and industrial ecology. J. Ind. Ecol. https://doi.org/10.1111/jiec.12241
Xue, M., Luo, Y., 2015. Dynamic variations in ecosystem service value and sustainability of urban system: A case study for Tianjin city, China. Cities 46, 85–93. https://doi.org/10.1016/j.cities.2015.05.007
Yang, P.P.J., Lay, O.B., 2004. Applying ecosystem concepts to the planning of industrial areas: A case study of Singapore's Jurong Island. J. Clean. Prod. 12, 1011–1023. https://doi.org/10.1016/j.jclepro.2004.02.028
Yin, R.K., 2013. Case study research: Design and methods. Case Study Res. Des. Methods. https://doi.org/10.1097/FCH.0b013e31822dda9e
ZenRobotics, 2019. ZenRobotics | Leader in Robotic Waste Separation [WWW Document]. URL https://zenrobotics.com/ (accessed 9.26.19).
Zhong, J., Nieminen, M., 2015a. Resource-based co-innovation through platform ecosystem: experiences of mobile payment innovation in China. J. Strateg. Manag. https://doi.org/10.1108/JSMA-03-2015-0026
Zhong, J., Nieminen, M., 2015b. Resource-based co-innovation through platform ecosystem: experiences of mobile payment innovation in China. J. Strateg. Manag. 8, 283–298. https://doi.org/10.1108/JSMA-03-2015-0026
Zink, T., Geyer, R., 2017. Circular Economy Rebound. J. Ind. Ecol. 21, 593–602. https://doi.org/10.1111/jiec.12545
Zink, T., Geyer, R., 2016. There is no such thing as a Green Product. Stanford Soc. Innov. Rev.
Zollo, M., Cennamo, C., Neumann, K., 2013. Beyond What and Why: Understanding Organizational Evolution Towards Sustainable Enterprise Models. Organ. Environ. 26, 241–259. https://doi.org/10.1177/1086026613496433
Zucchella, A., Previtali, P., 2019. Circular business models for sustainable development: A "waste is food" restorative ecosystem. Bus. Strateg. Environ. 28, 274–285. https://doi.org/10.1002/bse.2216
Zygiaris, S., 2013. Smart City Reference Model: Assisting Planners to Conceptualize the Building of Smart City Innovation Ecosystems. J. Knowl. Econ. 4, 217–231. https://doi.org/10.1007/s13132-012-0089-4

Appendices

APPENDIX A

The search strings used and articles retrieved from the literature review

Search focus	Search strings (limited to the business, management, accounting and engineering journals in the SCOPUS database)	Number of search results (April 2019)	Number of retrieved articles and references (each additional row mentions only new articles that were not yet found from previous search strings)
Circular economy in general	*"Circular economy"* AND *strategies* OR *principles*	345	10 articles (Allwood, 2014; Bakker et al., 2014; Herczeg et al., 2018; Heyes et al., 2018; Manninen et al., 2018; Mont, 2008; Moreno et al., 2016b; Pialot et al., 2017; Shahbazi et al., 2016; Walls and Paquin, 2015)
Circular product design	*"Circular economy" AND "product design"*	*12*	3 articles (Bocken et al., 2016; Ge and Jackson, 2014; Van Berkel et al., 1997)
Circular business Model innovation	*"Circular economy" AND "business model design"* OR *"business model innovation"*	*23*	2 articles (Chierici and Copani, 2016; Planing, 2018)
Circular ecosystem innovation	*"Circular economy" AND system* AND strateg**	*183*	1 article (Khan et al., 2018)
Narrow	*reduce AND sustainability AND strategies* (only titles to increase relevance)	*13*	0
Slow	*"product-life extension"* AND *strategies*	*11*	2 articles (Allwood et al., 2010; Moreno et al., 2016a)
Slow	*Servitization AND "circular economy" AND strategies*	*3*	*0*
Close	*recycling* AND *strategies OR principles*	135	0
Regenerate	*"circular economy" AND regenerate AND strategies OR principles*	11	0
Regenerate	*"circular economy" AND "renewable energy" AND strategies OR principles*	72	*0*
Inform	*"circular economy"* AND *platforms* OR *"internet of things"* OR *"artificial intelligence"* OR *"big data"*	*58*	5 articles (Alcayaga et al., 2019; Gupta et al., 2019; Jabbour et al., 2019; Nascimento et al., 2019; Nižetić et al., 2019)

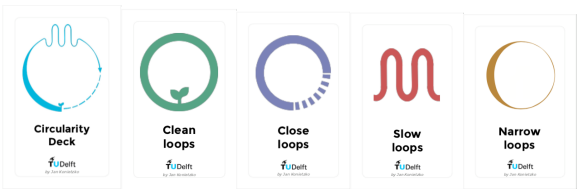
APPENDIX B

The form used to evaluate the ease-of-use and usefulness of the Circularity Deck

FEEDBACK FORM

The purpose of the Circularity Deck is to learn and ideate for a circular economy.

Circularity Deck



1. The Circularity Deck was useful to address the purpose stated above:

Do not agree at all 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ *Fully agree*

Please explain your answer (What was most useful? What was less useful? Why?)

.....
.

.....
.

.....
.

2. The Circularity Deck was easy to understand / use:

Do not agree at all 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ *Fully agree*

Please explain your answer (What was easy? What was difficult? Why?)

.....
.

.....
.

.....

TOC

APPENDIX C

The workshop feedback: rating and qualitative feedback

Workshop 1:Big health technology company

Number of participants: **8**
Average rating of perceived usefulness[5]: **4.14**
Average rating of ease-of-use[6]: **4.13**

Rating of 3:

- *"nice list of triggers, nothing really new for me personally"*

Rating of 4:

- *"Having guidelines and parameters helps to ensure that the brainstorm keeps being focused on the topic"*
- *"inspiration"*
- *"as an extrovert, I find it easier to think in pairs. Found the examples useful to spark ideas"*
- *"it would be nice to have examples"*

Rating of 5:

- *"felt more as a understanding the circular economy conceptually, which was by the way great :). Loved the cards"*
- *"loved the cards, it makes it a lot easier to brainstorm and prompt new ideas"*
- *"gave me some inspiration to come up with innovative idea"*
- *"nice perspective tool"*
- *"useful to reduce complexity"*

>>>

5 Statement: *"The Circularity Deck was useful to learn and ideate towards a circular economy";* Answer options: likert scale (1 = do not agree at all, 5 = fully agree)

6 Statement: *"The Circularity Deck was easy to use";* Answer options: likert scale (1 = do not agree at all, 5 = fully agree)

Workshop 2: Twelve circular startups during the 'Investment Ready Programme' of Impact Hub

Number of participants: **11**
Avr. rating of perceived usefulness: **4.55**
Avr. rating of ease-of-use: **4.55**

Rating of 4:

- *"The different loops à tools to explain your circularity, the cards à good examples of companies which produced something"*
- *"Good theoretical substantiations, we could relate it easily to our product"*
- *"It was very practical for us"*
- *"Some topics were not typically for a product"*
- *"Very useful to pitch your circularity and brainstorm improvements!"*
- *"At the start the purpose was a bit unclear but once we realized they were suggestions it made for an easy-going discussion on things that can be done"*
- *"Like I wrote above, at the start I didn't understand what the cards were for. Sometimes the examples are a bit confusing, probably because circularity is different for a food company than for a machine building company"*
- *"Useful: it sharpens what you already do, what you will never do and inspires next steps to optimize the impact of the business, I missed the cards about how we are closing loops: presumption: make people buy things that will change their behaviour in a positive way (induction cooking)"*
- *"Too much overlap in cards, some are too similar"*
- *"Requires some effort to understand how the example cards would translate into an idea for your business"*

Rating of 5:

- *"Insights in all different options, we are so into our daily work that an exhaustive list is of great use, helicopter view!"*
- *"Examples work really good, I do think it is fit for professionals and for people who have a basic understanding of a circular economy"*
- *"Very clear and helpful in giving ideas"*
- *"Simple and clear, liked the model with the different loops, thanks!"*
- *"It is nice to see where you stand with your products in the loops and where you can improve the loops"*
- *"I loved your cards, not too much info on them and it was well built up to our final assignment"*
- *"The text on the cards was clear, nice to have an example on each card"*
- *"It sparks ideas"*
- *"The explanations on the back really worked"*
- *"Provides clarity"*
- *"Written in a clear way which sparks ideas"*
- *"Note: circularity is interpreted in 'the resource way'. What about social inclusion/impact?"*
- *"Really helps to generate ideas, the cards are cool"*

>>>

Workshop 3: Mobility design agency

Number of participants: **6**
Average rating of perceived usefulness: **4.5**
Average rating of ease-of-use: **4.83**

Rating of 3:

- *"Good starting point, nice to have real-world examples, although this might also steer/limit a bit too much, maybe asking basic questions could also be a good way to get people thinking"*

Rating of 4:

- *"The cards ensure that many different aspects are considered in the brainstorm. The 'regenerate' cards were more difficult but that can be specific to this project"*
- *"Ideas from each strategy were kept distinct and separate, would be useful to integrate/cross-pollinate"*
- *"Understandable, but maybe feels slightly 'pragmatic', "businessy""*

Rating of 5:

- *"+ narrowing it down to smaller questions is helpful, - maybe more in question form (how, why, when etc)"*
- *"How to narrow it down?"*
- *"Yes, easy to use, good outcomes"*
- *"I didn't read any of the stories on the card, they were pretty self-explanatory. The presence of these cue cards make you think of stuff that can be pretty obvious but quickly overseen"*
- *"The product-design ones were easiest, there were also quite a few that just needed a "yes" (lets do that), cards should be a bit thicker for re-use"*
- *"Interesting to focus on specific aspects, next phase as a group phase was good to cluster ideas, the outcome? A concept profile."*
- *"Clear with the examples"*
- *"Fueled a lot of ideas on different levels"*
- *"The cards are like a morphological map tool, for holistic ideas might need a 2nd tool or step"*
- *"Maybe condense or highlight items in the text (quicker to read)"*

>>>

Workshop 4: Open workshop with 21 participants from different organizations of the 'Provincie Noord Holland' at Impact Hub in Amsterdam

Number of participants: **21**
Average rating of perceived usefulness: **4.52**
Average rating of ease-of-use: **4.29**

Rating of 3:

- *"I think if people are not already doing/practicing then it will sometimes not be clear – I can try out too – thank you!"*
- *"New to me, so need to adopt"*

Rating of 4:

- *"I really liked the simplified approach to start creating circular models"*
- *"I am now more curious about the next steps of this framework. As cost and performance are as important as environmental friendliness, it would be good to see how you evaluate a business models' financial feasibility"*
- *"Good to know about narrow, slow, regenerate…, connect with other's ideas"*
- *"Message is clear, but a lot of things were undiscussed"*
- *"The examples reinforced the 4 concepts, and had a wide range of inspirational stories"*
- *"The subject matter was covered very broadly so it felt all bases were covered. More instruction on the idea selection phase would be good"*
- *"Different angles and ideas inspire, one table missed the 'human' element in the examples, how to attract/involve others?, importance of communication, giving experiences"*
- *"Generally very good, but some related ideas were touched on in different types of loops"*
- *"Good examples, a lot of overlap, sometimes confusing"*
- *"Clear"*
- *"You have the circle in the powerpoint maybe also keep showing the examples so you know what it is (I am old and forget quickly :)"*
- *"New perspective"*
- *"The examples make it very clear"*
- *"It was good for a start to grasp the concept of circularity"*
- *"The more knowledge about circularity you have, the more difficult the use of the deck"*
- *"It helps to kick-start the thinking process and mindset"*
- *"When it was initially introduced, I was somewhat confused. The cards helped a lot."*

Rating of 5:

- *"The first two strategies were most concrete and helpful"*
- *"Putting these concepts into practice was useful to understanding them, and the framework was easy to apply to my idea"*
- *"Using the cards made it easy to understand the concepts and therefore the concept of circularity"*
- *"Practical"*
- *"Easy to digest the information"*
- *"A great thought exercise – clarified where we are already successful, and highlight immediate ways to improve"*
- *"Clear, user-friendly, well thought through"*
- *"A section on digital entities would add further value"*
- *"The examples were instrumental to understanding the cards"*
- *"The loops are clear, the questions are clear"*
- *"Conceptualizing based on the different loops is useful for classifying ideas – good framework for analysis"*
- *"I know a lot, but to have it in into 4 parts divided and explained it is easy to share"*
- *"I am missing a human component (fair wages, human rights) and stimulating ideas about transparency and communication"*
- *"Providing both descriptions and concrete examples on the cards helped to reinforce the concept and generate further ideas"*
- *"Simple/tactile"*
- *"Perhaps you could develop an online platform to distribute more widely and decrease inputs used"*
- *"The examples are very explanatory"*
- *"A way to initiate discussion and brainstorming"*
- *"Maybe work more on the 'how to use' card and have an online version that is constantly updated"*
- *"This gives real-life scenarios and examples that stimulate incorporation of the ideas into companies"*

>>>

Workshop 5: Workshop with a big civil engineering service company

Number of participants: **5**
Average rating of perceived usefulness: **4**
Average rating of ease-of-use: **3.6**

Rating of 2:

- *"I would use the Dutch language"*

Rating of 3:

- *"Gives ideas of possibilities"*
- *"Circularity is interpreted very broadly"*
- *"Well-described examples, some of which are very debatable"*

Rating of 4:

- *"It was useful, with many obvious examples, but it helped"*
- *"It was easy to use and helped generate ideas"*
- *"Useful because it was inspiring and it gave direction on the broad concept of circularity"*

Rating of 5:

- *"Gives a broad view of the concept and concrete ideas on what could be done"*
- *"Well categorized and in short bits well explained on the back side"*

>>>

Workshop 6: Open workshop with 21 participants in Sweden as part of an international coaching program to develop their circular business models

Number of participants: **21**
Average rating of perceived usefulness: **4.79**
Average rating of ease-of-use: **4.24**

Rating of 5:

- *"Thinking about a section (e.g. regenerate) that we excluded without thinking twice. Less useful: time too short"*
- *"It gave a lot of inspiration strategies we hadn't thought about, especially the 'inform' cards"*
- *"It mentions several strategies and explains them. Gives new ideas"*
- *"Example and explanation on the back side was very useful"*
- *"Separation into different categories makes it easy"*
- *"Provide an overview of all potential strategies to be combined which do not automatically come to mind."*
- *"Easy to read and place into context thanks to the examples"*
- *"Cards were easy to manipulate and place on the desk"*
- *"Well-colored which makes it easy to visualize"*
- *"The cards helped us to narrow our ideas and to improve the circular aspect of it. The inform and slow cards were particularly useful in our case"*
- *"Concrete and practical examples in very concise text. Helped in divergent thinking, and asking questions about the bigger picture"*
- *"workshop was super practical, fantastic example triggers for ideation"*
- *"good imagination for all possible strategies that could be applied towards a CE. Very clear and concrete way to explain what CE means, nice to have real examples"*
- *"Clear with explanations and examples, difficult sometimes to define difference between cards"*
- *"Lots of different strategies, clear explanations and examples"*
- *"Practical examples, clear and simple explanations, not always clear what the strategy is without explanation"*
- *"Helped with statement and to explore broader shape of idea. Cannot be used for all types of business"*
- *"It gives a different perspective in your business idea, provides original examples"*
- *"Everything was clear. It's nice that on one side you have the idea and on the other the examples to explain it in kore detail"*
- *"The different strategies and principles were presented in the cards in a clear and specific way – not too complex or broad vague concepts The variety helps a lot"*
- *"Very complete range of cards covering all aspects of business, the perfect tool for a circular transformation workshop"*
- *"it was very helpful to think outside the box and to consider a variety of different aspects"*
- *"it's useful to split the cycle in several parts in order to focus on them separately, for sure the most usable are the slow and close parts. Sometimes solutions involve several parts, some others involve single steps which makes some of them difficult to integrate fully"*
- *"it was easy due to the examples provided and the summarizing sentence"*
- *"I am already familiar with most principles, but to see them in the narrow-slow-close-regenerate structure is helpful to get a clear view on separate aspects and the examples on the back are refreshing"*
- *"Category and icons and examples"*

>>>

>> Workshop 6: Open workshop with 21 participants in Sweden as part of an international coaching program to develop their circular business models

Rating of 4:

- *"Easy: understand examples. Difficult: grasp small differences between very similar cards"*
- *"it was good that the example was explained with an example on the back, that way it was easier for us to see if it was applicable for an idea"*
- *"I loved the examples on the back of the cards and the front of the cards was really catchy"*
- *"There are not so many cards but still it's hard to have an overview of many cards. Having the type of design it addresses helps a lot in that sense. Picking up the cards one after the other was easy though"*
- *"Very simple tool but very effective, four categories are the right numbers, maybe more examples could be useful"*
- *"Very useful because we could spot useful techniques to use in our business"*
- *"Every card has image with text and is clearly understandable, and also the examples helped a lot when you cannot understand the goal of the card."*
- *"it was easy to understand the various practices but some of them overlapped."*
- *"For some cards had to read the explanation on the back"*
- *"I am a fan :)"*
- *"it was easy to understand but maybe a bit overwhelming as there are so many aspects"*
- *"I found very useful the examples provided and the division in sections"*
- *"Examples (real world) very inspiring, maybe some sort of feasibility rating could be nice"*
- *"Some tips seem similar, but the examples do provide clarity"*

Rating of 3:

- *"At first I didn't know where to start reading the cards but I found the examples very useful. The cards were very useful at the end"*
- *"Easy to find solutions in some steps, hard to find a solution that covers all steps, deck: many of the cards are redundant referring to the same concepts, but still good for examples"*

>>>

Workshop 7: Open workshop with a group of entrepreneurs, innovation managers and researchers from the Hamburg region

Number of participants: **15**
Average rating of perceived usefulness: 4.69
Average rating of ease-of-use: 4.4

Rating of 3:

- *"There were too many cards maybe too much text. Maybe make a pre-selection for different teams and contexts"*
- *"Process is a bit messy (too many cards, lack of organizing framework)"*
- *"Cards are intuitive/self-explanatory, process is a bit messy, not always clear what the next steps are"*
- *"a canvas would be needed to place the cards on and structure the process on the table"*

Rating of 4:

- *"Very elaborate and well thought through, great language and design, also examples are helpful, but quite complex, so would have liked more time to fully grasp the concept"*
- *"Once understood, it is straight forward to use and self-explanatory (almost)"*
- *"The context and complexity of a full product life cycle becomes very clear"*
- *"I see how different use cases might need different 'rules': 1) analyzing and mapping existing products, services, etc., 2) ideating on new ways to become more sustainable"*
- *"it is easy to use but it would be easier if there were less options"*
- *"a lot of cards, thus also confusing, ideas stay at high level"*

Rating of 5:

- *"Really cool to setting creative sparks. Throwing them on the table and say 'go' seems 'overflooding'. In a workshop context I would give clearer instructions and limit them"*
- *"there is a great variety of concepts to think about circularity that I have not thought about before."*
- *"It has a lot of great suggestions applicable to so many industries, context and for delving into circularity topics"*
- *"Explanation on the back is helpful, maybe some kind of playing board would be helpful to give even more structure to the brainstorm session"*
- *"It touches on all aspects, I really like it"*
- *"I find the graphics on the cards really accurate, I become much more aware of a lot more areas to consider"*
- *"I understand the flow, but the broad connection to the 'ecosystem perspective' is not 100% clear yet. How do they combine, practically?"*
- *"there are many cool strategies in the different areas of the flow that one could use to innovate"*
- *"Definitely good for inspiration just too many"*
- *"I like the icons and the display of the four categories in front as well as the explanation and examples on the back"*
- *"too many cards though can you bundle strategies?"*
- *"Love the given examples. They help to understand the strategy immediately and stick with me"*
- *"gives good examples for inspiration"*
- *"learn to know the different flows, cards are well-designed, suggestion: put flow type in the upper left corner for easier recognition"*
- *"lots of insights about the circular economy in action"*
- *"a cheat sheet with a short description of the 5 strategies would be helpful"*
- *"very hands on, explanation and example on the back very crucial"*
- *"gives ideas, helps map ideas to strategies, relatively generic, can be applied to almost any context, generic also means that very 'customized ideas' might not evolve"*
- *"straight forward titles of cards, explanation helps to understand context, example clarifies explanation and visualizes it"*
- *"By using the deck with all the examples, it was good to decide what kind of innovation your personal idea is"*
- *"Great for early users with no or low experience"*
- *"short, simple, specific, looks good"*
- *"Missing the cultural aspects (legal, human habits), many examples are about technology, products, or services"*

>>>

Workshop 8: Open workshop with a group of entrepreneurs and innovation managers from Riga, Latvia

Number of participants: **18**
Average rating of perceived usefulness: 4.67
Average rating of ease-of-use: 4.61

Rating of 3:

- *"Need a bit more time to get used to it, if the case study is not in your core competence circle"*

Rating of 4:

- *"Everything starts with structure"*
- *"If you are able to think out of the box you'll have no problem using this"*
- *"for us, it was just a repeating of existing knowledge, brainstorming"*
- *"lots of reading and writing but yes, it is very easy"*
- *"good tool for initiating conversation and spreading ideas"*
- *"Useful to a degree because for more technical challenges it might require higher degree of knowledge/ideas"*
- *The tool was partially hard to understand at first, but when you start using it, you get it"*
- *"information can be understood in context and associated"*
- *"no, it's a bit difficult to use, because in ordinary life you are focused on your own perspective"*
- *"helps to generate new ideas and ways how to achieve a particular goal"*
- *"By making new implementation you take someone's bread and butter away"*
- *"gives more questions than provides answers, but new questions lead to more studies"*

Rating of 5:

- *"The cards and the scheme give a universal approach on how to use and pitch circularity in different areas"*
- *"I got the idea very quickly"*
- *"it does help us to dive in and understand the situation and root cause of the problem, however in some cases there is a lack of info for this particular problem"*
- *"it is easy to use, because it is understandable, you can use your thoughts, you brainstorm, listen to others, widen your vision and perspective"*
- *"cards broaden perspective and point of view. They make you think outside everyday situations and make adjustments to decision making to think long term"*
- *"very handy, easy to understand, great examples"*
- *"it has broadened my perspective about circular economy and life cycle for products and services, thank you guys for an amazing workshop"*
- *"Haven't worked with this before, gives new perspective"*
- *"It takes time to understand each card, but still it's easy to use"*
- *"A bit hard in the short time to see the differences between the terms narrow, slow, etc."*
- *"would be easier if team members are in the field. And we should have narrowed the problem. More time was needed"*
- *"It helps to address problems in classified way"*
- *"Pretty straight forward"*
- *"I was able to put things in a more practical perspective"*
- *"I liked the idea of dividing the possibilities into four topics"*
- *"It is easy and understandable, so refreshing sometimes to see your problem from a different angle, even in non-sustainable product can be found something to make it greener. The workshop was interesting and resourceful"*
- *The tool was quite useful as it helped to generate a lot of different ideas for any specific project"*
- *"it is good that examples are given in cards"*
- *"tools give bigger perspective in circular idea to resolve problem"*
- *"idea of circles and cards are great to assess different goals in different stages of the circle"*
- *"Great activity, helped to generate ideas"*
- *"Great to understand how to implement a circular economy"*
- *Tools help to generate new ideas, great tool and workshop!"*
- *"cards help structure areas of improvement"*
- *"Cards are intuitive and easy to understand"*

>>>

Workshop 9: Workshop with a design agency from Helsinki, Finland

Number of participants: **6**
Average rating of perceived usefulness: 4.5
Average rating of ease-of-use: 4.83

Rating of 3:
Rating of 4:

- *"I think that the deck is very inspiring. The different principles and questions capture the idea well. Circular economy is quite complex concept and the tool helps me to understand it better. I think the cards are inspiring and help me to guide my thinking in the right direction. However, I'm not sure yet how to use in my work."*

Rating of 5:

- *"I find using the cards easy for example in a workshop."*
- *"I liked the 5 strategies which I thought was a clever way to categorize the principles. Strategies and principles gives you a good and structured way to think about circular economy related ideas with different angles."*
- *"I've used and created many tools myself as well. This was easy to understand and use."*
- *"I only got to see small part of the whole deck but already those cards immediately opened new ideas and I would have liked to skim through all of them. Still, the quick intro about the five approaches to circularity was necessary to understand the deck. Especially the Inform cards might have not opened otherwise."*
- *"I think it provides a wide range of approaches to the topic, enabling users to explore directions that may not otherwise come up. It also gives a great overview that allows you to see the bigger picture and make connections between factors that may otherwise have stayed hidden in the complexity of the whole chain."*
- *"As designers who already use similar approaches, it felt super easy and understandable, but in a setting with clients who are unaccustomed to these kind of tools and often very deeply set in their own silo or area of expertise, I think they might need someone to walk them through it and make sure they don't get stuck."*
- *"For me the most important learning was that this kind of approach is possible and there are things we can already do! Especially in the 'Trojan horse' fashion, but also very openly with clients who are interested and open minded. It makes it so tangible to approach these huge (literally life and death) topics.*

>>>

Workshop 10: Workshop with a group of entrepreneurs, innovation managers and researchers from the Helsinki region, Finland

Number of participants: **5**
Average rating of perceived usefulness: 4.4
Average rating of ease-of-use: 4.2

Rating of 3:

- *"As a designer, it is quite hard to understand what kinds of resources I need for this kind of business. but it is good that it is a tool can help me learn by doing and the content on the map can evolve."*

Rating of 4:

- *"Some details easy to understand some more difficult"*
- *"Very useful if don't know all principles."*
- *"The cards seem to collect different elements on CE very well."*
- *"It was a little bit confusing because there were so many cards"*
- *"as a mapping tool, it helps me to see a big picture and let me know what i have and what i missing"*

Rating of 5:

- *"Practical and understandable"*
- *"Very clear diagrams and explanations"*
- *"It opens new possibilities what could be done, stir the conversation"*
- *"Cards have simple design with decent amount of text & understanding"*

>>>

Workshop 11: Workshop with a group of entrepreneurs, innovation managers and researchers from the Helsinki region, Finland

Number of participants: **10**
Average rating of perceived usefulness: 4.8
Average rating of ease-of-use: 4.7

Rating of 3:

- *"I totally agree that the deck was easy to use, but making it in a team was a bit challenging. I think there could be some middle step between 'getting to know the deck' and 'coming up with ideas'.*

Rating of 4:

- *"Maybe the selection is a bit wide. It is hard to find the relevant ones.. at some point you are not so focused"*
- *"Again, focusing from such a wide variety of possibilities is hard to find the relevant ones."*
- *"Interesting how the framework is divided, good examples on the back of the cards, still rather abstract, hard to analyze what is actually relevant for sustainability"*

Rating of 5:

- *"The cards are very informative and gave good examples of the flow. I also liked the phases of the flow/circle, it made sense"*
- *"The four different flows make it clear about what factors need to be taken into consideration."*
- *"Yes, it is a good representation of thoughts. A big board/chart would be more helpful."*
- *"Yes, good reminder what can be done, for analyzing maybe not enough time."*
- *"Very easy, pleasant"*
- *"Pretty clear, well-explained (and self-explanatory)"*
- *"categorization narrow, slow, close… is good and makes the tool easy to understand."*
- *"Gives new perspectives and ideas how to connect different principles, especially when discussing in a team"*
- *"The deck is very comprehensive and as such provides a great database for thinking circular innovation strategies"*
- *"The deck format is very fancy and understandable way to approach the topic. Maybe to me the challenging part was to build a story with these cards, i.e. how to play the actual card game with the playing cards."*
- *"Easy to use, easy to understand, multiple choices"*
- *"The tool is clear, it makes you think, it gives a clear understanding of loops."*
- *"The tool is useful, good that examples were given."*
- *"The deck is easy to use, but maybe we were a little too many for one deck?"*

>>>

Workshop 12: Workshop with a group of innovation managers and researchers from the Lappeenranta region, Finland

Number of participants: **10**
Average rating of perceived usefulness: 4.7
Average rating of ease-of-use: 4.7

Rating of 3:

- *Definition of problems brings more explanatory power to the cards, strict definition first!"*

Rating of 4:

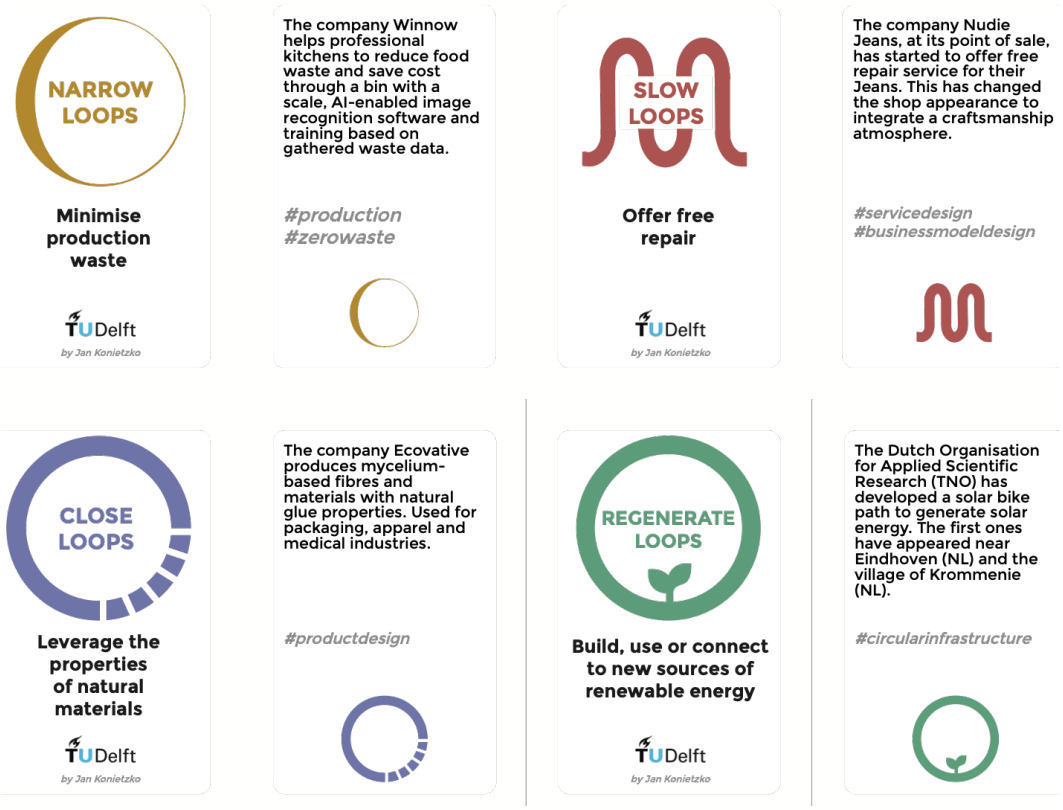
- *"There are quite a lot of cards, in a limited time frame that is a problem."*
- *"Needs a concrete business case, without it it will become quite ambiguous what we are doing."*
- *"The tool is easy and understandable to use but also in some cases and problems it needs more clarification."*
- *"The tool is easy but some cards are difficult."*

Rating of 5:

- *"The problem was not a pure business case, but the cards still provided nice starting points to the discussion."*
- *"Fairly easy, although narrowing down was a bit challenging, as there are so many cards."*
- *"Easy tool to generate a lot of ideas."*
- *"Gamification and group spirit works!"*
- *"Very comprehensive approach, easy to start ideating based on the cards. The explanations and examples on the backside were super. The only challenge is thinking outside the box, or outside the cards, rather."*
- *"Easy, comfortable, fun. There were a lot of cards so difficult to choose focus."*
- *"The point of the cards is to serve as a double-checking list of the general aspects and to facilitate associations and creativity"*
- *"How useful simple keywords/symbols can be to create relevant ideas, when first problem framed, improving, perhaps through discussion."*
- *"A thousand of ideas."*
- *"Well suited, easy going, promotes creativity"*
- *"There is a clear concept of CE, a lot of cards in the deck reflecting the CE in action."*
- *"It gets the discussion going, sparks new ideas, is structured into five categories, it is easy to point out the responsible functions and capacity. I think it is great to bring ideas to the table and ideate."*
- *"The explanations and examples are helpful and easy to understand."*
- *"Soooo many perspectives to consider that any one homogeneous group cannot come up with."*
- *"Different aspects and ideas, so your mind is not too narrow, e.g. you have open mind for new ideas."*
- *"It gives a holistic view on circular strategies and works well in that purpose."*
- *Yes it is easy once you get going. An introduction in the beginning is needed however."*
- *"Many angles I hadn't thought about, gives you new perspectives."*
- *"The amount of ideas generated was surprising. A lot of ideas!"*
- *"Broad examples, helps understanding"*

APPENDIX D

Some example cards from the first version of the Circularity Deck



TOC

APPENDIX E Search strings and strategy

Search strings	Number of articles	Top cited (and relevant) articles of all time	Top cited articles between 2015 and 2019	Other relevant articles (from scanning abstracts and snowballing)
Search for article titles (listing only additional articles in each following row and column)				
Ecosystem AND design OR strategy OR innovation	270	(Adner and Kapoor, 2010) (Adner, 2006) (Carayannis and Campbell, 2009) (Gawer and Cusumano, 2014) (Vargo et al., 2015) (Rohrbeck et al., 2009) (Nambisan and Baron, 2013) (Adner, 2016) (Adner and Kapoor, 2016) (Oh et al., 2016)	(Koskela-Huotari et al., 2016) (Abella et al., 2017) (Wong et al., 2016) (Siltaloppi et al., 2016) (Xu et al., 2018)	(Sarasvathy, 2008)
"Innovation ecosystem" AND design OR strategy OR innovation	248	(Zygiaris, 2013) (Ritala et al., 2013) (Traitler et al., 2011)	(Ritala and Almpanopoulou, 2017) (Gomes et al., 2018) (Walrave et al., 2018)	(Leten et al., 2013) (Davis, 2016) (Chesbrough et al., 2014) (Still et al., 2014) (Valkokari et al., 2016) (Bosch-Sijtsema and Bosch, 2014) (Emerson, Nabatchi & Balogh, 2011) (Boudreau, 2010)
"platform ecosystem" AND design OR strategy OR innovation	11	(Schreieck et al., 2016) (Scholten and Scholten, 2012) (Zhong and Nieminen, 2015b) (Hein et al., 2018) (Eckhardt et al., 2018) (not more found)	(not more found)	(Baldwin and Clark, 2000)

>>>

Search strings	Number of articles	Top cited (and relevant) articles of all time	Top cited articles between 2015 and 2019	Other relevant articles (from scanning abstracts and snowballing)
>> Search for article titles (listing only additional articles in each following row and column)				
"service ecosystem" AND design OR strategy OR innovation	17	(Vargo et al., 2015) (Koskela-Huotari et al., 2016) (Siltaloppi et al., 2016) (Chandler et al., 2019) (not more found)	(not more found)	
Search for article titles, abstract and keywords (listing only additional articles)				
Ecosystem AND strategy OR innovation OR design		(Teece, 2007) (Bansal, 2005) (Moore, 1993) (Iansiti and Levien, 2004b)		(Gottschalg and Zollo, 2007)
"innovation ecosystem" AND strategy OR innovation OR design	677 total	(Gawer, 2014)	(Scuotto et al., 2016) (Hayter, 2016) (Guerrero et al., 2016)	
"platform ecosystem" AND strategy OR innovation OR design	33	(Ceccagnoli et al. 2012) (Thomas et al., 2014) (Parker et al., 2016) (Parker and Van Alstyne, 2008) (Huang et al., 2018)		
"service ecosystem" AND strategy OR innovation OR design	114	(Lusch and Nambisan, 2017) (Barrett et al., 2015) (Vargo et al., 2015) (Lusch, 2011) (Vargo and Lusch, 2017)		

APPENDIX F Gathered interview data from the case

Organisation	Position of interviewee	Role of interviewee	Identi-fication code	Type	Length (minutes)	Month-year
Adaptive City Mobility	Founder and Project Leader	Project initiator, visionary	1	Phone	47	Jun-17
Remoso	Project manager	Ensure connectivity of all entities	2	Phone	60	Aug-17
Remoso	Project manager	Ensure connectivity of all entities	2.1	Phone	20	Sep-17
Eurodesign	Project manager	Provide displays and content management system	3	Phone	25	Oct-17
Eurodesign	Lead engineer	Provide displays and content management system	3	Phone	10	Nov-17
Adaptive City Mobility	Founder and Project Leader	Project initiator, visionary	1.1	Face to face	95	Oct-17
Adaptive City Mobility	Founder and Project Leader	Project initiator, visionary	1.2	Phone	49	Nov-17
German Aerospace Center	Project manager	Project monitoring	4	Phone	21	Dec-17
German Ministry of Economic Affairs and Energy	Project portfolio manager	Project funding and oversight of project portfolio	5	Phone	49	Nov-17
Naumann Design	Lead designer	External designer for the vehicle	6	Phone	35	Dec-17
Adaptive City Mobility	Founder and Project Leader	Project initiator, visionary	1.3	Phone	35	Dec-17
RWTH Aachen University	Lead engineer	Produce eight protoype vehicles	7	Phone	17	Jan-18
Green City Projekt	Project manager	Operator, potential customer	8	Phone	40	Jan-18
Remoso	Project manager	Ensure connectivity of all entities	2.2	Phone	30	Jan-18
Adaptive City Mobility	Founder and Project Leader	Project initiator, visionary	1.4	Phone	35	Jan-18
German Ministry of Economic Affairs and Energy	Project manager	Project funding and oversight of project portfolio	5	Face to face	120	Mar-18

>>>

Organisation	Position of interviewee	Role of interviewee	Identi-fication code	Type	Length (minutes)	Month-year
All project partners (one-day workshop)	-	-	11	Face to face	350	Aug-18
Streetscooter	Project manager	Homologation of the vehicle	9	Face to face	20	Sep-18
Green City Projekt	Project manager	Operator, potential customer	8.1	Face to face	25	Sep-18
BMZ	Project manager	Battery management system	10	Face to face	20	Sep-18
Adaptive City Mobility	Founder and Project Leader	Project initiator, visionary	1.5	Face to face	120	Jan-19
					Total:	
					20,3833333 hours	

APPENDIX G A list of questions that were asked during the semi-structured interviews

Principles	Questions
General	• What does your organization do? • What is the business model of your organization? • Please describe the project from your perspective • What is the current status of the project? • How do you perceive the project? • Do you have a personal vision for the project? • What is working well in the project? • What are problems and challenges in the project?
Experiment	• (How) have you experimented with different possible solutions, shapes, forms and concepts in this project? • How did the users get involved in developing this technology? • What did you learn from the user involvement? • What is new about this project? What principles does it follow for developing technology? • How do you develop the business model of the project? Are you following a specific method for that? • Are there already customers? How have potential customers been involved in the project? • How does the project intend to minimize emissions, resource use, waste and pollution, and maximize the material value of the assets?
Experiment/ Collaborate	• What is the goal of the project? • What is your role in the project? • What is your contribution to the project? • How do you take decisions? How do you prioritize? • (How) did the concept and goals change over time?
Collaborate	• How were the goals defined? • How did you select the partners? / How did you join the project? • Who are your key partners in the project? • How (often) do you correspond with other partners in the project? • Are you using particular tools to organize the collaboration? • How well does the collaboration among the partners work? • How do you deal with conflicts among partners? • What did you learn from the collaborative experience in this project? • How do you think can collaboration be improved? • What would you do differently now in the partner search and selection process? • How open is the participation in the further project development?
Platformize	• What is the architecture of the platform/software? • Who is going to use the platform? Who will have access? • Describe the connectivity of the different assets in the project. • Please describe the data flows among the project assets. • How open is the platform?

APPENDIX H

Interview themes and questions for the first workshop

Interview	Interview themes/questions
One interview after session	**The workshop material:** 1) What are your assumptions? 2) How do you want to test them? 3) How are you going to measure this? 4) When do you know whether you are on the right track? **Reflection:** 3) How helpful was it to think in terms of assumptions? 4) How did you formulate assumptions? 5) How did you prioritise them?
One interview during the testing	1) How is the testing going? 2) What are you testing? 3) What exactly are you measuring?
One interview after the testing	1) How did the testing go? 2) What have you tested? 3) What have you learned? 4) How does the testing experience help you move forward?

APPENDIX I Feedback form

Tool assessment form

You just used the **test cards** and the **validation graph** (see image below). Its purpose is to understand the assumptions underlying a business idea, and to decide how to test them, and what to test first.

Please quickly answer the following questions.

1. The tool is useful to address the purpose stated above.

	1	2	3	4	5	6	7	
Do not agree at all	○	○	○	○	○	○	○	Fully agree

Please explain your answer:

2. The tool is easy to use.

	1	2	3	4	5	6	7	
Do not agree at all	○	○	○	○	○	○	○	Fully agree

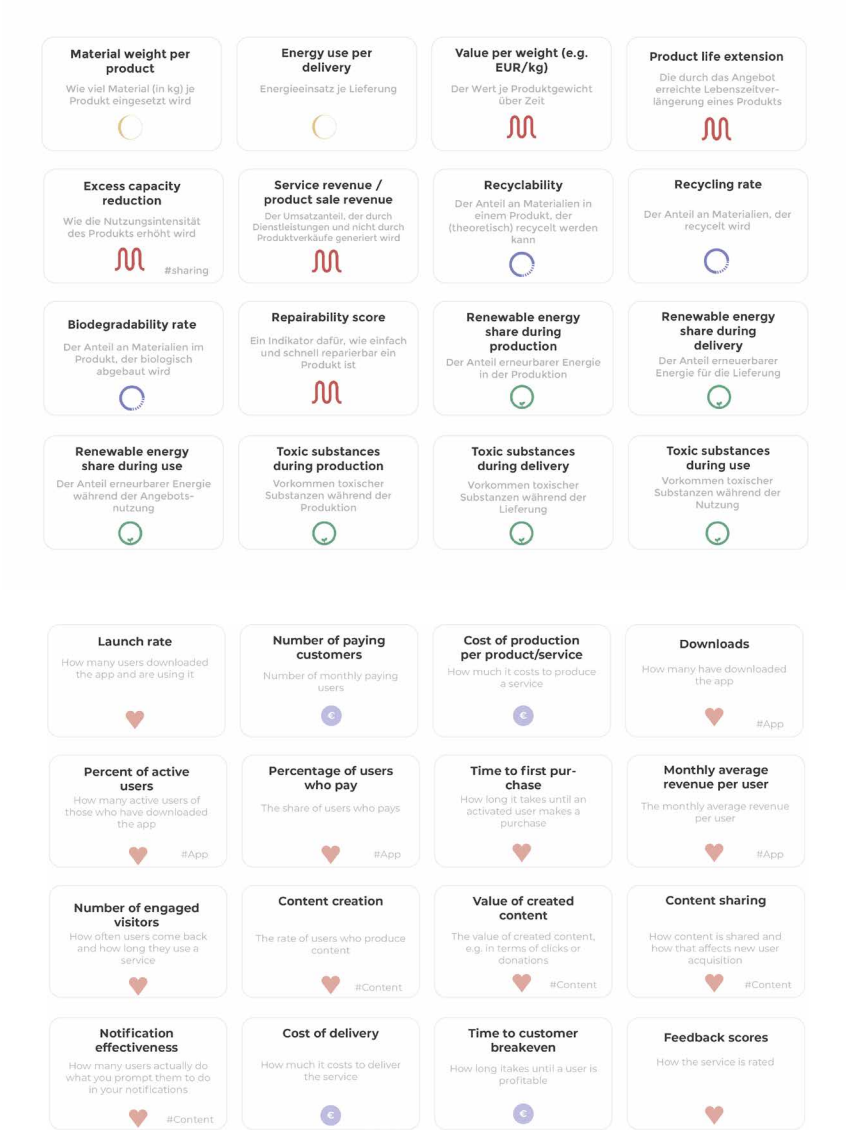
Please explain your answer:

3. Other remarks:

TOC

APPENDIX J

Example metrics for desirability, viability and circularity



(based on Croll and Yoskovitz, 2013; Heikkilä et al., 2016; Konietzko et al., 2020a)

TOC

About the author

Jan Konietzko

Born in Wangen (Allgaeu, German), Jan developed an early interest in sustainability, when he went to Cuzco, Peru for a year after highschool. He saw rivers polluted with plastics and felt for the children that were playing in these rivers. From then on, he studied and developed a deeper knowledge of the various sustainability problems that we have. He was always interested in the power that companies have in making a difference. That is why he did his Masters in Sustainability Economics and Management and assumed various roles to assess and benchmark the sustainability performance of companies. He worked for two years in a project on sustainability standards at Gesellschaft fuer Internationale Zusammenarbeit GmbH. The project aimed to assess and benchmark the sustainability of different standards in the consumer goods sector – to enable better decisionmaking for sustainability. Driven to learn more, he started a PhD at Delft University of Technology in circular business model design. The result of this four-year journey is documented in this thesis book.

21#01

Business Innovation Towards a Circular Economy

An Ecosystem Perspective

Jan Konietzko

We currently live in a carbon intensive linear economy. On the basis of burning fossil fuels, we take, make and waste an increasing amount of materials. This has pushed us against serious planetary boundaries. Radical reductions in environmental impact are needed over the coming decades. Entire economies and societies will have to reorganize. A promising candidate to support this reorganizing is a circular economy. It cuts waste, emissions and pollution, and it keeps the value of products, components and materials high over time. Companies can innovate towards a circular economy by following five key resource strategies: narrow, slow, close, regenerate, and inform. This thesis explores these strategies – through case research and a design science approach. It shows that an ecosystem perspective is necessary to implement these strategies – and provides tools and methods that can help to put an ecosystem perspective into action. This can help companies to develop circular ecosystem value propositions: that propose a positive collective outcome, fulfill user needs in exciting ways, and minimize environmental impact.

A+BE | Architecture and the Built Environment | TU Delft BK