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Examining longevity in tools for a circular economy

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Abstract: Industrial production contributes significantly to ecological sustainability challenges. One guiding approach to address these challenges is the circular economy. Slowing down resource flows is one of the main strategies of the circular economy. This involves extending the lifespan of products within and across multiple life cycles and increasing their utilization intensity. Various tools have been developed to support companies in adopting circular economy practices. This study examines how these tools facilitate designing for product longevity.

Specifically, the study analyzes 10 tools — five recent tools identified in academic literature and five first emerging through internet scraping. These tools are annotated and coded to reveal qualitative insights regarding the level of longevity they address (theoretical and methodological insights) and how these tools help handling longevity-related aspects (practical and applied insights). The findings highlight how these tools contribute to extending product lifespans and identify the extent to which they could support slowing down resource flows.

Introduction

Industrial production contributes significantly to ecological sustainability challenges, including waste management, pollution, CO2 emissions, and resources shortage. In Europe a substantial amount of waste is generated from durable goods, an average of 16.6 kg of e-waste alone (excluding all other durables) per person was recorded in 2016), highlighting the urgent need to reduce production and consumption levels (Baldé et al., 2017; Cooper, 2020). The circular economy (CE) offers a potential approach to tackle ecological sustainability problems by focusing on closing, elongating, and narrowing resource flows (N. M. P. Bocken et al., 2016).

CE is gaining popularity among companies. However, despite its popularity the influx of virgin materials into the market remains unabated (Fraser et al., 2024). Product longevity is a critical yet fundamental element of the circular economy. Longevity entails extending the use of products in one lifecycle and across multiple lifecycles (over multiple users). It prevents new products entering the economy, thus slowing down resource flows which helps to counter waste generation and resource depletion (Iraldo et al., 2017). Companies have multiple motivations to engage with longevity such as: higher up mark for high quality products, reducing costs, future revenue from circular business models etc. (Cooper, 2020; Gnanapragasam et al., 2017; Løvbak Berg & Hebrok, 2024; Oguchi et al., 2016; Salvia et al., 2015). Companies may avoid engaging with longevity due to high cost of changing business models, customer rejection, high price points of long-lasting products and other reasons (Alzaydi, 2024; Cooper, 2020; Gnanapragasam et al., 2017; Jensen, 2023; Jensen, Laursen, et al., 2021; Laitala & Berg, 2023; Oguchi et al., 2016). Companies might not see the potential or might not know how to start applying CE strategies.

The longevity of a product is defined by technical factors (e.g., design choices affecting usability and relevance over time), business models (e.g., services to extend product lifespans), user interactions, and contextual influences such as legislation, norms, and beliefs (C. A. Bakker et al., 2021; N. M. P. Bocken et al., 2016; Gnanapragasam et al., 2017; Haase & Lythje, 2022; Jensen, 2023; Jensen, Haase, et al., 2021; Jensen, Laursen,

et al., 2021; Løvbak Berg & Hebrok, 2024; Salvia et al., 2015, 2021). Consequently, many stakeholders impact longevity. Given this, the role of companies and designers is significant, as they make key decisions regarding function, design, material selection, repairability, and upgradeability. These key decisions influence how the use phase evolves. Thus, companies share responsibility when potential changes, defects and (mis)uses in the multiple lifecycles of the product lead to a decrease in lifespan (Cooper, 2020; Cooper et al., 2010; Jensen, 2023; van Nes & Cramer, 2005).
Numerous tools have been developed to support circular design practices., Bocken et al. (2019) and Rexfelt & Selvefors (2024) gathered and analysed circular economy tools. Yet, these papers did not describe if these tools were slowing down resource flows. Royo et al. (2023) analyzed circular tools to see what parameters of life-extension were discussed in circular economy tools and found that only 14 out of 70 tools discussed some parameters of life-extension. This paper will extend this research, by revealing qualitive insights into how the most recent and most findable tools tackle life-extension aspects.

State of the art

Longevity and obsolescence

Longevity refers to "the lifespan of consumer products" (Cooper et al., 2010, p.3). Longevity is the time between acquisition by the first user and disposal by the last user, synonyms of longevity are (product) lifespan, life, life cycle, cycles and lifetimes (C. A. Bakker et al., 2021; Cooper et al., 2010; Eisenriegler et al., 2020; Hummen et al., 2023; Jensen, Laursen, et al., 2021; Park, 2009; van Hinte, 2004).

Factors impacting longevity

Product longevity is influenced by a multitude of aspects on product- (micro), consumer- (meso) and socio/economic - (macro) level (Cooper et al., 2010; van Nes & Cramer, 2005). These factors include product specifications, curative actions of the company, use context, etc. A list of factors can be found in Table 1.

Factors impacting longevity
Curative actions of the company: the service and product support the company provides after sales (Nyström et al., 2021)
Use context: the environment in which the product is used (natural elements as well as social elements (e.g. public space)) (Cooper et al., 2010; Den Hollander, 2018; Jensen, 2023; Ostuzzi, 2017)
Technological advancement: technological advancement of the product compared to or compatible with other products on the market (Cooper et al., 2010; Den Hollander, 2018; Jensen, 2023; Nyström et al., 2021).
Economic aspects: financial cost to keep a product in use compared to buying new product (Cooper et al., 2010).
Product's appearance: the wear and tear and what is considered fashion and style (Bridgens & Lilley, 2017; Lilley et al., 2019)
Emotional aspects of the product: (e.g. the memories coupled with the product).
User behavior: the attitude and behavior of users in relation to product lifespans (Cooper et al., 2010; Jensen, 2023; Park, 2009; Shi et al., 2022; Wastling et al., 2018)
Consumer/ user preferences, needs and identity: match between the product features and the user needs and user identity (Alzaydi, 2024; Cooper et al., 2010; Haines-Gadd et al., 2018; Jensen, 2023; Jensen, Laursen, et al., 2021; Nyström et al., 2021)
Social aspects: social norms, trends and fads (Cooper et al., 2010; Nyström et al., 2021)
Legislation: legislative changes (Cooper et al., 2010; Nyström et al., 2021)

Table 1: Factors impacting longevity

Design for longevity

Multiple academics describe how to engage with longevity (C. Bakker et al., 2014; Den Hollander, 2018; Haase et al., 2023; Jensen, 2023; Jensen et al., 2023; Jensen, Laursen, et al., 2021; Løvbak Berg & Hebrok, 2024; Nyström et al., 2021, 2023; Park, 2009; Van Den Berg & Bakker, 2015).
Various circular economy strategies address (sub-)aspects of longevity, such as design for durability, reliability, performance, emotional durable design, attachment and trust, (ease) of maintenance and repair, upgradability and future expansion, anticipate legislation,

roadmap fit, refurbishment (N. M. P. Bocken et al., 2016; Chapman, 2005, 2009; Haines-Gadd et al., 2018; Kasarda et al., 2007; Nyström et al., 2021, 2023; Park, 2009; Van Den Berg & Bakker, 2015; Van Den Berge, 2024).

Method

A literature search and internet scraping approach were conducted to identify relevant circular economy tools. Following, a systematic coding analysis examined how these tools address longevity. Figure 1 provides an overview of the method used.

Data collection

A literature search on Web of Science was conducted on 12 November 2024. The following key string was used *TI= (((circular* AND (econom* OR design* OR product* OR business* OR innovation* OR future*)) OR circularity) AND ("design method" OR "design methods" OR "design methodology" OR guid* OR design support* OR tool* OR game* OR roadmap* OR "design process" OR software* OR canvas* OR map*)) – limited to 2024.*

In addition, the most accessible tools, methods and guides (further referred to as tools) were identified through an internet scraping approach, which simulates how companies might search for tools using Google. The search was conducted using Serper with the query 'circular economy tool' using the date range 'last year' (Serper, n.d.). The search was repeated for 4 countries in the north, east, south and west of Europe (Belgium, Sweden, Poland, Greece). Tools were ranked in order of appearance (tools listed first in Serper ended up first) and tools listed by multiple (from the 4 European countries) searches ended higher up in the ranking (last executed on 21 November 2024).

Scientific articles and websites were selected based on their explicit focus on supporting circular economy principles (e.g., general sustainability design tools were excluded). Only English tools accessible to researchers and applicable in an industrial-product-design context (e.g. excluding food and building industries or monitoring the circularity of regions) were considered. Papers and blogs listing multiple tools of third parties were excluded. The analysis included the five most recent tools identified in literature and the five most accessible tools from the internet scraping, resulting in a total of 10 tools for analysis.

Data analysis

Theoretical framework analysis

In the first round of analysis, each tool was examined using the guiding question "D*oes the tool mention or contain elements that link to slowing down resource flows?*". Text and visual elements referring to this concept were highlighted, and coded, following the annotated portfolio technique (Gaver, 2012; Sauerwein et al., 2018). These codes were then categorized into the following groups: (1) Broad circular economy concepts that inherently include slowing down resource flows (e.g., "environmental impacts of the organizations value chain"), (2) Direct references to slowing down resource flows (e.g., "All services relating to material or products after they have been used or while in use that help keep materials in the economy or that help keep the product in use for longer"), (3) Indirect mentions of longevity, further divided into keeping products in a loop for longer within one lifespan, closing loops over multiple lifespans, Intensifying product use and other emerging aspects of longevity.

The frequency of codes within each category was recorded and visualized in a graph, providing an indication of the depth at which each tool addresses longevity. This allowed for distinctions between tools that discussed circular economy in a broad sense (potentially encompassing longevity) and those that engaged more explicitly with specific aspects of longevity.

Practical support for longevity

In the second round of analysis, the tools were examined for content providing practical guidelines, advice or exercises aimed at extending product lifespans. Any instructions or recommendations supporting the slowing down of resource flows were identified, marked, and coded using the guiding question *"what tangible support (example: advice, guideline, exercise, etc.) does the tool give to slow down resource flows?"*.

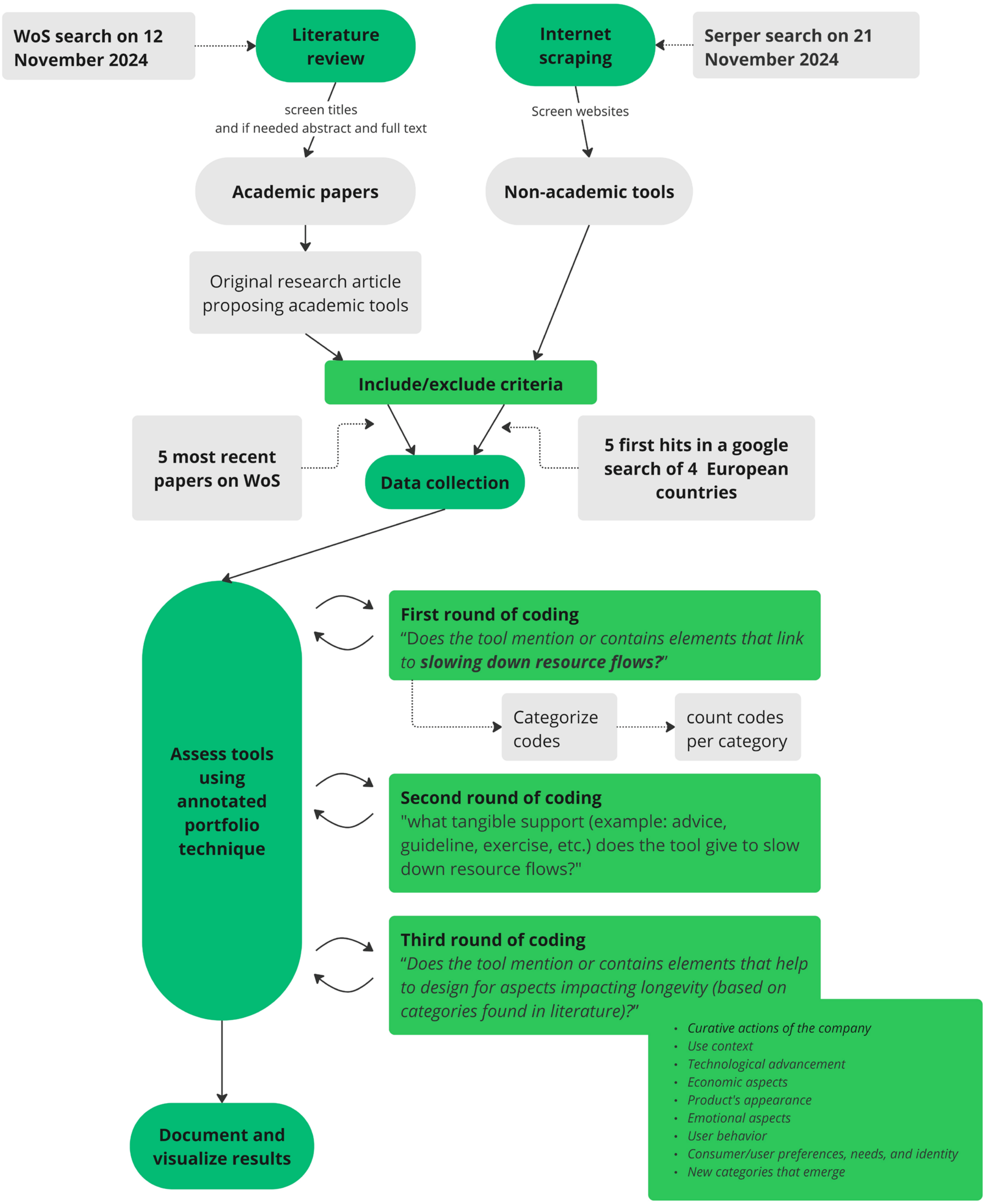

Figure 1: The applied method

Practical support for elements influencing longevity

The third round of analysis systematically scanned for support towards elements influencing slowing down resource flows. These influencing elements were based on categories found in the state-of-the-art (see Table 1). The guiding question of “practical support for longevity” was further narrowed down based on the categories. To illustrate, for the category “product specifications” the question was narrowed down towards *"what tangible support (example: advice, guideline, exercise, etc.) does the tool give towards managing product specifications (that influence product longevity)?”* All identified elements were coded and categorized.

Results

Analyzed tools

Table 2 depicts an overview of the found and analyzed tools.

	Literature or internet scraping	**Name tool**	**Author**
1	Literature	Circular economy roadmapping	(Abu-Bakar & Charnley, 2024)
2	Literature	Cradle-to-cradle business model tool	(Hoang & Böckel, 2024)
3	Literature	Circular design tool (CD-tool)	(Dagilienė et al., 2024)
4	Literature	Circularity design methodology for urban factories	(Ijassi et al., 2024)
5	Literature	Modularity and circular economy tool (MCE-tool)	(Machado et al., 2024)
6	Internet scraping	The circular design guide	(Foundation, Ellen MacArthur, n.d.)
7	Internet scraping	Circulytics	(Foundation, Ellen MacArthur, n.d.)
8	Internet scraping	CTI tool	(IQ, Circular, n.d.)
9	Internet scraping	The circular rebound tool	(Das et al., 2023)
10	Internet scraping	Circulab academy – the value chain canvas	(circulab academy, n.d.)

Table 2: The 10 tools analyzed in this study

Theoretical Framework Analysis

Figure 2 shows notable variations in how tools address theoretical aspects. On one hand, 5 tools mention explicitly slowing down resource flows (Tools 5, 6, 7, 8 and 9). To illustrate, Tool 7 mentions “Keep products and materials in use. All services relating to material or products after they have been used or while in use that keep materials in the economy, or that help keep the product in use for longer.” On the other hand, some tools barely speak about aspects of slowing down resource flows (Tools 1, 3, 4).

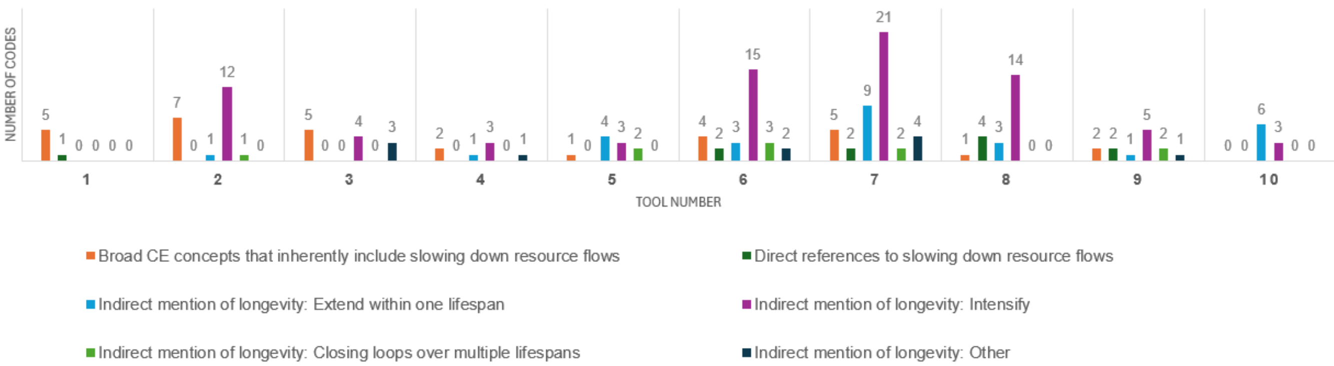

Figure 2: Longevity mentions per category

8 tools mention at least one longevity aspect (Tool 2,3,5,6,7,8,9,10). Among them "closing loops for longer lifespans" is more emphasized, compared to "keeping products in the loop for longer within one cycle" and "intensifying product use". Tools 1, 3, 4, 8 and 10 don't mention any aspects of intensifying product use. Tool 1, 3 does not mention any longevity aspect about "extend within one lifespan".

Practical Support for Longevity
The tools offer varied practical support for increasing longevity including brief inquiries, scoring mechanisms that assess the current circularity state of the company, scoring the circularity of a product, theoretical explanations, mapping the lifecycle or value chain exercises, specific questions integrated in a business model canvas and illustrative cards demonstrating concepts, examples and rebound effects of strategies such as repurposing and remanufacturing.

The tools barely mention longevity aspects (Tool 1, 3, 4) don't provide specific help for longevity. In one of the tools (tool 8) longevity aspects are explained, yet the **tool provides barely practical support besides the theoretical explanation**. Tool 8 assesses the current circularity of a product similar to a simplified life cycle analysis. Longevity aspects are important in a life cycle assessment, yet the tool ignores aspects such as the real lifespan of a product in its calculations.

The support provided is sometimes superficial. For example, tools might ask broad inspiring guiding questions, yet limits tool-users in answering these questions. To demonstrate, in tool 2 tool-users need to sketch multiple elements to answer a broad question yet limit the user to a single Excel box to sketch this complex content. Tool 6 shows another example, the tool asks, in the context of prolonging product life, if the product can become a service in some way, yet the tool-user only needs to answer Yes or No and list a possible barrier. A similar example can be found in Tool 7, where tool users only need to input percentage of mass that for example get reused or redistributed.

Remarkably, strategies intended to intensify product use such as "product-service-systems" are mentioned in some tools, **without questioning if this results in slowing down of resource flows**. For example, in tool 2, following code emerged "Can costs be avoided, reduced or distributed, e.g. by product-service-systems, renting or other options". The tool speaks about avoiding costs for the company (or user) and does not refer to reducing ecological impact. Similar can be observed in a worksheet of tool 6, where the tool-user is asked to describe the user needs and how these needs can be met without owning the product. No reflection is made if this then reduces the flow of products.

It can be observed that questions are posed from the companies' point of view, leading to an **ideal or hypothetical point of view**. To illustrate, in Tool 6, the tool-user sketches what happens in the multiple uses of the product. Which triggers the tool-user to think in multiple lifecycles. Yet, likely preferred/ideal scenarios will be sketched rather than scenarios that happen in reality. Similar in Tool 2, the tool-user is asked "How can they [technical nutrients] be returned to their cycle". Tool 8 asks the "recovery potential" of reuse. Both examples illustrate the hypothetical nature of the questions.

Practical Support for Elements Influencing Longevity
A further analysis highlights gaps in the tools regarding elements influencing longevity. Several factors remain unaddressed, including the use context, technological advancements, product appearance, emotional attributes, and social considerations.
Interestingly, Tools can indirectly provide support for factors that influence the slowing down of resource flows without explicitly referencing this concept (Tool 3). To illustrate, tool 3 asks to systematically map user-, usage- and after usage- ecosystems. Although longevity is not specifically mentioned, the mapping of the users and usage might aid in detecting for example use behavior impacting longevity.
New categories that influence longevity emerged from the analysis, including consumer and user knowledge on longevity, corporate marketing strategies, and the accessibility of product and material information related to longevity.

Discussion and conclusions

The analysis of the tools does not give an answer whether the tools can be a useful tool to transition to a circular economy, nor was this the scope of the study. Yet, one of the main strategies for circularity (slowing down resource flows by elongating lifespans in one and over multiple lifespans) was barely mentioned in three of the analyzed tools. In the tools that mention and provide support for longevity, the focus is on closing loops rather than elongating the lifespan within one loop or intensifying use.

Strategies to intensify product use such as "product-service-systems" can be expected to be used as a means to slow down resource flows, yet in the tools it is sometimes decoupled from resource flows. Similar can be observed for the closing of loops.

Tools that do tackle (indirect) aspects of elongation within and over multiple lifespans and tackle aspects of intensifying use, have the potential to reduce ecological impact using longevity strategies. Yet, the tools use guiding questions, giga mapping exercises and lifecycle mapping exercises with a hypothetical/abstract starting point often aiming for initial ideation of ideas. Reality aspects impacting longevity such as how users really behave, how products and their context change over time, are barely touched upon.

Thus, even though the analyzed tools (7 out of 10) speak about longevity aspects and 6 out of 10 provide practical support for longevity. The tools support in slowing down resource flows is somehow superficial.

The emerging new categories influencing longevity can be further analyzed to consider in the development of comprehensive tools for supporting the slowing down of resource flows.

Future studies can do a more extensive and in-depth analysis of the tools on longevity aspects and observe tools and methods companies indicate to use.

References

Abu-Bakar, H., & Charnley, F. (2024). Developing a Strategic Methodology for Circular Economy Roadmapping: A Theoretical Framework. *Sustainability (Switzerland)*, *16*(15). https://doi.org/10.3390/su16156682

Alzaydi, A. (2024). Balancing creativity and longevity: The ambiguous role of obsolescence in product design. *Journal of Cleaner Production*, *445*. https://doi.org/10.1016/j.jclepro.2024.141239

Bakker, C. A., Mugge, R., Boks, C., & Oguchi, M. (2021). Understanding and managing product lifetimes in support of a circular economy. *Journal of Cleaner Production*, *279*. https://doi.org/10.1016/j.jclepro.2020.123764

Bakker, C., Wang, F., Huisman, J., & Den Hollander, M. (2014). Products that go round: Exploring product life extension through design. *Journal of Cleaner Production*, *69*, 10–16. https://doi.org/10.1016/j.jclepro.2014.01.028

Baldé, C. P. ., Forti, V. ., Gray, V. ., Kuehr, R. ., & Stegmann, P. . (2017). *The global e-waste monitor 2017 : quantities, flows, and resources*. International Telecommunication Union.

Bocken, N. M. P., de Pauw, I., Bakker, C., & van der Grinten, B. (2016). Product design and business model strategies for a circular economy. *Journal of Industrial and Production Engineering*, *33*(5), 308–320. https://doi.org/10.1080/21681015.2016.1172124

Bocken, N., Strupeit, L., Whalen, K., & Nußholz, J. (2019). A review and evaluation of circular business model innovation tools. In *Sustainability (Switzerland)* (Vol. 11, Issue 8). MDPI. https://doi.org/10.3390/su11082210

Bridgens, B., & Lilley, D. (2017). Understanding material change design for appropriate product lifetimes. *PLATE, Product Lifetimes and the Environment*, 54–59.

Chapman, J. (2005). *Emotionally Durable Design: Objects, Experiences and Empathy*.

Chapman, J. (2009). Design for (Emotional) Durability. In *Source: Design Issues* (Vol. 25, Issue 4). http://www.product-life.

Cooper, T. (2020). Slower Cycles: An Essential Characteristic of the Circular Economy. In S. Eisenriegler (Ed.), *The Circular Economy in the European Union: An Interim Review* (pp. 99–116). Springer International Publishing. https://doi.org/10.1007/978-3-030-50239-3_9

Cooper, T., Burns, B., Chapman, J., Christer, K., Curran, A., Ervine, C., Evans, S., Fisher, T., Fuad-Luke, A., Garnett, K., Mackenzie, D., Park, M., Peattie, K., Shipton, J., Simon, M., Stahel, W. R., Twigg-Flesner, C., & van Nes, N. (2010). *Longer Lasting Products*.

Gower publishing limited and Ashgate publishing company.

Dagilienė, L., Čeičytė-Pranskūnė, J., Telešienė, A., Valušytė, R., & Varžinskas, V. (2024). Developing a circular design framework: Co-creation and validation of a circular product and service design tool. *Journal of Industrial Ecology*, *28*(4), 783–799. https://doi.org/10.1111/jiec.13494

Das, A., Konietzko, J., Bocken, N., & Dijk, M. (2023). The Circular Rebound Tool: A tool to move companies towards more sustainable circular business models. *Resources, Conservation and Recycling Advances*, *20*. https://doi.org/10.1016/j.rcradv.2023.200185

Den Hollander, M. (2018). *Design for Managing Obsolescence-A design methodology for preserving product integrity in a circular economy* [Delft University of Technology]. https://www.researchgate.net/publication/326368488

Eisenriegler, S., Schally, H.-M., Stahel, W. R., Webster, K., Lohan Cillian, Pietikäinen, S., Bonafe, S., Wachholz, C., Mandl, S., Tröger, N., Cooper, T., Bocken, N., Brand, U., Wissen, M., Frank-Stocker, A., Shields, K., Nagel, M., Paech, N., Holzinger, H., & Bhardwaj, A. (2020). *The Circular Economy in the European Union*.

Fraser, M., Conde, À., Haigh, L., Bailey, L., Veillet Lavalellee, M., Valli Shankar, A., Birliga Sutherland, A., & Murdie, M. (2024). *CIRCULARITY GAP REPORT*. www.deloitte.com.

Gaver, W. (2012). What should we expect from research through design? *Conference on Human Factors in Computing Systems - Proceedings*, 937–946. https://doi.org/10.1145/2207676.2208538

Gnanapragasam, A., Oguci, M., Cole, C., & Cooper, T. (2017). Consumer expectations of product lifetimes around the world: a review of global research findings and methods. *Product Lifetimes And The Environment 2017 - Conference Proceedings*, 464–469.

Haase, L. M., & Lythje, L. S. (2022). User Strategies for Prolonging Product Lifetimes: A New Starting Point for Circular Conceptual Design. *Sustainability (Switzerland)*, *14*(22). https://doi.org/10.3390/su142215133

Haase, L. M., Lythje, L. S., & Jensen, P. B. (2023). Designed to Last: Reframing Strategies for Designing Value Propositions that Support Product Longevity in 17 Best Practice Companies. *Circular Economy and Sustainability*, *3*(4), 2009–2035. https://doi.org/10.1007/s43615-022-00244-z

Haines-Gadd, M., Chapman, J., Lloyd, P., Mason, J., & Aliakseyeu, D. (2018). Emotional durability design Nine-A tool for product longevity. *Sustainability (Switzerland)*, *10*(6). https://doi.org/10.3390/su10061948

Hoang, K. M., & Böckel, A. (2024). Cradle-to-cradle business model tool: Innovating circular business models for startups. *Journal of Cleaner Production*, *467*. https://doi.org/10.1016/j.jclepro.2024.142949

Hummen, T., Hellweg, S., & Roshandel, R. (2023). Optimizing Lifespan of Circular Products: A Generic Dynamic Programming Approach for Energy-Using Products. *Energies*, *16*(18). https://doi.org/10.3390/en16186711

Ijassi, W., Evrard, D., & Zwolinski, P. (2024). Development of a circularity design methodology for urban factories based on systemic thinking and stakeholders engagement. *Sustainable Production and Consumption*, *46*, 600–616. https://doi.org/10.1016/j.spc.2024.02.031

Iraldo, F., Facheris, C., & Nucci, B. (2017). Is product durability better for environment and for economic efficiency? A comparative assessment applying LCA and LCC to two energy-intensive products. *Journal of Cleaner Production*, *140*, 1353–1364. https://doi.org/10.1016/j.jclepro.2016.10.017

Jensen, P. B. (2023). *Designed to Last: A Study to Support Increased Product Longevity* [Aalborg University]. https://doi.org/10.54337/aau528217970

Jensen, P. B., Haase, L. M., Cooper, T., Steward, J., Marsh, P., & Laursen, L. N. (2023). The LaST Tool – The Longevity and Sustainable Transition Tool. *Lecture Notes in Mechanical Engineering*, 757–771. https://doi.org/10.1007/978-3-031-28839-5_85

Jensen, P. B., Haase, L. M., & Laursen, L. N. (2021). A practical approach to companies' transformation toward product longevity: A best-case study. *Sustainability (Switzerland)*, *13*(23). https://doi.org/10.3390/su132313312

Jensen, P. B., Laursen, L. N., & Haase, L. M. (2021). Barriers to product longevity: A review of business, product development and user perspectives. *Journal of Cleaner Production*, *313*. https://doi.org/10.1016/j.jclepro.2021.127951

Kasarda, M. E., Terpenny, J. P., Inman, D., Precoda, K. R., Jelesko, J., Sahin, A., & Park, J. (2007). Design for adaptability (DFAD)-a new concept for achieving sustainable design. *Robotics and Computer-Integrated Manufacturing*, *23*(6), 727–734. https://doi.org/10.1016/j.rcim.2007.02.004

Laitala, K., & Berg, L. L. (2023). *Why won't you complain? Consumer rights and the unmet* *product lifespan requirements*. http://urn.fi/URN:ISBN:978-952-64-1367-9

Lilley, D., Bridgens, B., Davies, A., & Holstov, A. (2019). Ageing (dis)gracefully: Enabling designers to understand material change. *Journal of Cleaner Production*, *220*, 417–430. https://doi.org/10.1016/j.jclepro.2019.01.304

Løvbak Berg, L., & Hebrok, M. (2024). Holding on or letting go: Conflicting narratives of product longevity. *Resources, Conservation and Recycling*, *210*. https://doi.org/10.1016/j.resconrec.2024.107834

Machado, N., Morioka, S. N., & Gohr, C. F. (2024). Can product modularity boost strategies for circular business models? A visual tool proposal representing benefits and barriers considering expert opinion. *Journal of Cleaner Production*, *448*. https://doi.org/10.1016/j.jclepro.2024.141522

Nyström, T., Selvefors, A., Diener, D., Algurén, P., Hallquist, L., Eriksson, M., Whalen, K., Boyer, R., Sellén, J., Linder, M., Williander, M., Ohnell, S., Östling, J., & Andersson, K. (2023). *FUTURE ADAPTIVE DESIGN How to create longer-lasting products for circular offerings AN INNOVATION GUIDE FOR CIRCULAR CHANGE AGENTS*. www.ri.se

Nyström, T., Whalen, K. A., Diener, D., Hollander, M. Den, & Boyer, R. H. W. (2021). Managing circular business model uncertainties with future adaptive design. *Sustainability (Switzerland)*, *13*(18). https://doi.org/10.3390/su131810361

Oguchi, M., Tasaki, T., Daigo, I., Cooper, T., Cole, C., & Gnanapragasam, A. (2016). Consumers' expectations for product lifetimes of consumer durables. *Electronics Goes Green 2016+*.

Ostuzzi, F. (2017). *Open-Ended Design. Explorative Studies on How to Intentionally Support Change by Designing with Imperfection*.

Park, M. B. (2009). *Product Life: Designing for Longer Lifespans*. Kingston University Londen.

Rexfelt, O., & Selvefors, A. (2024). Mapping the landscape of circular design tools. *Resources, Conservation and Recycling*, *209*. https://doi.org/10.1016/j.resconrec.2024.107783

Royo, M., Chulvi, V., Mulet, E., & Ruiz-Pastor, L. (2023). Analysis of parameters about useful life extension in 70 tools and methods related to eco-design and circular economy. *JOURNAL OF INDUSTRIAL ECOLOGY*, *27*(2), 562–586. https://doi.org/10.1111/jiec.13378

Salvia, G., Cooper, T., Fisher, T., & Harmer, L. (2015). What is broken? Expected lifetime, perception of brokenness and attitude towards maintenance and repair. *PLATE Conference Proceedings*. https://www.researchgate.net/publication/281268978

Salvia, G., Zimmermann, N., Willan, C., Hale, J., Gitau, H., Muindi, K., Gichana, E., & Davies, M. (2021). The wicked problem of waste management: An attention-based analysis of stakeholder behaviours. *Journal of Cleaner Production*, *326*. https://doi.org/10.1016/j.jclepro.2021.129200

Sauerwein, M., Bakker, C., & Balkenende, R. (2018, June 28). *Annotated Portfolios as a Method to Analyse Interviews*. https://doi.org/10.21606/drs.2018.510

Shi, T., Huang, R., & Sarigöllü, E. (2022). Consumer product use behavior throughout the product lifespan: A literature review and research agenda. *Journal of Environmental Management*, *302*. https://doi.org/10.1016/j.jenvman.2021.114114

Van Den Berg, M. R., & Bakker, C. A. (2015). *A product design framework for a circular economy*. *17*.

Van Den Berge, R. B. R. (2024). *Product lifetime extension through design Encouraging consumers to repair electronic products in a circular economy*. https://doi.org/10.4233/uuid:ab99217e-5ae7-4322-b4c9-311547a3feb9

van Hinte, E. (2004). *Eternally Yours: Time in Design: Product, Value, Sustenance*. 010 Publishers.

van Nes, N., & Cramer, J. (2005). Influencing product lifetime through product design. *Business Strategy and the Environment*, *14*(5), 286–299. https://doi.org/10.1002/bse.491

Wastling, T., Charnley, F., & Moreno, M. (2018). Design for circular behaviour: Considering users in a circular economy. *Sustainability (Switzerland)*, *10*(6). https://doi.org/10.3390/su10061743