ADAPTING A DASHBOARD-BASED APPROACH FOR FEASIBILITY ANALYSIS TO CIRCULAR PSS BUSINESS MODELS

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ABSTRACT

Sustainability and circular economy are currently some of the strongest trends in industry as well as in politics. They are seen as the best chance to tackle emissions, pollution and climate change while maintaining the prosperity of society. Product-Service System (PSS) business models are seen as an enabler of the circular economy. However, the development of such business models is a major challenge, especially for SMEs. Therefore, there is a need for support through a methodical approach in the development and decision-making. This paper combines and extends an existing approach for assessing the feasibility of PSS-driven business models and a decision-support matrix for recirculation strategies to provide support to practitioners in the early development phases of circular PSS business models. The existing approach for feasibility analysis was focused on PSS only. To include the perspective of circularity and sustainability a systematic literature review was conducted to identify necessary criteria. Combined with the decision-support matrix the improved method aims to be a lean method to support feasibility analysis and decision-making in circular PSS business model development.

Keywords: Circular economy, Circular Business Models, Product-Service Systems (PSS), Sustainability, Feasibility Analysis

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1 INTRODUCTION

The topic of sustainability is more important than ever. Backed by the "European Green Deal"-initiative with the goal to transform Europe into the first climate neutral continent by heavily reducing carbon emissions (European Commission, n.d.). This requires the economy to change from a linear "take-make-waste" economy towards a circular economy (CE) (Guldmann, 2017). The circular economy focuses on recapturing the value of products after their use-phase with the goal to close the material loop (Jabbour *et al.*, 2019) and, thus, losing only minimal amounts of resources as waste while using renewable energy sources in order to cause less emissions.
In order to realise a circular economy, the concept of Product-Service Systems (PSS) is seen as a promising approach (Kjaer *et al.*, 2019). PSS are an integrated offering of goods and services (Lins *et al.*, 2021) and is defined by Meier *et al.* (2010) in the B2B context as follows: "An Industrial Product-Service System is characterized by the integrated and mutually determined planning, development, provision and use of product and service shares including its immanent software components in B2B applications and represents a knowledge-intensive socio-technical system". The aim of PSS is therefore to offer the customer a holistic and specific solution to his problem (Mahl *et al.*, 2021). The PSS offer itself can be sustainable, but it is not necessarily sustainable just because it is a PSS (Tukker, 2015). It is therefore necessary to develop the PSS offer with a direct focus on sustainability respectively circular economy to ensure to achieve the goal.
The concept of PSS is already spreading in industry yet mainly in larger companies (Biege *et al.*, 2013; Bahrke & Kempermann, 2015). This can be attributed to the fact, that the transformation towards being the provider of a PSS and the development of a fitting business model is a complex process that requires financial, time and human resources, which are more limited in small and medium sized enterprises (SME) (Lins *et al.*, 2021). The same applies to the development of business models in the circular economy (Jabbour *et al.*, 2019).
To support the early phases of the development of PSS for CE this contribution proposes a decision-making support tool for a multi-criteria feasibility analysis of PSS for CE concepts, since current literature offers only little support in this area and especially in the context of SMEs.
The proposed tool combines previous work of a dashboard-based approach to support the feasibility analysis of PSS-driven business models in SMEs and the development of a decision support model for recirculation strategies and therefore enabling a CE. Thus, the contribution aims to answer the following research question: how the process of feasibility analysis for PSS-driven business models in the context of a CE can be systematically supported?
To answer the question this contribution first briefly presents the input from the previous work of the authors. Then the results of systematic literature review for criteria, development tools and feasibility analysis tools in the context of CE business models and sustainable PSS business models are presented. Afterwards the adapted feasibility analysis dashboard for PSS-driven CE business models is introduced. Finally, an outlook on further fields of application and development possibilities for the presented approach is given.

2 METHODOLOGICAL BACKGROUND

This section briefly presents the two concepts building the basis for the later presented tool.

2.1 Dashboard-based approach for feasibility analysis for PSS-driven business models

This dashboard-based approach is meant to support companies, especially SMEs, while carrying out a feasibility analysis in the early stage of the development of a PSS business model (Mahl *et al.*, 2022). The tool was designed to be applicable with limited time, financial and human resources as well as to be structured, easily understandable and with clear decision criteria. The first iteration of the tool was developed in a project focused on the development of PSS business models for SMEs. In this project the feasibility analysis for new PSS business models was identified as an important development step. However, no suitable procedure for feasibility analysis of PSS business models could be identified in the existing literature. Various textbooks on project management or technical product development

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mentioned feasibility analysis as an important part of the process, but did not provide a specific procedure. Therefore, the development of this dashboard-based feasibility analysis approach was started.
The dashboard is shown in Figure 1. The dashboard is divided into five sections: technical feasibility, marketability, organisational feasibility, non-monetary benefits and monetary benefits. Each section represents a dimension of feasibility which has to be checked in order to fully analyse the PSS concept at hand and to make a decision for further development and implementation of the PSS concept. The dashboard itself lists criteria in the various dimensions that need to be checked in order to make a statement about the feasibility of the PSS concept. The criteria are rated with the help of a traffic light after a review has taken place, so that the dashboard reflects the current status regarding the progress of the analysis as well as an assessment of the feasibility of the concept at any time. However, the dashboard does not work alone, but is supported by other elements, as well as a step-by-step approach (Mahl *et al.*, 2022).

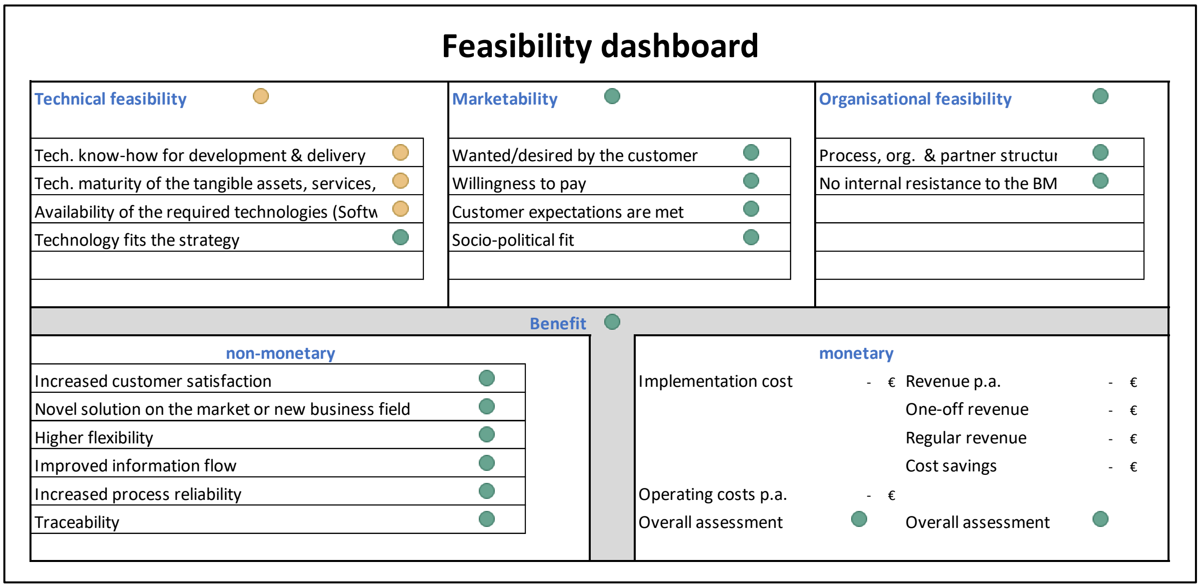

Figure 1: Dashboard for feasibility analysis for PSS-driven business models (Mahl et al., 2022)

The supporting elements are a list of possible criteria for the different dimensions to be checked, a list of tools and methods for checking the feasibility of individual criteria and defined states for the traffic light system for evaluation. In addition, the approach requires an elaborated concept for a PSS business model in the form of a Business Model Canvas (BMC) (Osterwalder *et al.*, 2010) as input as well as the BMC which represents the current status of the company's business model.
The procedure for checking the feasibility of a PSS business model using the dashboard approach is as follows: First, since the existing business model is assumed to be feasible new elements of the desired conceptual business model get compared to the current state and selected as elements to be checked in the corresponding dimension of the dashboard method. In this step, a criteria list can be used for support.
Second, with the help of the appropriate tools from the tool list, the elements are examined and evaluated for their feasibility and the result is transferred to the dashboard. After all elements have been checked, a decision can be made on the basis of the evaluations as to whether the concept should be pursued further, whether it should be revised and subjected to a new examination or whether the concept should be discarded (Mahl *et al.*, 2022).
A major criticism of the concept is the lack of verification of sustainability.

2.2 Decision matrix for CE strategies

An approach to support decision-makers in developing sustainable business models is presented by Petry and Köhler (2022). This approach presents an application-oriented decision supporting model, as a tool to help decision-makers in selecting the recirculation strategy providing the greatest benefit from an economic, environmental and social point of view. The decision matrix (Figure 2) was built based on insights from literature, as well as on results from workshops with a practical partner in the field of production equipment. Overall, nine Recirculation Strategies: Reuse, Upgrade,

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Maintain/Repair, Refurbish, Remanufacture, Repurpose, Recycle, Cascade and Recover (Hildenbrand *et al.*, 2020) were considered in the matrix shown in the first line. In the left column the questions or criteria leading to the recirculation strategy that should be preferred are listed. In the remaining boxes, the answers to the question, which are needed to preserve the functioning of the strategy shown in the same column are itemized. If the answers match the answers in the matrix and a grey box is reached, the strategy should be preferred, based on the condition of the product, the EU waste framework directive (*DIRECTIVE 2008/98/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL 2008*) and the design and demand of this product. In the next step, the proposed recirculation strategy can be evaluated by checking the assessment criteria in the table below. The shown evaluation criteria were developed through literature and practical experiences and validated with a practical partner in the context of production equipment.
This approach therefore helps to decrease the lack of tools to assess recirculation strategies, instead of focusing on environmental or sustainability assessment which is well described in literature according to (Barkmeyer *et al.*, 2017).

Criterion/Strategy	Reuse	Upgrade	Maintain/Repair	Refurbish	Remar
Use of prohibited/toxic substances?	no	no	no	yes/no	yes/no
Visual condition acceptable?	yes	yes	yes	yes/no	yes/no
Fully functional?	yes	yes	no	yes/no	yes/no
Does the product meet all standards and regulations set by the market?	yes	yes/no	yes/no	yes/no	yes/no
Does the product meet the performance requirements of the customer/market?	yes	yes/no	yes/no	yes/no	yes/no
Disassembly possible?		yes/no	yes	yes	yes
Fulfillment of requirements technically possible through an upgrade?		yes	yes/no	no	no
Fulfillment of requirements technically possible through repair?			yes	no	no
Possibility to remove prohibited/toxic				yes	yes
Can a visually acceptable condition be achieved by refurbishment?				yes	no
Fulfillment of requirements technically possible through refurbishment process? (Customer requirements, standards, regulations... -> Attention: Product appears "as new", but is not up to the latest technical				yes	no
Fulfillment of requirements technically possible by remanufacturing process? (Creation of an as good as new or better condition (optical + functional) by reusing only the components that correspond to an as good					yes
Is repurposing possible?					
Can different materials be separated from each other?					
Is it technically possible to reuse the					
Can material properties be preserved?					
Does the recycled material meet all regulatory requirements and qualities to be used again for the same purpose?					
Is there a utilization cycle for material of lower quality?					
Are the materials used suitable for energy recovery?					
Can the suitable and unsuitable materials be separated?					

Figure 2: Decision matrix for recirculation strategies (Petry & Köhler, 2022)

3 SYSTEMATICAL LITERATURE REVIEW

In order to adapt the existing approach to the feasibility check with a dashboard to the requirements of sustainability and the circular economy, a systematic literature review was carried out with the aim of identifying the necessary criteria and tools for checking feasibility in the context of sustainability and the circular economy. The process for the systematic literature review is based on the PRISMA-statement (Moher *et al.*, 2015; Lame, 2019). The procedure including search phrases and the databases searched are shown in Figure 3. The search yielded 590 hits. After removing duplicates, papers with unfitting titles and abstracts 40 publications were left for full text reviews. Finally, 14 publications fitted the criteria of the review. Criteria for inclusion were language, the type of the publication and the context of the publication. Only English or German publications in conferences or journals were included. In addition, only papers dealing with either the feasibility analysis, evaluation or assessment of sustainable PSS business models, circular business models or circular PSS business models were accepted.
To extend the range of the literature review the "snowballing"-method by Wohlin (2014) was used. With this method the bibliographies of selected papers were checked (backward snowballing) and also

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papers citing the selected papers (forward snowballing). Following this, three more publications were included in the review.

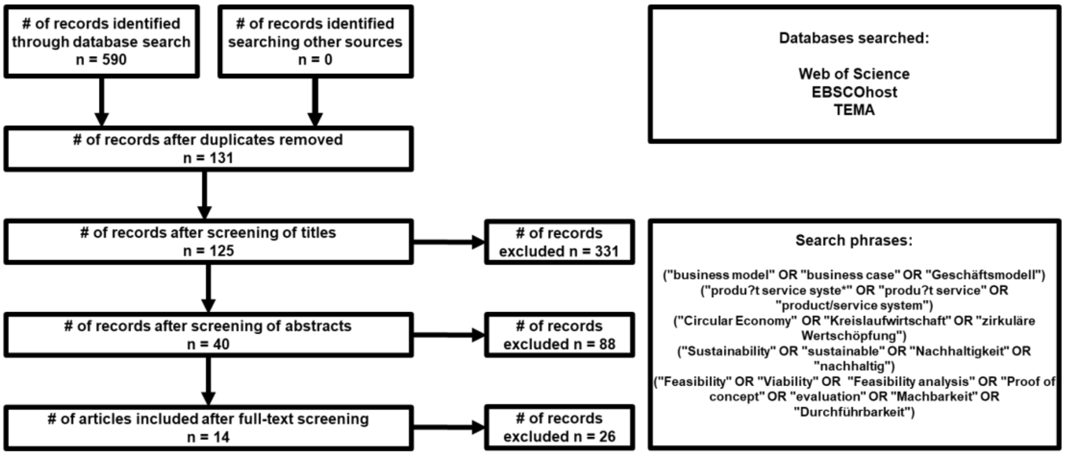

Figure 3: Systematic literature review process based on Lame (2019) and Moher et al. (2015)

The results of the literature review are shown in Figures 4 to 6. Figure 4 lists important criteria for the success and circularity of the circular business models that could be extracted from the publications. In order to simplify the process, the criteria were clustered and subdivided into criteria and sub-criteria. The main criteria are competences, cooperation, materials, product/packaging, second-life products, sustainable procurement, reducing and minimising emissions, pollution and waste as well as end-of-life/second-life strategies and social sustainability.

		Source										
Criteria	**Sub-criteria**	Averina et al. 2021	Cong et al. 2018	Manninen et al. 2018	Toker et al. 2022	Hu et al. 2012	Arredondoi-Soto et al. 2022	Werning et al. 2019	Pieroni et al. 2020	Dowie et al. 1994	Allione et al. 2011	Bocken et al. 2013
Competencies	engineering skills, market knowledge, design expertise, understanding customers	x										
Cooperation	partner network, partner competencies fitting, partner incentives, transparency towards customers	x							x			
Materials	appropriate materials, minimized/optimized use, use of fewer materials, use of recycled materials, use of recycable materials, closing matrial loop, avoiding hazardous materials		x	x		x	x		x	x	x	x
Product / packaging	low complexity, easy to disassamble, high durability, high modularity, design		x		x	x		x	x	x	x	
Second-life products	Quality/Performance/durability/security of 2nd-life product, Quality of returns						x	x				
Sustainable sourcing	using renewable resources/materials, sustainable sourcing of raw materials, renewable energy sources, minimized energy use			x	x	x	x		x		x	
Reducing / minimizing emissions, pollution, waste	separate waste collection, incineration and landfill minimised			x	x	x	x	x				x
End-of-Life and Second-Life strategies	reverse logistics, repair information & support		x		x	x		x	x			
Social sustainability	Job creation, training & education, improving customers life quality, Health and safety, fairness and justice in the supply chain, sustainable consumption				x	x						x

Figure 4: Criteria and sub-criteria for sustainability (Dowie & Simon, 1994; Allen Hu et al., 2012; Allione et al., 2012; Bocken et al., 2013; Manninen et al., 2018; Cong et al., 2019; Werning & Spinler, 2020; Pieroni et al., 2021; Arredondo-Soto et al., 2022; Averina et al., 2022; Toker & Görener, 2022)

The group of competences includes, among other things, the necessary engineering skills for implementation but also the understanding of customer requirements and the market (Averina *et al.*, 2022). The criterion cooperation includes aspects such as the appropriate partner network, the appropriate competences of the partners, but also transparency towards customers (Pieroni *et al.*, 2021; Averina *et al.*, 2022). The criterion materials was mentioned most frequently and includes items such as the use of recycled materials, the avoidance of hazardous materials, the minimisation or optimisation of material use and the reduction of the number of materials used (Dowie & Simon,

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1994; Allen Hu *et al.*, 2012; Bocken *et al.*, 2013; Manninen *et al.*, 2018; Pieroni *et al.*, 2021). Another criterion often mentioned is product / packaging. Here, a high degree of durability, modularity and a design with a focus on the disassemblability of the product or packaging is required (Allione *et al.*, 2012; Cong *et al.*, 2019; Toker & Görener, 2022). Arredondo-Soto *et al.* (2022) studied the consumers perception of remanufactured products and found that well informed customers are more likely to buy them since they can have concerns about the quality, safety and durability of remanufactured products. Also, Werning and Spinler (2020) identified the uncertainty regarding the quality of returns for remanufacturing as a risk for the circular business model. Another criterion often mentioned is sustainable sourcing including the use of renewable energy for production, sustainable sourcing of raw materials and minimizing of energy used (Allen Hu *et al.*, 2012; Manninen *et al.*, 2018; Toker & Görener, 2022). An equally frequently mentioned point is the reduction or minimisation of emissions, pollution and waste with the demands for separate waste collection and the avoidance of burning materials or storing them in landfills (Bocken *et al.*, 2013; Cong *et al.*, 2019; Toker & Görener, 2022). Furthermore, the selection of the appropriate end-of-life or second-life strategy is an important task in the development of a circular PSS and the verification of its feasibility. In addition to the right strategy, there is also a need for appropriate logistics for the return of the products as well as information and support for the repair (Cong *et al.*, 2019; Pieroni *et al.*, 2021). Finally, social sustainability must also be achieved. This includes issues such as job creation, ensuring health and safety for stakeholders, encouraging sustainable consumption, and fairness and justice throughout the supply chain (Allen Hu *et al.*, 2012; Bocken *et al.*, 2013; Toker & Görener, 2022).
Figure 5 shows social and environmental benefits that can be achieved through circular PSS. These benefits are non-monetary but can have a significant impact on the success of the business model. To distinguish the individual items, the triple-bottom-line for sustainability (TBL) according to Elkington (1998) is used. The TBL is a widely used framework for sustainability implementation in business (Palmer & Flanagan, 2016) and is also adapted by many authors from the literature review (Bocken *et al.*, 2013; Joyce & Paquin, 2016; Averina *et al.*, 2022; Sarancic *et al.*, 2022). The TBL divides sustainability in three areas: economic, environmental and social. The literature review was carried out with the assumption that the benefits that are already listed in the previous version of the dashboard correspond to the economic area. Therefore, the literature was only screened for environmental and social benefits.

		Source											
	Benefits	Averina et al. 2021	Okorie et al. 2021	Cong et al. 2018	Manninen et al. 2018	Toker et al. 2022	Hu et al. 2012	Arredondoi-Soto et al. 2022	Blüher et al. 2020	Werning et al. 2019	Höse et al. 2022	Cardeal et al. 2020	Bocken et al. 2013
Social	Community benefits								X			X	X
	Employment / job creation					X	X		X			X	X
	Improving living conditions					X	X		X				X
	Improving Health					X	X		X		X	X	X
	Improving Security					X	X		X		X		
	Improving fair labour					X	X		X				
	Improving workplace safety	X				X	X					X	
Environmental	Dematerialization		X	X	X								
	Material use off set		X										
	Extended product life cycle		X		X						X		
	Less emissions				X	X	X	X		X			X
	Pollution prevention				X	X	X	X	X	X			X
	Reducing waste				X	X	X	X		X	X		X

Figure 5: Social and environmental benefits (Allen Hu et al., 2012; Bocken et al., 2013; Manninen et al., 2018; Cong et al., 2019; Blüher et al., 2020; Cardeal et al., 2020; Werning & Spinler, 2020; Okorie et al., 2021; Arredondo-Soto et al., 2022; Averina et al., 2022; Höse et al., 2022; Toker & Görener, 2022)

Figure 6 shows a list of methods and tools which are referred to or are described in the publications which can be uses for designing, evaluating, assessing or checking the feasibility of a sustainable

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circular business model. In the literature reviewed, methods or tools were named that were already recommended in the original version of the dashboard for the analysis of PSS, but also new methods specifically tailored to the analysis of sustainability or circularity that were developed by the authors. These tools include various customised versions of the BMC (Osterwalder *et al.*, 2010) like the Circular Business Model Canvas (Okorie *et al.*, 2021), the triple layered Business Model Canvas (Joyce & Paquin, 2016) and the Sustainable Business Model Canvas (Cardeal *et al.*, 2020). Furthermore Sarancic *et al.* (2022) introduced a tool to assess the sustainability of PSS in early development stages based on the TBL approach (Elkington, 1998).
Dowie and Simon (1994) formulated design guidelines to allow easy disassembly and recycling and Allione *et al.* (2012) formulated guidelines for material selection.

	Source								
Methods / Tools	Averina et al. 2021	Okorie et al. 2021	Frost et al. 2020	Cong et al. 2018	Lahrour et al. 2019	Manninen et al. 2018	Cardeal et al. 2020	Joyce et al. 2016	**Tool author**
Life cycle assessment	X		X	X	X		X		
Prototyping			X						
System Dynamics			X						
Techno economic assessment			X						
Decision trees			X						
PESTEL			X						
House of Quality				X					
FMEA					X				
Design for disassembly and recycling				X					Dowie/ Simon 1994
Circular Business Model Canvas		X							Okorie et al. 2021
Guidelines for material selection				X					Allione et al. 2011
Value Mapping Tool						X			Bocken et al. 2013
Sustainable Analysis Tool						X			Yang et al. 2014
Triple layered Business Model Canvas						X			Joyce et al. 2016
Sustainable Business Model Canvas							X		Cardeal et al. 2020
BESST-PSS (Business, Evironmental, Social screening tool for PSS)								X	Sarancic et al. 2022

Figure 6: Methods and tools to support the feasibility analysis in the context of sustainability and circular economy (Dowie & Simon, 1994; Allione et al., 2012; Bocken et al., 2013; Yang et al., 2014; Joyce & Paquin, 2016; Manninen et al., 2018; Cong et al., 2019; Lahrour et al., 2019; Cardeal et al., 2020; Frost et al., 2020; Okorie et al., 2021; Averina et al., 2022; Sarancic et al., 2022)

4 FEASIBILITY ANALYSIS DASHBOARD FOR CIRCULAR PSS BUSINESS MODELS

The results of the literature review have been used to upgrade the feasibility analysis dashboard approach and its supporting elements. The updated dashboard-based approach for PSS-driven circular business models is shown in Figure 7. In the top half of the board sustainability has been added as a fourth dimension and in the bottom half the non-monetary benefits have been splitted into the three areas of the triple-bottom-line approach: economical, environmental and social.
The procedure for conducting the feasibility analysis was also adapted. A description of the current business model, using Business Model Canvas, is still required as an input. As a second input to start the feasibility analysis process, a description of the intended circular PSS business model is needed. Though the approach aims at the feasibility assessment of circular business models, the new business model has to be developed supported by the decision matrix described in chapter 2.2. For documentation of the new business model, the Business Model Canvas (Osterwalder et al., 2010) is still considered suitable, but also, for example, one of the modified BMC tools, like the triple layered BMC (Joyce & Paquin, 2016), that have been specialised in the application of circular business model design. Now the two business model states are analysed for their differences to identify which

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elements were changed or added. Unchanged elements of the initial business model are assumed to be feasible and are initially not analysed further. Elements that are now included in the analysis are marked and transferred to the corresponding dimensions of the dashboard. The criteria list can support this and prevent important elements from being forgotten. Now the project team can decide which elements are most critical for the implementation and success of the business model, so these elements should be reviewed first. Elements of technical feasibility should therefore be considered first, as non-feasibility from a technical perspective renders any further analysis obsolete. Now the feasibility analysis for the elements can begin. Suitable tools can be selected from the tool collection, for example expert interviews and the construction of first prototypes to investigate the technical feasibility and the use of the "BESST-PSS" tool (Sarancic *et al.*, 2022) to check the sustainability of the business model. If the team has the manpower, several elements can be examined at the same time, but not too many elements should be examined at the same time, as there is always the chance that one element is not feasible and thus the further examination would be superfluous. Therefore, it should be done in smaller iterations until all elements are considered feasible or the result of an analysis requires a change in the business model or even a complete revision.

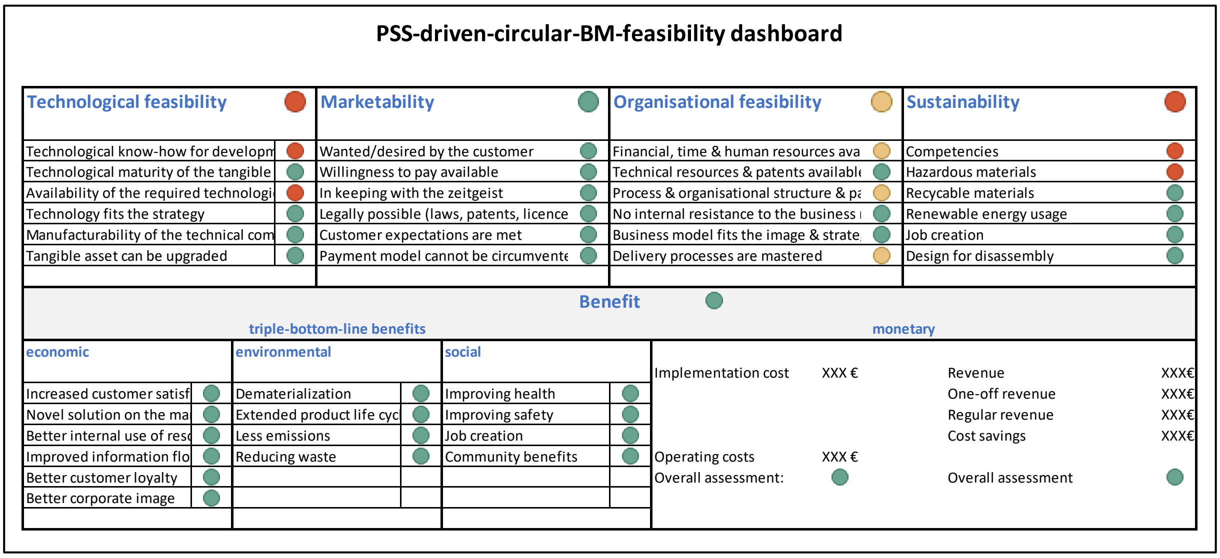

Figure 7: Feasibility analysis dashboard for PSS-driven circular business models

5 CONCLUSION & OUTLOOK

This contribution introduces a new approach to perform a feasibility analysis in the early phases of the development of PSS-driven circular business models. The approach combines an existing approach for assessing the feasibility of PSS-driven business models and a decision support matrix for selecting second-life or end-of-life strategies for circular business models. Furthermore, the tool was enriched by a systematic literature research with necessary criteria to check the feasibility of circular economy business models and sustainability. The aim of the tool is to support practitioners in industry, especially in SMEs, to develop appropriate and sustainable circular PSS business models and to analyse their feasibility in order to reduce risks as much as possible when implementing a new business model.

However, the approach presented in this publication has limitations. So far it is only theoretical as it has not been tested, yet. Therefore, extensive testing in practical use cases with partners from industry as well as start-ups but also by other scientists is necessary to validate the method. Additionally, it is planned to discuss the proposed method with decision makers in SMEs to gain feedback and improve and validate the procedure. Moreover, it is planned to extend the approach with a flexible simulation scenario using an IT-supported tool to obtain more precise assessment results and to analyse potential interdependencies.

In conclusion, no approach will be able to cover all risks or unveil them. The remaining residual risk can be reduced by an interdisciplinary composition of the development team and a systematic methodological approach.

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REFERENCES

Allen Hu, H., Chen, S.H., Hsu, C.W., Wang, C. & Wu, C.L. (2012) Development of sustainability evaluation model for implementing product service systems. *International Journal of Environmental Science and Technology*, 9(2), 343–354. Available from: https://doi.org/10.1007/s13762-012-0037-7.

Allione, C., Giorgi, C. de, Lerma, B. & Petruccelli, L. (2012) From ecodesign products guidelines to materials guidelines for a sustainable product. Qualitative and quantitative multicriteria environmental profile of a material. *Energy*, 39(1), 90–99. Available from: https://doi.org/10.1016/j.energy.2011.08.055.

Arredondo-Soto, K.C., Jiménez-Zaragoza, A., Miranda-Ackerman, M.A., Blanco-Fernández, J., García-Lechuga, A. & Hernández-Escobedo, G. et al. (2022) Design and Repair Strategies Based on Product–Service System and Remanufacturing for Value Preservation. *Sustainability*, 14(14), 8560. Available from: https://doi.org/10.3390/su14148560.

Averina, E., Frishammar, J. & Parida, V. (2022) Assessing sustainability opportunities for circular business models. *Business Strategy and the Environment*, 31(4), 1464–1487. Available from: https://doi.org/10.1002/bse.2964.

Bahrke, M. & Kempermann, H. (2015) *Hybride Geschäftsmodelle als Lösungsanbieter zum Erfolg: Eine vbw Studie, erstellt vom Institut der deutschen Wirtschaft Consult GmbH Stand: Mai* 2015, München.

Barkmeyer, M., Kaluza, A., Pastewski, N., Thiede, S. & Herrmann, C. (2017) Assessment of End-of-life Strategies for Automation Technology Components. *Procedia CIRP*, 61, 34–39. Available from: https://doi.org/10.1016/j.procir.2016.11.220.

Biege, S., Schröter, M., Gandenberger, C., Buschak, D., Weißfloch, U. & Schlummer, M. et al. (2013) *Chancen für die nachhaltige Entwicklung durch neue hybride Wertschöpfungskonzepte: Abschlussbericht des Projekts "HyWert"*. Fraunhofer: Stuttgart.

Blüher, T., Riedelsheimer, T., Gogineni, S., Klemichen, A. & Stark, R. (2020) Systematic Literature Review—Effects of PSS on Sustainability Based on Use Case Assessments. *Sustainability*, 12(17), 6989. Available from: https://doi.org/10.3390/su12176989.

Bocken, N., Short, S., Rana, P. & Evans, S. (2013) A value mapping tool for sustainable business modelling. *Corporate Governance: The international journal of business in society*, 13(5), 482–497. Available from: https://doi.org/10.1108/CG-06-2013-0078.

Cardeal, G., Höse, K., Ribeiro, I. & Götze, U. (2020) Sustainable Business Models–Canvas for Sustainability, Evaluation Method, and Their Application to Additive Manufacturing in Aircraft Maintenance. *Sustainability*, 12(21), 9130. Available from: https://doi.org/10.3390/su12219130.

Cong, L., Zhao, F. & Sutherland, J.W. (2019) A Design Method to Improve End-of-Use Product Value Recovery for Circular Economy. *Journal of Mechanical Design*, 141(4). Available from: https://doi.org/10.1115/1.4041574.

DIRECTIVE 2008/98/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL 2008.

Dowie, T. & Simon, M. (1994) *Guidelines for designing for disassembly and recycling*.

Elkington, J. (1998) Partnerships from cannibals with forks: The triple bottom line of 21st-century business. *Environmental Quality Management*, 8(1), 37–51. Available from: https://doi.org/10.1002/tqem.3310080106.

European Commission (n.d.) *A European Green Deal: Striving to be the first climate-neutral continent*. Available from: https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en [Accessed 26 November 2022].

Frost, K., Jin, H., Olson, W., Schaffer, M., Spencer, G. & Handwerker, C. (2020) The use of decision support tools to accelerate the development of circular economic business models for hard disk drives and rare-earth magnets. *MRS Energy & Sustainability*, 7(1). Available from: https://doi.org/10.1557/mre.2020.21.

Guldmann, E. (2017) *Best Practice Examples of Circular Business Models*, Copenhagen. Available from: https://doi.org/10.13140/RG.2.2.33980.95360.

Hildenbrand, J., Shahbazi, S., Dahlström, J., Jensen, T.H., Pigosso, D.C.A. & McAloone, T.C. (2020) *Closing the Loop for a Circular Economy: CIRCit Workbook 5*.

Höse, K., Süß, A. & Götze, U. (2022) Sustainability-Related Strategic Evaluation of Business Models. *Sustainability*, 14(12), 7285. Available from: https://doi.org/10.3390/su14127285.

Jabbour, C.J.C., Jabbour, A.B.L.d.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. *Technological Forecasting and Social Change*, 144, 546–552. Available from: https://doi.org/10.1016/j.techfore.2017.09.010.

Joyce, A. & Paquin, R.L. (2016) The triple layered business model canvas: A tool to design more sustainable business models. *Journal of Cleaner Production*, 135, 1474–1486. Available from: https://doi.org/10.1016/j.jclepro.2016.06.067.

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? *Journal of Industrial Ecology*, 23(1), 22–35. Available from: https://doi.org/10.1111/jiec.12747.

Lahrour, Y., Brissaud, D. & Zwolinski, P. (2019) The strategy for implementing remanufacturing process in a commercial enterprise, the case study of a French company. *Procedia CIRP*, 80, 554–559. Available from: https://doi.org/10.1016/j.procir.2019.01.046.

Lame, G. (2019) Systematic literature reviews: an introduction. In: Wartzack, S., Schleich, B. & Gon (Eds.) *DS 94: Proceedings of the Design Society: 22nd International Conference on Engineering Design (ICED19): Responsible Design for Our Future, Delft, The Netherlands, 5-8.08.2019, ICED2019*, 05.-08 August, Delft, Niederlande, 1633-1642.

Lins, D., Arnold, D., Köhler, C., Mahl, T., Prinz, C. & Kuhlenkötter, B. (2021) *Analysis Of Process Models For The Business Model Development Considering Special SME Requirements For Offering PSS*. Available from: https://doi.org/10.15488/11263.

Mahl, T., Köhler, C., Arnold, D., Lins, D. & Kuhlenkötter, B. (2021) PSS-FMEA: Towards an integrated FMEA method to support the development of product-service systems in SMES. *Proceedings of the Design Society*, 1, 2501–2510. Available from: https://doi.org/10.1017/pds.2021.511.

Mahl, T., Köhler, C., Collet, P., Arnold, D., Lins, D. & Kuhlenkötter, B. (2022) Dashboard-supported approach for feasibility and benefit analysis of Product-Service System-driven business models. In: Mortensen, N.H. & Hansen, C.T. and Deininger, M. (Eds.) *DS 118: Proceedings of NordDesign 2022, Copenhagen, Denmark, 16th - 18th August 2022: How product and manufacturing design enable sustainable companies and societies, Proceedings of NordDesign* 2022, 16th - 18th August 2022. The Design Society, p. 12.

Manninen, K., Koskela, S., Antikainen, R., Bocken, N., Dahlbo, H. & Aminoff, A. (2018) Do circular economy business models capture intended environmental value propositions? *Journal of Cleaner Production*, 171, 413–422. Available from: https://doi.org/10.1016/j.jclepro.2017.10.003.

Meier, H., Roy, R. & Seliger, G. (2010) Industrial Product-Service Systems—IPS 2. *CIRP Annals*, 59(2), 607–627. Available from: https://doi.org/10.1016/j.cirp.2010.05.004.

Moher, D., Shamseer, L., Clarke, M., Ghersi, D., Liberati, A. & Petticrew, M. et al. (2015) Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. *Systematic Reviews*, 4(1), 1. Available from: https://doi.org/10.1186/2046-4053-4-1.

Okorie, O., Charnley, F., Russell, J., Tiwari, A. & Moreno, M. (2021) Circular business models in high value manufacturing: Five industry cases to bridge theory and practice. *Business Strategy and the Environment*, 30(4), 1780–1802. Available from: https://doi.org/10.1002/bse.2715.

Osterwalder, A., Pigneur, Y. & Clark, T. (2010) *Business model generation: A handbook for visionaries, game changers, and challengers*. Wiley: Hoboken NJ.

Palmer, T.B. & Flanagan, D.J. (2016) The sustainable company: looking at goals for people, planet and profits. *Journal of Business Strategy*, 37(6), 28–38. Available from: https://doi.org/10.1108/JBS-09-2015-0095.

Petry, M. & Köhler, C. (2022) Circular Economy: A Decision-Support Model for Recirculation Strategies. In: Bitran, I., Bitetti, L., Conn, S., Fishburn, J., Huizingh, E. & Torkkeli, M. et al. (Eds.) *ISPIM Connects Athens – The Role of Innovation: Past, Present, Future, ISPIM Connects Athens – The Role of Innovation: Past, Present, Future*, 28. - 30. Novemvber 2022, Athen. Event Proceedings: LUT Scientific and Expertise Publications.

Pieroni, M.P., McAloone, T.C. & Pigosso, D.C. (2021) Circular economy business model innovation: Sectorial patterns within manufacturing companies. *Journal of Cleaner Production*, 286, 124921. Available from: https://doi.org/10.1016/j.jclepro.2020.124921.

Sarancic, D., Pigosso, D.C., Colli, M. & McAloone, T.C. (2022) Towards a novel Business, Environmental and Social Screening Tool for Product-Service Systems (BESST PSS) design. *Sustainable Production and Consumption*, 33, 454–465. Available from: https://doi.org/10.1016/j.spc.2022.07.022.

Toker, K. & Görener, A. (2022) Evaluation of circular economy business models for SMEs using spherical fuzzy TOPSIS: an application from a developing countries' perspective. *Environment, Development and Sustainability*. Available from: https://doi.org/10.1007/s10668-022-02119-7.

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

Werning, J.P. & Spinler, S. (2020) Transition to circular economy on firm level: Barrier identification and prioritization along the value chain. *Journal of Cleaner Production*, 245, 118609. Available from: https://doi.org/10.1016/j.jclepro.2019.118609.

Wohlin, C. (2014) Guidelines for snowballing in systematic literature studies and a replication in software engineering. In: Shepperd, M., Hall, T. & Myrtveit, I. (Eds.) *Proceedings of the 18th International Conference on Evaluation and Assessment in Software Engineering - EASE '14, the 18th International Conference*, 13-14 May, London, England, United Kingdom. ACM Press: New York, New York, USA, pp. 1–10.

Yang, M., Vladimirova, D., Rana, P. & Evans, S. (2014) Sustainable value analysis tool for value creation. *Management Science and Applications*, 1(4), 312–332. Available from: https://doi.org/10.1504/AJMSA.2014.070649.