Journal of Cleaner Production 390 (2023) 136083

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

A conceptual methodology to screen and adopt circular business models in small and medium scale enterprises (SMEs): A case study on child safety seats as a product service system

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ARTICLE INFO

Handling Editor: Maria Teresa Moreira

Keywords:
SMEs
Circular economy
Circular business model innovation
Circular value creation
Circularity score
Circular transitions

ABSTRACT

While small and medium enterprises are already aware of the increasing benefits of resource efficiency, reducing waste, and closing material loops, the adoption of circular economy principles in small and medium enterprises is still nascent. Despite a large body of academic literature providing numerous definitions and business models to elucidate circular economy, these approaches lack systemic research from a small and medium enterprise's perspective and are often vague and overwhelming. Furthermore, small and medium enterprises lack financial and organizational resources to implement a (systemic) change to their already optimized business models. This paper addresses this knowledge gap by presenting a conceptual approach that not only serves as a decision-making tool and a possible starting point towards circular value creation, but also provides an initial estimation on how well forms of circularity can be achieved within the adapted business models. The developed methodology was applied to a complex product within the plastics sector. Starting with the product-disassembly-workshop, an in-depth analysis to identify various circular concepts was then conducted, using design thinking tools. The results are presented and summarized in the form of a decision tree analysis. Using a contradiction matrix and environment mapping tool, it was then attempted to narrow down the circular solution spectrum to a manageable level. To conclude, a cross impact balance analysis was applied to validate the identified business model scenarios. The presented methodology aims to show small and medium enterprises how to generate business model innovations systematically, narrow down the solution space in a structured manner, and how to evaluate the resultant solution options against each other and weigh their trade-offs. The tools and techniques used were chosen in such a way that they can be applied with as few resources and complexity as possible, and therefore can serve as a guidance for small and medium enterprises in their transition towards circular value creation.

1. Introduction

Waste management is a global problem affecting the planetary ecosystem. In 2016, more than 2 billion tons of municipal waste were generated worldwide [Kaza 2018]. Forecasts predict that the amount of waste will increase to up to 3.4 billion tons in 2050 due to urbanization and further population growth. Conservative estimates suggest that at least 33% of this waste is released untreated into the environment [Hoornweg et al. 2012; Kaza et al., 2018].

The global plastics production alone in 2018 was around 360 million tonnes. Europe accounted for about 17% of the plastics produced worldwide (Plastics Europe, 2019). Wherein, almost 50% of plastics produced is usually disposed of in the very same year (Geyer, 2020). Worryingly, if current trends continue, by 2050 around 26 billion tonnes of plastic waste would have been generated (Geyer, 2020). As industrialized society's growing need for resources is breaching our planetary boundaries (Steffen et al., 2015), calls to decouple economic growth from resource use have increased in the past decade (UNEP, 2017). One such concept that promises sustainable economic growth and is gaining momentum recently is the Circular Economy (CE) model (EMF, 2014). Since the concept of CE is now being widely adopted across the political and academic world, the literature research is limited to this concept.

CE may be defined as *"an economic system that represents a change of paradigm in the way that human society is interrelated with nature and aims*

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https://doi.org/10.1016/j.jclepro.2023.136083
Received 11 April 2022; Received in revised form 15 November 2022; Accepted 15 January 2023
Available online 18 January 2023

*to prevent the depletion of resources, close energy and materials loops, and facilitate sustainable development through its implementation at the micro (enterprises and consumers), meso (economic agents integrated in symbiosis) and macro (city, regions, and governments) levels" (*Prieto-Sandoval et al., 2018*)*.

The CE concept is now embraced by the European Union (EU) and several other countries worldwide including Canada, China, India, Japan, and the UK (Ranta et al., 2018). E.g., the EU has put forth an ambitious initiative to address the issue of plastic waste through the circular plastics alliance. This initiative aims to increase the share of recycled plastics in Europe to 10 million tonnes by 2025 (EC, 2018). These and several other initiatives worldwide are based on the concepts of dematerializing, closing resource loops and extending producer responsibility to potentially optimize each life cycle stages of plastic. Finally, adapting business models to circular value creation is seen as a key pathway to fulfil the sustainable development goals (SDG) adopted by 193 countries worldwide (Schroeder et al., 2019).

Looking beyond environmental sustainability, from an economic perspective, the manner in which products are currently managed or discarded at their end-of-life (EoL), conspicuously neglects to capture the full economic benefits of a product's residual material value (Robaina et al., 2020). The economic and environmental transformation potential of CE business models and strategies are extensively discussed in literature (Bocken et al., 2019; Ghisellini et al., 2016). For example, the Ellen MacArthur Foundation estimates that there is a savings potential of USD 700 billion worldwide in the fast-moving consumer goods sector alone (EMF, 2019).

While these findings propose promising economic and environmental benefits, in practise, however, there are several barriers that hinder businesses from realizing the benefits of circular economy (Rizos et al., 2016). One key aspect of circular business models (CBM) is to sustain value after a product's end of life, either by prolonging a product's useful life (e.g., repair model) or by closing its material loop (e.g., recycling model) (Nußholz, 2018). Nevertheless, established businesses that are rooted in the traditional "take-make-dispose" model (Blomsma and Brennan, 2017) face serious constraints while adapting to the principles of CE. Such challenges range from lacking internal organizational capabilities and technical expertise, to external infrastructural, institutional and financial barriers (Bianchini and Pellegrini, 2019; Dey et al., 2020).

Although both large and small and medium-sized enterprises (SMEs) face such barriers, they, however, show heterogeneity regarding respective circular economy adoption strategies (Bassi and Dias, 2019). SMEs, in particular, face challenges in achieving their environmental and social targets and at the same time remain competitive (Dey et al., 2018). Therefore, owing to their size and constrained access to resources, SMEs undertake minimal changes to their business models (Ormazabal et al., 2018) which could otherwise enhance circular value creation. Despite that, SMEs are an important subset of the business ecosystem and account for about 99% of all businesses in the OECD countries, generating an added value between 50 and 60% (OECD, 2019). Likewise, 99% of all European enterprises are SMEs, which employ around 100 million people (EC, 2017). While there have been several studies analysing circular business models in large organization (Fortunati et al., 2020; McIntyre and Ortiz, 2016), there is still limited knowledge on the adoption of CE principles in SMEs operations. Therefore, this paper aims to focus on the micro-level to develop a conceptual methodology to identify solutions for the wider adoption of CE principles within SMEs operating in the plastic sector.

To this end, this paper starts out by exploring existing literature to identify the need for circularity in SMEs, followed by identifying available business model innovation tools for transitioning from a linear to CE. In section 3, it is described how the research methodology as well as the data sources were used. Finally, section 4 presents the key findings as well as the application of the conceptual model to enable circular transitions in SMEs through business model innovation.

2. Theoretical background

2.1. Increasing need for sustainability and circularity in business model development

Tackling the waste problem requires a targeted approach to yield technological innovations along with organizational or structural innovations (Dijkstra et al., 2020). Business model innovations (BMIs) can enable organizations to adapt and realign their existing operations and practices of creating, capturing and delivering value (Schneider and Spieth, 2013). It can also be used to design and develop an entirely new business model reflecting a broader set of environmental and social values (Padilla-Rivera et al., 2020). Realignment of business models have often proven to be an effective means in overcoming far-reaching obstacles.

Traditionally, business models pertaining to the linear plastics value chain often disassociate the downstream effects of their products, whereby a product that has reached its end of life is classified as waste and hence discarded. This creates challenges in financing the return and recycling of a product that is deemed to have negligible economic value. Developed countries have established a way to externalize the environmental costs through municipal waste management systems, wherein the end of life plastics are by large incinerated (Scarlat et al., 2019). Public activism and policy directives (EC, 2019) surrounding the plastic waste topic is ushering in a new ecosystem that aims to turn environmental externalities to financial opportunities by capitalizing on the valorisation of end of life plastic products (CircularPlastics, 2021). Nonetheless, existing approaches to incorporate circular business models are often limited exclusively to recycling. Conversely, this rather leads to downcycling instead of value retention due to lower quality recyclate (Steinmann et al., 2019).

In attempts to make a meaningful transition from the linear value chain to a circular one, several studies have attempted to map and adapt business models for circular value creation (Bocken et al., 2014; Lewandowski, 2016). While some models target to minimize or eliminate waste through closed loop production systems and closed loop supply chains (Winkler, 2011), others aim at the consumption-end focussing on reverse logistics (Julianelli et al., 2020) and product life extension models (Bakker, Wang, Huisman, & den Hollander, 2014). Finally, several indicators are now available to measure and assess the circularity of products (Moraga et al., 2020). However, in practice, previous attempts to transform the business model canvas (BMC) into a circular business model canvas have often been limited to deriving a product-service system from an existing business model without rethinking the basic value creation logic (Lewandowski, 2016; Lüdeke-Freund et al., 2019). Furthermore, in their analyses of existing circular business models, both Lewandowski (2016) and Lüdeke-Freund (Lüdeke-Freund et al., 2019) conclude current business model innovation approaches for CE as insufficient. They highlight the trade-offs emanating due to mismatch in CE strategies and at times clear deviation from CE principles, weighing one end of the supply chain more than the other.

The nature of CE necessitates a comprehensive collaboration across the supply chain, and with it a fundamental rethink of the entire value creation logic. Material, value, and information cycles must be integrated across the entire product life cycle to reflect interdependency between each individual participants of the value chain compared to linear value creation (Mendoza et al., 2017). The integration along the value chain also requires the consideration of economic, ecological and social aspects equally (Breuer et al., 2018). Thus, integrating circularity in business operations can take on different forms or characteristics. A possible representation of these is shown in Fig. 1. It shows that the business models indeed have a comprehensive influence on all phases of a product life cycle, and business model innovation is therefore a valuable tool for transitioning from linear to circular value creation. The arrows within the circle represent possibilities for extending and

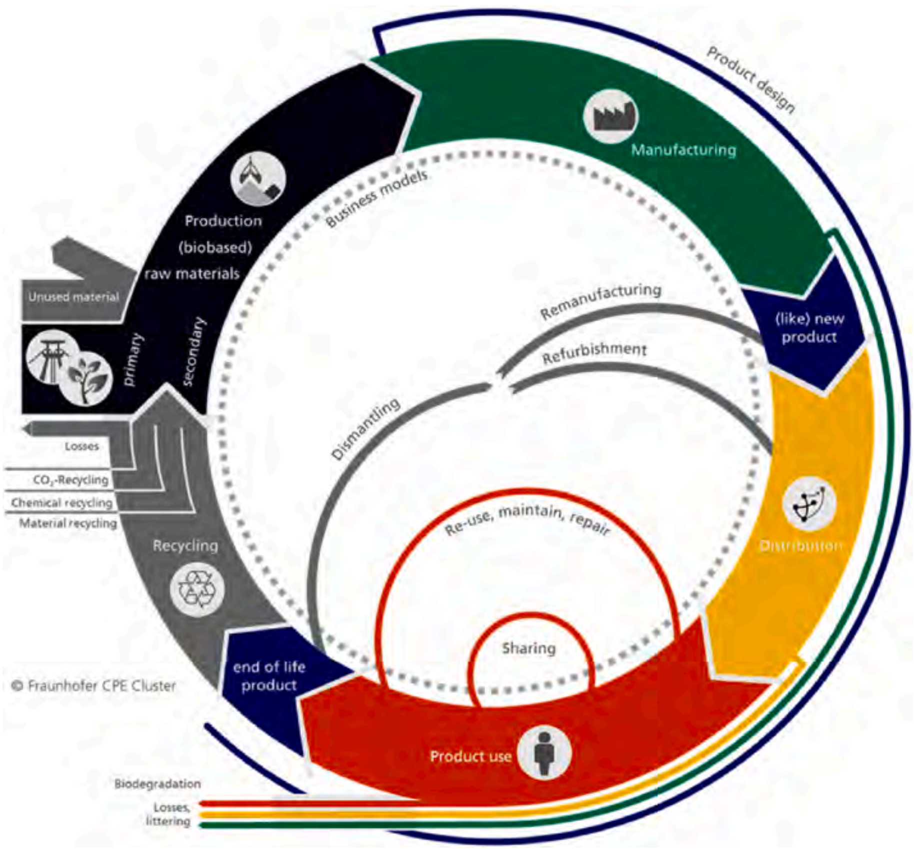


Fig. 1. Life cycle stages and integrating circularity in business operations.

intensifying the benefits of a product through BMI. The aim here is to stay as close as possible to the product use phase. The further one moves towards the end-of-life or recycling options (shown in grey), the more energy and raw material costs increase to restore value.

2.2. Business model innovation for transitioning from a linear to circular value creation in SMEs

There is still much ambiguity concerning the implementation of circular business model in SMEs. For circular value creation, SMEs must balance between economic, social and environmental aspects (Ghisellini et al., 2016), so that existing problems of linear value creation are not merely shifted along the actors down the value chain. Thus, a comprehensive redesign of an already highly optimized production and supply chains must include BMI, as a holistic approach to address a multitude of possible issues along transformation process of each building block of the linear business model (Chesbrough, 2002), as well as other supportive approaches on an organizational level with new product development on a technical level. Nonetheless, one common criticism concerning the practice of CE is the lack of systemic research on a firm-level, as well as the application of vague ideas from various disciplines at a superficial level (Korhonen et al., 2018).

One comprehensive analysis of the academic literature and practitioner case-studies has identified 33 circular business models (CBMs), which was reduced to 26 by grouping models that are similar (Lüdeke-Freund et al., 2019). This study categorizes CBMs into six overarching patterns, namely repair and maintenance, reuse & redistribution, refurbishment & remanufacturing, recycling, cascading, and repurposing, and finally organic feedstock, which entail a spectrum of product and service solutions. Wherein, repair and maintenance, reuse, and distribution as well as refurbishment and remanufacturing targets product-life-extensions; recycling models attempt to create a closed-loop manufacturing and supply chain system. Fig. 2 shows the six circular economy patterns (CEP) and their CEBMs. The category "other" is not explicitly described by Lüdeke-Freund et al., (2019) and represents a supplement to the 6 CEPs.

Circular economy patterns can be understood as guidelines for the development of circular business models. At the same time, they offer the possibility for a qualitative assessment regarding the circularity of a business model.

Business models do not operate isolated. As successful implementation of CEBMs will depend on several internal and external factors, it is therefore important to identify external factors that exert pressure or have an impact on the business model. Business model environment mapping (EM) is one such tool that can be used to analyse the external forces (Osterwalder, 2014; Osterwalder and Pigneur, 2013). A key feature of the EM is an analysis of possible future developments to future-proof a business model. EM can be grouped into 4 key influencing areas. (1) key trends, (2) market forces, (3) sector forces and (4) macroeconomic trends. The analysis of key trends serves to secure a business model by providing foresight against trends that an organization cannot influence. An analysis of market forces helps to understand what shapes and changes the market from a customer and supply chain perspective. The competition analysis deals with the direct competition of the company, wherein, both established and new competitors are considered. Furthermore, potential stakeholders are also identified. Finally, an analysis of macroeconomic forces provides a comprehensive picture of the overall market situation.

In summary, there are several business models available for incorporating circular economy principles in the business operations of SMEs. However, as demonstrated in the earlier sections, there is limited work on implementation and adoption of CE in SMEs. To implement circular economy principles through business model innovation, an SME must first identify the current state of their product and its degree of

Fig. 2. Circular economy business model patterns (Venturely, 2019) based on (Lüdeke-Freund et al., 2019).

circularity. The next step would be identifying those business models that would enable a transition from a linear to circular value creation along each phase of the supply chain (raw material extraction, manufacturing, distribution, and recovery). The analysis of each life cycle stage will yield a range of trade-offs and synergies from an economic, social and environmental perspective. Therefore, the next sections will take a holistic approach to analyse and present a conceptual methodology to narrow the circular economy solution spectrum for the product case – child safety seats.

3. Methodology

This study adopts an exploratory approach to close or narrow the gap in adapting business model development methods currently used in practice with the requirements for circular value creation in the context of a CE. For this purpose, child safety seat was chosen as an example for analysis, since it represents a complex everyday product encompassing various material and value chains (plastic, foam, textile, metal etc.). The methodology, as illustrated in Fig. 3, follows these seven steps:

Step 1: Analyse the product components, properties, and the market
Step 2: Screen possible business model scenarios using a decision tree
Step 3: Apply contradiction matrix to identify the possible solutions from step 2
Step 4: Screen for external influencing factors using the environment mapping
Step 5: Apply a second contradiction matrix with the new framework conditions provided by the environmental analysis to further narrow down the possible solutions
Step 6: Apply a cross-impact balance analysis to identify the trade-offs as well as validate most promising results
Step 7: Assess the circularity of selected business models

. Each of the above illustrated assessment methodology steps is

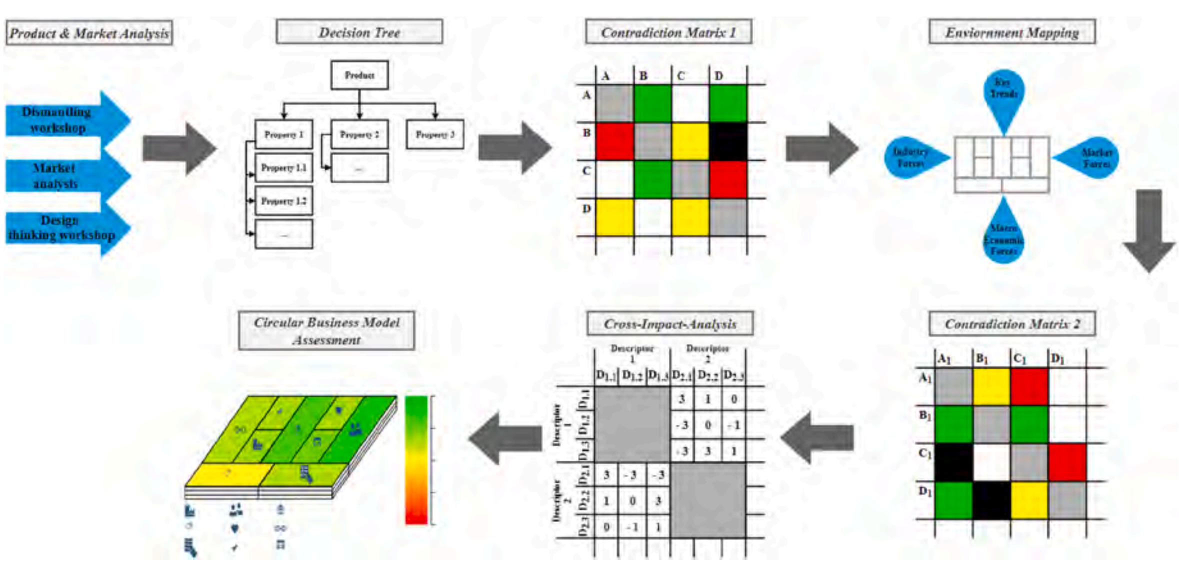


Fig. 3. Methodology overview.

explained in detail in the subsequent subsections 3.1-3.7.

Table 1
Questionnaire as part of a design-thinking workshop.

Product	
Type	Which types of child seats exist? Which suites a CBM the best?
Mounting	Which options are available for fastening the seat in the car?
Safeguarding of the child	How is the child secured in the seat?
Field of application	By which means of transport can the seat be used?
Re-/Disassembly	How easy is it for the customer to disassemble/assemble a seat?
Material properties	Which materials are used? Do they have special properties?
Service	
Cleaning & Sterilization	Can the customer sanitize their seat/have it sanitized?
Damage assessment	Can the customer check their seat for damage/have it checked?
Repair	If there is damage, can a customer have the seat repaired?
Refurbishment	Are there any approaches by the manufacturers, or do external services exist?
Remanufacturing	Are there any providers to recondition the seats?
Payment service providers	Are billing models apart from a sales offered (e.g. leasing, pay-per-use etc.)?
System	
Distribution channels	What are the distribution options?
Take-back channels	Are used products taken back? If so, how?
Testing facilities	Are the technical requirements for damage assessment fulfilled?
Reprocessing-Facilities	Are the technical requirements for reprocessing fulfilled?
Recycling-Facilities	Are the technical requirements for recycling met?

3.1. Analysis of the product components and product properties

The fundamental basis of this study is the market and product analysis of the product – child safety seat. During the data collection and analysis phase, a market analysis for the product in Europe was carried out. Special attention was paid to the product variants from leading manufacturers. Product and safety standards as well as patent applications were also analysed. In addition, a dismantling workshop with a multidisciplinary team consisting of engineers, product designers etc., was held. Fig. 4 shows the result of the dismantling workshop. The purpose of the dismantling workshop was twofold: (a) to test the product regarding its modularity (disassembly and reassembly capability), (b) to make a comprehensive list of the individual components (bill of materials).

Modularity of a product is often identified as a key feature to enable circular products and services (Nowak et al., 2018). Likewise, knowing a product's inventory would enable to "design out" problematic polymers and chemicals that could hinder the circularity of a product. The bill of materials for the child safety seat is provided in the supplementary material (SM), see Table S1.

In summary, the aim of this step was to assess the current circularity status of the most common child safety seats available on the market today.

3.2. Decision tree analysis of the product service system under study

Following the previously presented disassembly workshop, the product, its possible services and the business model ecosystem were examined in a comprehensive analysis. The results were then illustrated thanks to a decision tree. The basis for the analysis is the questionnaire shown in Table 1. These questions were generated from the market analysis described above, in which products, business models, market data and existing regulations were analysed, later questions were selected in such a way that they reflect the entire life cycle of the product and thus the business model behind it. The aim of the analysis was to present the current conditions of the product and business model to derive the ideal state within a circular economy as a subsequent step.

3.3. Residual value analysis

Capturing the residual value, especially the residual monetary value, is a central part of the analysis of possible options and scenarios for the development of a circular business models (Nußholz, 2017). Another form of residual value is the material value. However, this would require an extension/intensification of the product's usefulness, typically through recycling to extract the material value and leading to the destruction of the product. Hence, only the product's residual monetary value was considered. In particular, business models based on product life extension in the form of reuse, refurbishment and remanufacturing also require comprehensive knowledge about the residual value of the product (Lüdeke-Freund et al., 2018). To analyse the residual value, the resale value of various child safety seat models on different sales portals (e.g., eBay, Gumtree, Marktplaats) was randomly recorded, irrespective of the visual condition or the service life to date, as long as the functionality was fully given, i.e., products for "spare part harvesting" were ignored. By allowing a broad, "random" spectrum of child safety seats into the analysis, we avoided a biased market value in the end, allowing for a first estimation on the feasibility of a child safety seat as a circular product. The recorded sample size was 325 child safety seats, distributed over 7 product models from 3 leading manufacturers. Only those products that comply with the currently valid standards – UN ECE Reg. 44/04 or UN ECE Reg. 129 (i-Size) (EC, 2014) were considered in the

Fig. 4. Dismantling workshop.

analysis.

3.4. Identification and analysis of potential B2C PSS scenarios

As a next step, various business-to-consumer (B2C) scenarios were identified using design thinking tools, restricted to the European market. For example, commonly used methods such as brainstorming, mind maps, pin boards and the 6-3-5 method were applied. The 6-3-5 method represents a well-established creativity technique in the field of product design and engineering that promotes the generation of new ideas in a group. Problems of low to medium complexity are suitable. Each of the six participants receives a sheet of paper. This is divided into 18 boxes with three columns and six rows. For a given problem, each participant writes down his or her suggested solution before passing the sheet on in a circle. The following participant now add their ideas to the existing solution. This allows a yield of up to 108 ideas ($6 \times 3 \times 5$) in roughly 30 min.

During the numerous workshops held, of which many focused the product itself, special attention was paid to the sale (including wholesale and retail) and return options, as well as payment and ownership options, were analysed in detail. This is due to the fact that, within the framework of circular business models, the transfer of ownership takes place only temporarily, which consequently requires new ways of establishing this and consequently demand new billing models.

Concluding in the first possible product service systems (PSS), such as a long-term model in the form of leasing and a short-term model in the form of rental, etc., were analysed. In both analyses, particular attention was paid to the possibilities for circular value creation, possible challenges, and potentials.

3.5. Contradictions matrix of potential B2C PSS scenarios using the environmental mapping framework

Following the identification of potential B2C scenarios, the next step was to systematically narrow down the possible business models using a contradiction matrix (see Fig. 5).

For this purpose, possible product and business model characteristics were mirrored along the diagonals, wherein each individual characteristic combination was qualitatively assessed regarding its compatibility. The colour-coding (see Fig. 9) used for the assessment follows the pattern: status quo (black), high potential combinations (green), combinations that have less potential (yellow), combinations that are associated with major obstacles (red) and finally combinations that have no correlation (white).

Since this approach yielded too many possible combinations for possible future business model scenarios, it was decided to carry out the qualitative assessment again, this time using a contradiction matrix alongside Osterwalder's business model environment mapping (EM) (Osterwalder, 2014). Introducing the EM allowed us to derive further selection criteria in the form of external framework conditions, which were then applied during the second screening. The external framework conditions that could have a potential impact on the business model include: (a) key policy trends, (b) sectoral workforce, (c) market forces, and (d) macroeconomic forces. The further attempt to narrow down the possible solution spectrum following the contradiction matrix using the EM model framework (Fig. 6) succeeded and provided sufficient descriptors for a subsequent cross-impact balance analysis (C-I-B).

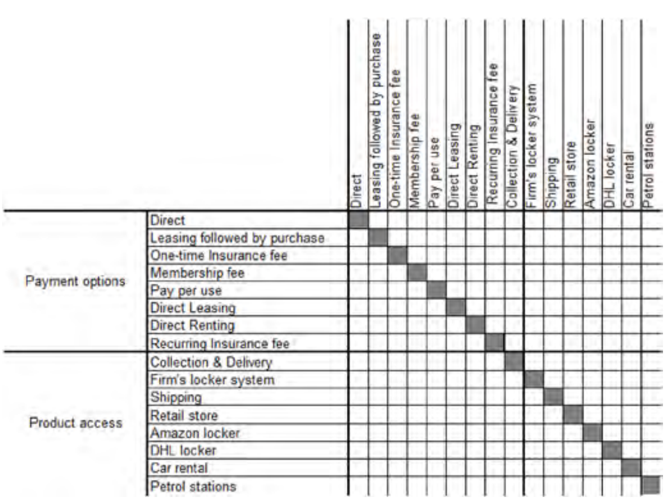


Fig. 5. Excerpt from the contradiction matrix.

3.6. Cross-impact balance analysis of potential B2C PSS scenarios

The C-I-B as shown in Fig. 7 is a guided and easy to learn standard tool used in scenario analysis (Weimer-Jehle, 2006), and was used as the final step to identify potential business model solutions/scenarios for the chosen product service system.

It was employed to describe and analyse the relationship between interacting social, political, technological, and environmental factors, while at the same time providing an as simple tool to use, considering the different horizons of experience of the users. The genesis and validation of a plausible scenario for the development of the circular business model was done thanks to descriptors derived from the EM model and respectively the second contradiction matrix. The descriptors represent both the internal and external parameters that can influence the business model.

3.7. Circularity indicators and qualitative evaluation of the degree of business model circularity

The final step in the business model transition from a linear to circular value creation was the evaluation of the synthesized business models and the product regarding their current degree of circularity. The circularity assessment followed a qualitative approach using various circular economy patterns (CEP). The CEPs compiled by Lüdeke-Freund (Lüdeke-Freund et al., 2019) were firstly checked for compatibility with the scenario outcomes from the cross-impact balance analysis. Further on, the compatible circular economy patterns were then evaluated for their circularity. To use the circular economy patterns as a qualitative assessment tool, a set of key circularity indicators was firstly chosen and weighted.

Table 2 shows the qualitative circularity score assigned to each CEP category. The assigned values correspond to the ranking for which the respective circular economy patterns promotes circularity the most, based on the usage expansion and intensification activities within the respective CEP category. The overarching circularity strategies correspond to the strategies mentioned in the literature (Lüdeke-Freund, Gold and Bocken, 2019).

The circularity scorecard presented for assessing the circularity of a business model is primarily suitable for evaluating competing circular business model scenarios as a whole, but not for making a quantitative statement about the percentage of a business model that is circular. Since the circularity score only reflects the number of characteristics, no percentage value, of the business model that promote circularity, overall circularity scores >1 can be achieved. The value within a category can only take on values between 0 and 1. E.g., a value equal to 0 is given if the tools and strategies to establish circular economy principles are not developed. A value equal to 1 corresponds to the efforts being made to establish and protect circularity. Therefore, the circularity scorecard serves as an indicator to assess which business model has the most favourable features for CE.

The degree of the exemplary business model circularity was later evaluated by experts in terms of the three core elements of sustainability (environment, social and economic). The catalogue of questions that

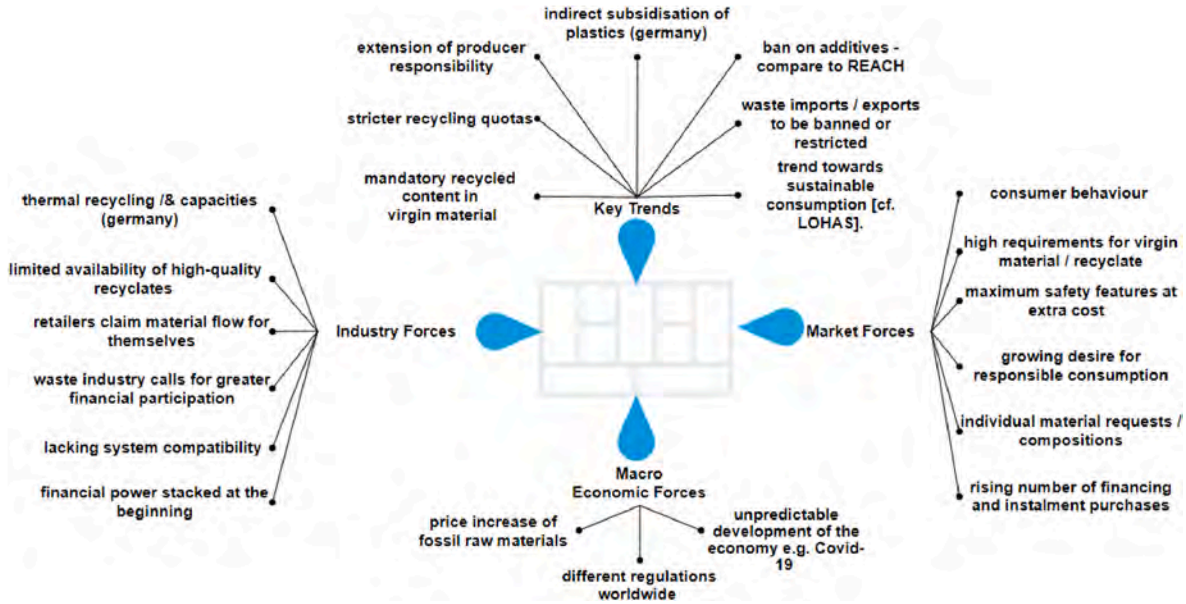
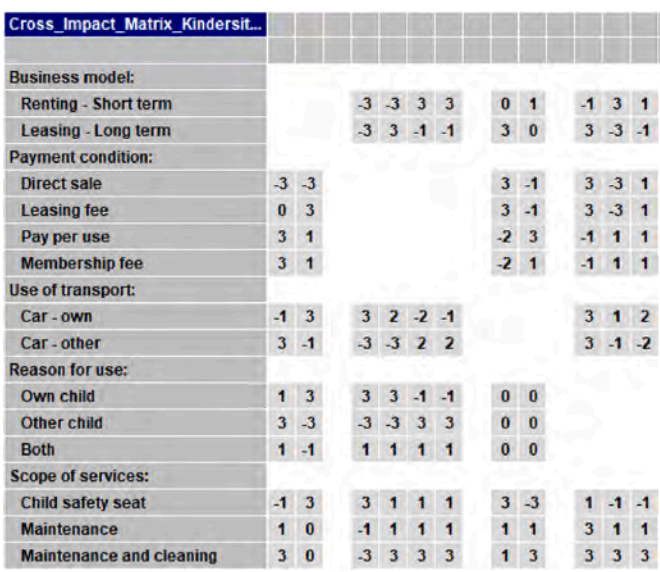


Fig. 6. EM framework.



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Business model:											
Renting - Short term			-3	-3	3	3	0	1	-1	3	1
Leasing - Long term			-3	3	-1	-1	3	0	3	-3	-1
Payment condition:											
Direct sale	-3	-3					3	-1	3	-3	1
Leasing fee	0	3					3	-1	3	-3	1
Pay per use	3	1					-2	3	-1	1	1
Membership fee	3	1					-2	1	-1	1	1
Use of transport:											
Car - own	-1	3	3	2	-2	-1			3	1	2
Car - other	3	-1	-3	-3	2	2			3	-1	-2
Reason for use:											
Own child	1	3	3	3	-1	-1	0	0			
Other child	3	-3	-3	-3	3	3	0	0			
Both	1	-1	1	1	1	1	0	0			
Scope of services:											
Child safety seat	-1	3	3	1	1	1	3	-3	1	-1	-1
Maintenance	1	0	-1	1	1	1	1	1	3	1	1
Maintenance and cleaning	3	0	-3	3	3	3	1	3	3	3	3

Fig. 7. Cross impact balance analysis.

Table 2
Circularity scorecard.

Overarching circularity strategy	Sample score
Repair & maintenance	0.25
Reuse & redistribution	0.15
Refurbishment & remanufacturing	0.1
Recycling	0.1
Cascading & repurposing	0.1
Organic feedstock	0.05
Other	0.05

was drawn up to evaluate the core elements within each business model can be found in the SM (see Table S3). First, the experts qualitatively assessed the feasibility of the business model under current technical conditions. This was followed by a quantitative evaluation of the business model building blocks regarding inhibiting and promoting factors on circularity. The evaluation spectrum ranged from strongly inhibiting factors (–) to no influence (0) to strongly promoting factors (++). The overall circularity value obtained then served as a qualitative assessment of the business model under consideration. The initial assessment serves as a guideline and allows further attempts at optimization to improve circular value creation can be made within each of the building blocks of the business model canvas by the SMEs. It is to be noted that the evaluation did not include an assessment of the economic feasibility.

4. Results and discussion

4.1. Status on the circularity of child safety seats today

Traditionally, business model development within a value chain is by and large carried out without contemplating the impact of a product after its end-of-life. This poses problems, in particular when aiming to close material and value loops (Nußholz, 2018). As a result, existing approaches to circular value creation are often limited exclusively to saving primary resources along with the reuse of primary materials (Schroeder et al., 2019). Conversely, this often leads to downcycling instead of value preservation or circular value creation (Steinmann et al., 2019). Hence, for a circular product system and therewith a circular business model, it is equally important to consider which material flows should in the first place be prevented from entering the product-loop besides analysing the merits of those already entering.

During the disassembly workshop, the child seat was disassembled into 17 main components. Nine different materials, eight of them plastics, were identified, while one component remained unknown. The

Table 3
Results of the dismantling workshop.

Material	Weight [%]
Polypropylene (PP)	48.9
Metal	25.7
Polyamide 6 (PA6)	14.3
Polyamide with glass fibres (PA GF30)	4.1
Polyamide (PA)	3.9
Acrylonitrile butadiene styrene (ABS)	1.4
Expanded polystyrene (EPS)	1.0
Expanded Polypropylene (EPP)	0.4
Thermoplastic polyurethane (TPU)	0.1
Polyoxymethylene (POM)	0.1
Unknown polymers	7.7

largest share was found to be polypropylene with about 51.8% by weight, followed by metals with 27.2%. Table 3 below shows a list of the material mix. A detailed bill of materials can be found in the SM (see Table S1).

During the dismantling workshop, it was found that in addition to the high number of materials, there was also a diverse mixture of polymers in the individual components, some of which could only be dismantled with a great deal of time and effort. This indicates that a typical child seat is not suitable for recycling from a product perspective under the current circumstances, as the individual material components are difficult to recover without intensive recycling technologies. Furthermore, higher R-strategies such as repair, remanufacturing and refurbish are currently unsuitable (Lüdeke-Freund et al., 2018). Although they may seem simple, such workshops provide an important insight from an SME's perspective when considering which circularity strategy to prefer.

To analyse the status of circularity of child safety seats from a business model perspective, the existing business models of leading European child safety seat manufacturers were analysed from publicly available information. It was found that predominantly the existing business models of child seat manufacturers ended with the sale of the product and did not offer any further end-of-life management services. Although repair options and spare parts from some manufacturers are occasionally available to the end-consumer, these are not part of the actual business model. There is no reprocessing in the sense of repair & maintenance or refurbishment & remanufacturing. Furthermore, it was also found that no recycling or cascading & repurposing takes place. Likewise, the existing business model does not yet utilize any bio-based feedstock. As shown in Table 3, the plastic components of the child seat consisted entirely of conventional, petroleum-based plastics. The only end-of-life strategy to be mentioned is waste recycling, which in most cases was incineration, however, this contradicts the principles of circular economy (Dehoust and Alwas, 2019; Schmitt, 2018; Dominghaus et al., 2012).

Table 4 shows the results of the residual value analysis. It was found that child safety seats, despite unknown origin and accident history, retain a residual value of up to 60% of their recommended retail price (RRP). Therefore, the strategy of product value retention is preferable and more economically viable to the strategy of material value retention in form of recycling. Therefore, a business model solution such as the PSS can support the transition from a linear to a circular economy by extending the product's life and retaining the residual value.

Table 4
Residual value analysis.

Manufacturer	Model	Norm	Sample size	ADAC rating	RRP [€]	Residual value [%]
1	A	UN ECE Reg. 44/04	88	Good (1.8)	139.99	44
	B	UN ECE Reg. 44/04	38	Good (1.8)	109.99	44
	C	UN ECE Reg. 44/04	16	Good (2.1)	99.99	42
	D	UN ECE Reg. 44/04	53	N/A	79.99	35
2	A	UN ECE Reg. 44/04	90	Good (1.9)	189.00	36
3	A	UN ECE Reg. 129	14	Good (1.9)	209.95	60
	B	UN ECE Reg. 129	26	Good (1.7)	122.00	64

Our findings show that for circular value creation, it is essential to change the existing value creation logic. It was therefore decided to adapt the existing value creation logic by using business model innovation. Since a significant residual value has been proven, it was decided to pursue the circular economy strategy of product value retention, rather than material value retention. In doing so, the results were limited to possibilities for extending and intensifying the use-phase of the product, to assure that potential benefits, especially from the perspective of sustainability, are maximized.

4.2. *Explorative approach to identify possible features of the product and therewith business models*

To enable a shift from the existing business model of child safety seats to a circular business model, the potential characteristics of the product were correlated against the circular economy patterns shown in Fig. 2. To visualize the results, a decision tree chart was created. This resulted in 7 main nodes, which contained 24 sub nodes, with a total of more than 150 end nodes (see Fig. 8). Wherein, the main nodes are shown in orange, the sub nodes in blue and the respective end nodes in light blue. Additional properties from each of the end nodes is depicted in grey. The main nodes include: (1) payment options, (2) shipping of the product, (3) reason of usage, (4) materiality, (5) types of child seats, (6) safeguarding the child, and (7) fastening the seat.

Fig. 8 shows a cross-section of the tree diagram with the above-mentioned decision nodes, as well as their respective chance nodes and end nodes for child safety seats. The entire decision tree can be found in the supplementary material (see Fig. S1). E.g., for the decision node "payment options", two chance nodes – "one-time payment" and "recurring payments" are possible. For "recurring payments" several end nodes such as of "pay-per-use", "direct leasing", "direct renting", "recurring insurance fee" and "membership fee" can occur.

The choice of the end nodes resulted partly from the design thinking workshop conducted with a multidisciplinary team of engineers, product designers etc. and partly from market analysis, as well as from the dismantling and analysis of the product. In total, 150 conceivable end nodes were assigned to the 24 chance nodes. To further reduce the number of end node options to a manageable level as a first step, the scope was limited to the class of child seats for children aged 3–12 years. This age group offers high potential for circular value creation due to its long period of use compared to the other groups, especially considering that not all children up to the age of 12 needs a child seat due to their physical development and therefore an individually adaptable form of use is necessary. As a result, the solution spectrum could be reduced to 53.

4.3. *Contradictions matrix and environmental mapping framework – systematic reduction of the solution set*

To systematically narrow down the solutions (end nodes) identified in the earlier section, the resultant 53 specifications were transformed into a contradiction matrix. These 53 specifications were mirrored along the diagonals, and each individual characteristic combination was qualitatively evaluated as per its compatibility. The aim was to visualize the compatibility of the characteristic expressions with each other to identify possible business model scenarios. Fig. 9 shows a cross-section of the contradiction matrix with a focus on the payment methodology as well as the form of value transfer to the customer. A brief explanation of these specifications can be found in the SM (see Table S2). The two complete opposition matrices can also be found in the SM (see Fig. S2 & Fig. S3).

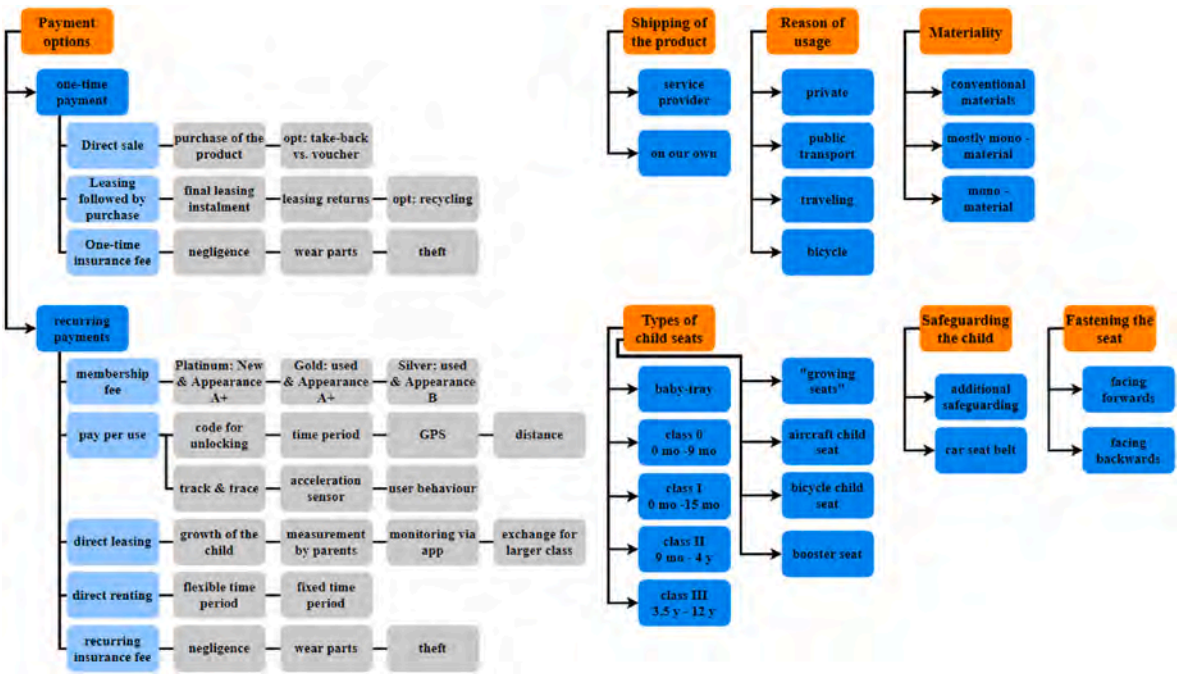

Fig. 8. Excerpt of the decision tree.

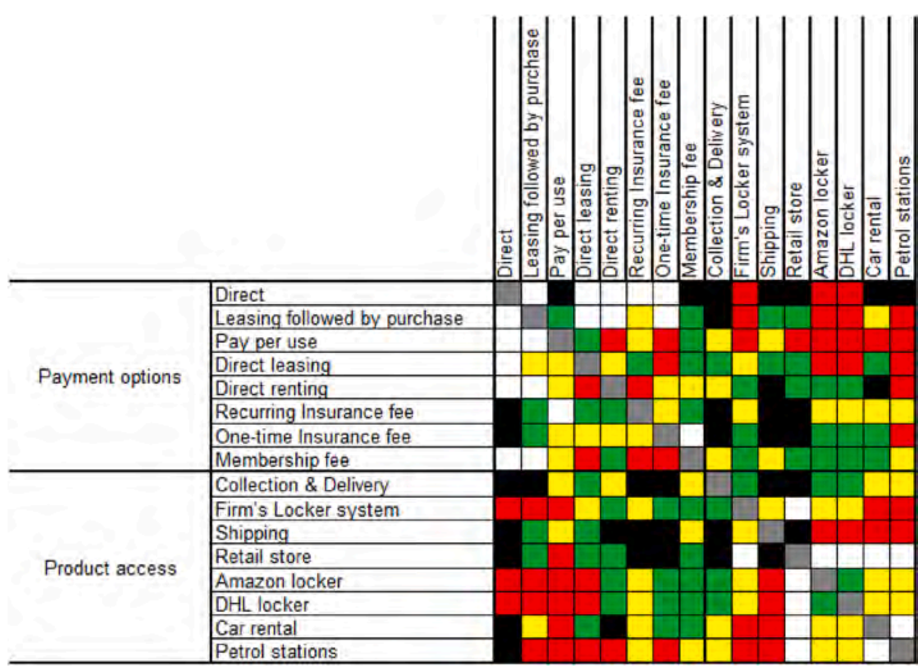

Fig. 9. Extract from the contradiction matrix.

For example, if the relationship between the variables "direct leasing" and the options for distribution is explored, "shipping" and "retail store" turn out to be feasible options without further obstacles (shown in green). "Shipping" using a "firm's locker system" is marked yellow, as it presents obstacles that could rise from generating and implementing new contractual obligations with a third party. Shipping to an external, existing locker stations was marked as "red", since a data interface must first be created. Moreover, existing locker stations are too small for a standard child seat. This type of evaluation was initially carried out for all, 2809 combinations (53 × 53) of specifications under the conditions of the status quo. This yielded in a total of 1370 potential business solutions.

Nonetheless, this procedure turned out to be insufficient for the synthesis of business model scenarios due to the vast number of solutions (Ünal et al., 2019). Therefore, a subsequent evaluation method was carried out using the environmental mapping framework. Here, the compatibility of the characteristic values was again critically examined. In this evaluation method, the extended environmental mapping framework conditions outlined in section 3.1.4 were applied. Fig. 10 shows the environmental mapping framework used during the analysis.

The following framework conditions were identified as especially influential:

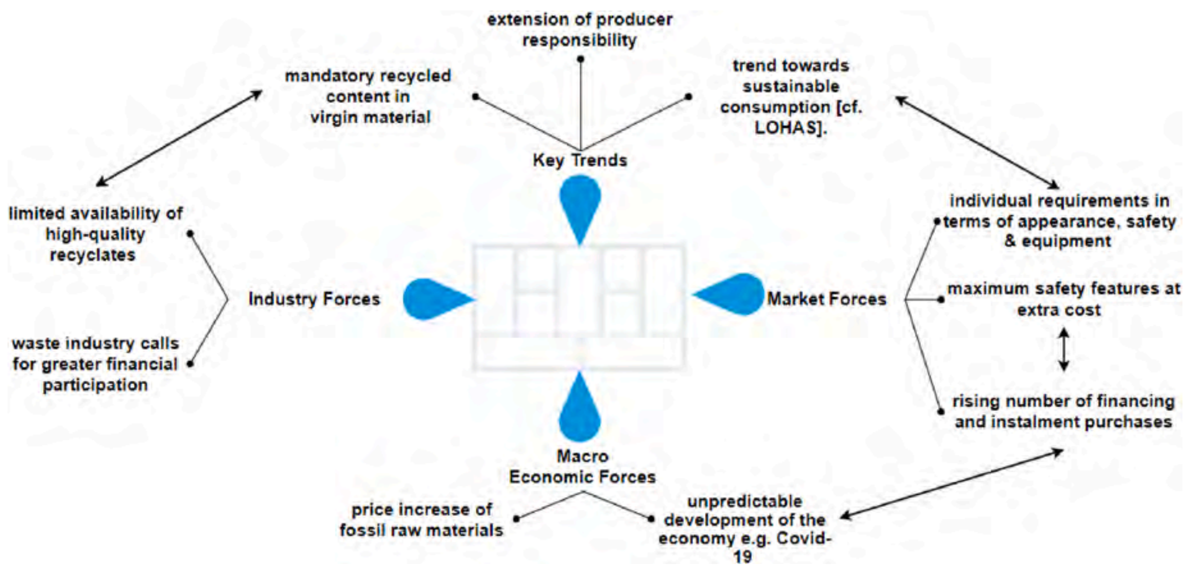

Fig. 10. Environment Map/modified framework conditions.

1. Key trends – extended producer responsibility, mandatory recycled content, trend towards sustainable consumption
2. Industry forces – limited availability of recycled material, waste management demands, greater financial costs for manufacturers
3. Market forces – increasing number of financing options and instalment purchases
4. Macroeconomic forces – price increase in fossil raw materials

The above-mentioned points particularly underline the necessity of adapting the value creation logic and thus the business model not only in a transition to a circular economy, but also to remain competitive and sustainable as a SME in a future market environment (Lüdeke-Freund et al., 2019). Using the modified framework conditions for a second application of the contradiction matrix, with special attention to the most influential conditions, the solution spectrum could be reduced from 1370 to 654 potential business solutions.

4.4. Deriving possible business model scenarios using cross-impact balance analysis

To be able to derive the optimal scenario or, in this case, the framework conditions for a business model, a cross impact balance analysis (C-I-B) was applied. For this purpose, we first recorded the number of remaining business model solutions per specification. This allowed us to identify the most promising of the 53 specifications (see 4.2 "end nodes"). The descriptors needed for the implementation of the C-I-B and their properties were then derived from these. Again, the selection was kept to a necessary minimum (Weimer-Jehle, 2006) so that the entire system could be described with only 13 descriptors and their 37 properties.

In addition to deriving the business model scenarios, the cross impact balance analysis offered us the opportunity to validate the scenarios for consistency. In this case, a scenario was assessed as consistent if none of the selected descriptor properties was in conflict of interest with another, by doing so trade-offs could be avoided right from the beginning. Therefore, the cross impact balance analysis could be used for a final validation of our previous results. The following is a rather obvious example of inconsistency for visualization purposes:

The customer wants to use the short-term model. The customer chooses direct sales as the payment condition and shipping as the product access.

While the selected access to the product is conceivable in this context, the direct purchase in a renting model creates a contradiction and thus inconsistency, which leads to excluding this scenario.

Table 5 shows a complete overview of all descriptors and their properties.

Following the strategies described by (Achterber et al., 2016; Hofmann, 2019) for maintaining the product value and closing the material cycle, the following two PSS models – leasing and renting were selected as target-oriented strategies, representing a long-term and a short-term use, as described in 3.4. It is to be noted that the first descriptor "business model" therefore only serves to differentiate between the two PSS while conducting the cross impact balance analysis and guarantees a consistent result for each of them. The result of the C-I-B is shown in Table 6. The results provide information on the most promising business model to be established on the market and to meet the needs of benefit extension and intensification within a circular economy. The results can be summarized as four scenarios, each of which can be assigned to one of the two possible business model use cases.

The key differences between the four scenarios are in the following descriptors: (2) "Payment conditions", (3) "Use of transport", (4) "Reason for use", (5) "Scope of service", (6) "Test interval", (10) "Prioritized material property" as well as the (12) "Product access". It must also be noted that the scenarios correspond to each other in the descriptors that have a direct influence on possible benefit extensions, respectively use-intensity, and thus correspond to each other in the descriptors that directly influence the circularity of the business model. These are the following: (8) "Material collection", (9) "Material selection" and the (11) "Dismantling properties".

The key differences between the four scenarios of each business model use case have been highlighted in Table 6. As for long-term use, it is the (12) "Product access" and in the case of short-term use, it is the (2) "Payment conditions". A complete overview of the C-I-B can be found in the SM (see Fig. S4). The validated results of the C-I-B were finally used to develop two circular business models using the business model canvas. One business model was created for long-term use and one for short-term use. A full presentation of the two business model canvases can be found in the SM (see Fig. S5 & Fig. S6).

4.5. Value proposition of the identified B2C business model scenarios

In summary, the long-term model offers comprehensive services, such as maintenance and repair, over the entire period of the child seat warranty. At the same time, it is possible to exchange the product at any time so that the seat remains state-of-the-art concerning safety without the loss or additional use of valuable materials. The short-term model,

Table 5
Descriptors.

Descriptors	Property 1	Property 2	Property 3	Property 4
Business model	Renting – Short term	Leasing – Long term		
Payment condition	Direct sale	Leasing fee	Pay per use	Membership fee
Use of transport	Car – own	Car – other		
Reason for use	Child – own	Child – other	Child – own and/or other	
Scope of services	Child safety seat	Maintenance	Maintenance and cleaning	
Test interval	Per customer	Per interval	Per sensor deflection	
Sensor technology	Active – responsive	Passive – Readable	No sensors	
Material collection	Separate collection	Conventionally collected		
Material selection	mono material (plastics)	mono material (plastics) & metal	Conventional material	
Prioritized material property	Sanitisable	As few additives as possible	No legacy additives	
Dismantling property	Completely disassembled	Safety components only	wear parts only	Not possible
Product access	Shipping	Retail shop	Locker station	
Product return	Identical to the access option	Different to the access option		

Table 6
Consistent scenarios.

Descriptors	Scenario 1	Scenario 2	Scenario 3	Scenario 4
1. Business model	Leasing – Long term		Renting – Short term	
2. Payment condition	Leasing fee		Pay per use	Membership fee
3. Use of transport	Car – own		Car – other	
4. Reason for use	Child -own		Child – own and/or other	
5. Scope of services	Maintenance		Maintenance and cleaning	
6. Test interval	Per sensor deflection		Per customer	
7. Sensor technology	Active – responsive			
8. Material collection	Separate collection			
9. Material selection	mono material (plastics) & metal			
10. Prioritized material property	As few additives as possible		Sanitisable	
11. Dismantling property	Completely disassemble			
12. Product access	Shipping	Retail shop	Locker station	
13. Product return	Identical to the access option			

on the other hand, is characterized by the highest degree of flexibility, but offers only few choices in terms of the aesthetics yet without compromising on the safety of the seat. This is mainly due to the significantly higher frequency of user changes and the resulting inspection requirements and possible repairs, as well as the resulting demands for quick disassembly and reassembly of the product to ensure economic efficiency (Lüdeke-Freund et al., 2018).

4.6. *Assessment of the circularity of the business model scenarios*

To make the circularity of the business model assessable for the experts, a questionnaire was created that describes the core components of each building block (see SM Table S3). Experts in the field of life cycle engineering and material sciences made the assessment. Firstly, the experts qualitatively assessed the feasibility of the business model under current technical conditions. This was followed by a quantitative assessment of the building blocks regarding inhibiting and promoting effects on circularity. The evaluation spectrum ranges from strongly inhibiting (–) to no influence (0) to strongly promoting (++). The consideration of economic feasibility is not the subject of this evaluation. Fig. 11 shows the visualization of the results from the expert assessment in the form of a heat map. On the right side of the representation is the applied colour scale used for visualizing the results. Below the illustration, the average rating of the experts' opinion as to how far a building block is inhibiting or promoting circularity is given. Table 7 also shows an overview of the qualitative expert ratings assigned to each building block of the BMC.

With two exceptions, the experts see the feasibility of a transition towards a circular business model as possible assuming technological conditions available today. The exceptions are the recovery of high-quality recyclate and the guarantee of recallability. The experts justify this with the current orientation of the recycling plants towards a stream

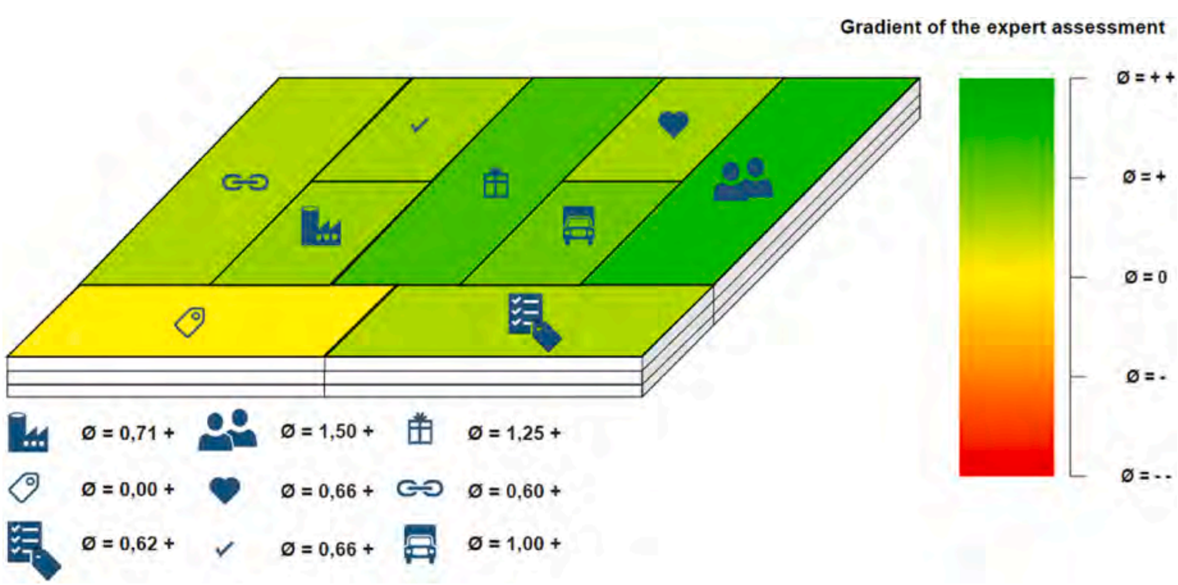

Fig. 11. Expert assessment on the degree of circularity of business model.

Table 7
Qualitative expert assessment.

BMC Building Block	Expert rating
Customer Relationships	1.5 +
Value Proposition	1.25 +
Channels	1.0 +
Key Resources	0.71 +
Customer Relationship	0.66 +
Key Activities	0.66 +
Revenue Streams	0.62 +
Key Partners	0.6 +
Cost Structure	0

of packaging material.

This confirms the barrier identified applying the environment map and highlights the need for separate collection and recycling of child safety seats. However, in reality, collecting and recycling individual product waste streams separately is not possible. Nonetheless, through the principle of extended producer responsibility, the manufacturer can have a better control over a product along its life cycle and through proper take-back management systems can handle a product properly when it reaches its end-of-life.

To evaluate the circularity score of scenarios identified in Table 6 individually, a qualitative value was assigned to the respective overarching strategies, e.g., “repair & maintenance”, “reuse & redistribution, etc.“, derived from the expert opinions (see section 3.6). This value was derived according to the ranking of these strategies in forms of usage intensification/extension mentioned in the literature. The results of this qualitative score can be found in Table 8.

The derived score of the short-term model was determined to be 1.65 points. This is 0.4 points higher than that of the long-term model, which is 1.25 points. The higher score for the short-term model can be explained by the fact that in the assessment of circularity, as in the literature, the options that supposedly require less resource input to restore the value of the product are assessed as more conducive in a transformation to circularity. For example, the strategy “repair & maintenance” is rated better in comparison to “refurbishment & remanufacturing”, as it is assumed to require more resources due to more extensive reprocessing.

However, it is critical to consider whether a single refurbishment or remanufacturing after intensive use in the long-term model is more resource intensive than the ongoing repair and inspection of the seat after short-term usage by frequently changing users. Since even in the short-term model, intensive reprocessing in the form of refurbishment or remanufacturing becomes necessary after a certain point. Therefore, it still needs to be precisely defined, perhaps through a life cycle analysis, on whether the highest form of circularity can be achieved by increasing use-intensity (short-term renting) or by elongating the product life (long-term leasing).

In addition to the experts’ evaluation of the basic business model logic, the short- and long-term models were examined separately thanks to the circular economy patterns. For this purpose, the 26 circular economy patterns identified by Lüdeke-Freund et al. (2019) were

Table 8
Qualitative circularity score.

Overarching circularity strategy	Long-term business model	Short-term business model
Repair & maintenance	0.25	0.5
Reuse & redistribution	0	0,45
Refurbishment & remanufacturing	0.4	0.1
Recycling	0.4	0.11
Cascading & repurposing	0.15	0.15
Organic feedstock	0	0
Other	0.35	0.35
Gradient of circularity	1.25	1.65

systematically compared to the two business models. The corresponding visualization of the assessment methodology can be found below (Fig. 12 & Fig. 13); CEPs coloured grey are considered to be not fulfilling the criteria for the chosen PSS.

4.7. Limitations of the study

This study is limited to deriving a conceptual methodology for developing a circular business model in form of a PSS. Different methodology could yield marginally different outcomes. Furthermore, the economic, environmental, and social benefits of the exemplary business model developed with the present methodology still need to be quantified precisely in further research. Finally, it must be examined whether the ranking of the circular economy strategies prevailing in the literature can be presumed as such, or whether, for example, frequent repair has to be placed in a worse position than extensive remanufacturing, particularly in the comparison between the chosen strategies for short-term and long-term use of the product.

As already mentioned, the current linear system is also strongly influenced by human decisions. A significant change in the framework parameters can lead to the need to adapt the developed business model and, if necessary, also the present methodology. This can also include, for example, a change in strategy from maintaining the product value (PSS business models) to maintaining the material value (closed loop manufacturing and supply chains), as it would be the case for products like lightweight packaging.

5. Conclusions

Lately, the push for more sustainable value creation, especially in the plastics industry, has increased strongly both in business and academia, as well as at the legislative level. In its current strategy for 2050, the EU is pursuing the goal of a shift towards a circular economy and thus to a sustainable, climate-neutral, but above all competitive economy. In doing so, the pressure for change poses challenges for SMEs, which often do not have the financial and organizational resources to fundamentally restructure their business models as, for example, a publicly listed company. Although limited areas of CE adoption within large organizations have been extensively researched (e.g., recycling, green procurement), research on the adoption of CE principles in SMEs in still sparse.

For SMEs that are at an early stage of transitioning to circular value creation, the plethora of available definitions for CE, lack of systemic research to incorporate CE principles and business models, along with the infusion of vague concepts from various disciples can be confusing and thus inhibiting. Therefore, this paper attempts to present a conceptual methodology on how to identify circular value creation opportunities and adapt existing structures from an SME’s perspective, using the example of a plastic product (child safety seat) traditionally produced by SMEs. The developed methodology aims to serve not just as a decision support tool to adopt or adapt CE principles for circular value creation, but also to measure the overall circularity score of the developed business model. To this end, this paper used an exploratory approach to narrow the gap to adapt business model development methods currently used in practice, with the requirements for circular value creation in the context of a CE. Since the development of new value creation logics, respectively business model innovation has in the past proven to be an effective means in overcoming far-reaching problems in the introduction of new technologies, it was decided to pursue this approach as well.

At first a complete disassembly of the product to gather information on the bill of materials through a multidisciplinary workshop took place. This data is later used to understand the effects of modularity, repair as well as to identify non-recyclable component and find bio-based plastic alternatives. While the disassembly workshop, allowed us to gain a comprehensive insight into the product and to derive first general

Fig. 12. CEP Evaluation long-term model.

Fig. 13. CEP Evaluation short-term model.

requirements for a future circular business model scenario, the market analysis, made it possible to ascertain that the customer's demands and respectively on a circular product were clearly challenging at times.

Using a contradiction matrix, the circular solution spectrum was narrowed down from 2809 combinations to a manageable level. Since an isolated consideration of the business model independent of its environment did not prove to be effective, therefore it was supplemented by the environment mapping tool to build up a conceivable future scenario considering the influence of external factors. In this way, the solution spectrum could be narrowed down to 654 conceivable business solutions. Concluding our methodological approach, a cross impact balance analysis (C-I-B) was applied to validate prior results.

Finally, from the C-I-B, four scenarios for a circular child seat were derived, two for each of the two strategies pursued, namely, use-intensification and product-life-expansion. Following which, the derived business model scenarios were qualitatively evaluated under consideration of circularity indicators. Finally, the derived business model scenarios were qualitatively evaluated under consideration of circularity indicators. Thereby, the elements of the analysed business models could be differentiated by their influence on the business model, while some were mandatory but passive (e.g., data collection) others actively promoted circularity (e.g., take back systems).

The simplicity of the established tools used, combined with the comprehensiveness of the methodology, offers SMEs the decisive advantage by not having to overhaul their already highly optimized production and supply chain but adapt changes step-by-step through the application of BMI as a starting point in their transition to a more sustainable circular value chain. Thereby, SMEs can vary the speed of their transition process according to their capabilities and avoid overwhelming burdens, while at the same time stay competitive while transitioning to a circular economy. In conclusion, the presented conceptual methodology along with the applied case study provides SMEs with a template for the transformation of their value creation logics and helps them build a fully circular supply and demand network.

CRediT authorship contribution statement

Philipp Rittershaus: Conceptualization, Data collection, Formal analysis, Investigation, Methodology, Software, Validation, Visualization, Writing – original draft, Writing – review & editing. **Manfred Renner:** Funding acquisition, Project administration, Supervision, Conceptualization. **Venkat Aryan:** Supervision, Data curation, Writing – original draft, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jclepro.2023.136083.

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