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An Approach for Idea Generation on Sustainable and Cycle-Oriented Products in the Early Phase

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Executive Summary

Sustainability and circular economy are becoming increasingly important for new products due to new EU legislation and serve as orientation for product development. This is particularly significant for the automotive industry, as 'new' products such as electric vehicles present new challenges. This sustainability orientation influences fundamental requirements of a product, such as material, construction, joining techniques, design and production. Some of these requirements are determined particularly in the early phases of the innovation process. Decisions are made almost exclusively based on theoretical data, while the inclusion of physical prototypes in the evaluation and decision-making process often only takes place at later stages. In particular, an early, disruptive, sustainability-oriented idea generation, which is not only based on a data-based evaluation but is also supported by physical realization in the early phase, contributes significantly to well-founded decision-making processes. A procedure developed for this purpose is presented in this article.

Keywords: Recycle, Re-use, Life Cycle Analysis, Design for Second Life, Environmental Impact

1 Introduction

The European Union has set itself the goal of becoming climate-neutral and establishing a circular economy by 2050 [15]. With the EU regulation for the environmentally friendly design of sustainable products (ESPR) [16], the directive for corporate sustainability reporting (CSRD) [31] or the planned EU directive to improve the circularity of the automotive industry [47], framework conditions are already being created that offer companies incentives and impose regulatory obligations on them in part to bring ecologically sustainable and circular products to market. However, the necessary ecological potential can only be achieved if the economic, ecological and social advantages and disadvantages and their trade-offs are taken into account in product development [20]. Technologies and design approaches that are not used or are used incorrectly can reduce the desired sustainable effect or even have the opposite effect (so-called rebound effects).

Due to the expected legislation in relation to sustainability and the circular economy in Europe, these factors already play an important role in the generation of product ideas. The generation of ideas is one of the first steps in the innovation process, considering the requirements of a corporate strategy, the market, customers and legislation. In this so-called fuzzy front end, far-reaching decisions are made. Changing these at a later stage leads to increased costs. The validation of the decisions, with the involvement of all key stakeholders, is therefore an important task and must be carried out at an early stage. In the process of developing ideas and making decisions about them, prototypes must be used to enable all stakeholders to have a unified understanding. This article looks at the combination of existing sustainability requirements in the generation of ideas and the use of early prototypes for decision-making. In addition to a consideration of existing approaches, a procedure is presented and the results are described.

2 State of the Art

Companies are generally aware of the challenges of sustainability and the circular economy, but there are too few approaches to solving them [28]. For example, it is not yet possible to automatically derive the effects of sustainability-oriented decisions. In the BMBF research project Cyclometric, an approach to defining specific and product-related definitions of possible circular measures was developed [19].

2.1 Evaluating Sustainable and Cycle-Oriented Products depending on the Company Corporate Strategy

Circular economy-oriented product development is closely connected with the company's corporate strategy, as it influences the creation and successful placement of new products or services in the market. Sustainable product development typically involves an overhaul of the entire value chain, which may require substantial investments and modifications [3,23,24].

Circular economy (CE) is an economic model that aims to reduce the waste of resources and retain the value of products and materials [11,17,40]. Walker [50] defines "…CE is implemented to achieve sustainability, but sustainability is wider than CE… the difference between CE and sustainability is not important, as CE and sustainability are the same in practice." Products are designed to be reused, repaired or recycled at the end of their life cycle. The aim is to minimize waste and maximize resource efficiency. These approaches can help assess, measure and improve the sustainability performance of products. Circular economy is a specific approach within the broader framework of sustainability. The challenge is to integrate them properly into the product development process. This takes place in Life Cycle Engineering (LCE), which describes the technical activities for developing and manufacturing products with the aim of optimizing the product life cycle and improving sustainability [25]. In this context, product properties are prioritized in terms of sustainability, taking into account several product life cycles [22,30,51]. Typical product properties in this context include "reliability", "longevity" or "recyclability" [41,52].

The focus on a circular design is seen as a series of "Design for X" (DfX) approaches [44], which promote adaptation to the circular economy [4,6,18,27,38]. However, the DfX approach increases process complexity and the need for information to such an extent that it is not feasible for early development phases. An individual assessment must be made for each product. Bovea and Pérez-Belis offer a different approach and analyze existing products from the perspective of the circular economy [6]. Design guidelines are derived and approximations defined to estimate possible effects on product design. However, the challenge with all the approaches mentioned is that design guidelines only provide a set of criteria and advice that can be used to identify better design options. They are not specific enough to support circular design decisions for complex products with many interdependencies, where one decision can have multiple side effects on circularity and sustainability (see, for example [5,12]).

Similarly, Potting [41] provides a structured framework for R-strategies to implement the circular economy. They distinguish between material efficiency (recovery, recycling), extended product lifecycles (repurposing, remanufacturing, refurbishment, repair, reuse) and smart product development (reduce, rethink, waste prevention). The German Institute for Standardization [9] is introducing a similar approach that aims to align business processes with circular principles. These standards cover various sections, including modular design, product simplification, reduction of toxic substances, digital product passports, and information sharing platforms.

Furthermore, there are several ways to measure and track sustainability aspects when developing and adjusting a product [37,40]. These involve assessing the product's Life Cycle, which evaluates its ecological impact throughout its entire operation. Resource consumption, emissions, and waste are considered in each stage of the product's life cycle, from raw material acquisition to production, usage, and disposal. Life cycle assessment (LCA) enables the identification and evaluation of the environmental impact of products, highlighting potential areas for optimization [22]. Nonetheless, this approach is solely utilized to confirm the environmental impact of a product and not in the planning phase. In addition to the LCA, there is also the recyclability assessment, material flow analysis, eco-design method, C2C, resource conservation analysis [11,40]. However, all these methods are only partially suitable for evaluating prototypes in the early phases of product development.

2.2 Idea Generation of Sustainable and Cycle-Oriented Products in the Early Phase

Idea generation is a crucial process in the development of creativity and innovation at the beginning of the innovation process. In its early phases, analysis such as market and trend research, problem identification and customer analysis are carried out. Based on these results, the idea generation phase takes place, in which new product ideas are generated and then evaluated. Creative methods are mainly used in the idea generation process to efficiently generate new ideas. A selection of idea generation methods is shown below [8,45].

- Brainstorming: The most common method is brainstorming, a group-oriented method for finding ideas that quickly produce numerous solutions.
- Mind-Mapping: Mind Mapping is a visual technique for organizing ideas, where a central theme is placed in the middle and related concepts are structured through branches and sub-branches.
- SCAMPER-Methode: The SCAMPER method is a creative thinking technique that encourages idea generation by prompting users to Substitute, Combine, Adapt, Modify, Put to another use, Eliminate, and Reverse aspects of a product or problem.
- Synectic: Systematic alienation of the design task to develop new and original ideas.
- Functional analysis: breakdown of functions into various components, elements, aspects, etc., followed by abstraction, division, and classification according to characteristics, features, or attributes.
- TRIZ: Systematic extraction of technical principles from patents to address challenging technical questions.
- Design Thinking: Understanding customer needs through empathy, developing solutions, and verifying through interviews whether the solution resonates.
- Lego Serious Play: An innovative method that uses LEGO bricks to foster creative thinking and problem-solving skills in groups.
- Fast Track Innovation: Is a structured process for promoting innovation and entrepreneurship. The approach emphasizes collaboration, creativity and the use of methods such as prototyping and customer feedback to ensure that the solutions developed meet market needs. [21,32]

These methods demonstrate how to generate new ideas. They do not focus on sustainability or the circular economy.

Another important part of the early phases is the planning phase, also known as the design phase, in which the ideas are illustrated in sketches for the first time. This is where ideas are made visible and further developed for the first time. In the design phase, there are isolated approaches that integrate the circular economy into the design and development process. A selection of these are terms and procedures such as Design for Longevity, Design for Circularity, Design for Sustainability or Design for Environment. These approaches are usually based on strategies such as material selection, recycling or reuse. In the automotive field, various manufacturers already have isolated approaches. Some of them are shown here:

- BMW: The principle of circular design: Rethink new materials, new technologies, new processes and, in general, new ideas. Reduce of components, materials, refinements. Reuse by creating new use cases. Recycle of plastic, aluminum and steel [46]
- Mercedes Benz: Design for Environment: Lightweight construction, long lasting materials, reduce raw materials, reuse of various components and recycling [34]
- Volvo: Design for circularity: Maximizing resources by designing for durability, reuse and recycling
- Renault: Eco-Design: Using fabrics, plastics, glass and metals including recycled materials, refurbishing spare parts or reusing batteries [43]

Product design presents the challenge of developing a product that meets customer requirements while standing out from the competition. Key aspects such as functionality, aesthetics, quality and costs were taken into account. Sometimes only a few environmental impacts are considered. Design for Environment methods are one possible approach to incorporating sustainability and circularity into product development, with the goal of reducing the environmental impact of products [26,42]. At the design stage, environmental concerns are addressed to minimize the product's environmental footprint over its entire life cycle [29]. An alternative strategy is to establish circular economy models, wherein products and materials are designed to be reused or recycled at their end of life [39,49]. Concepts like cradle-to-cradle or circular economy are applicable [33]. The objective is to fashion products in a manner that they retain their value as a resource at the end of their life cycle and can be reintroduced into the loop.

The examples from literature and practice show that it is necessary to address sustainability and circular economy in the early phases, at the beginning of the innovation or development process, and not just to make adjustments in terms of material and recycling at the end of the development. When it comes to generating ideas of a new product design, there is often a lack of practical examples of sustainable functional and product solutions [28]. These examples are necessary to develop product ideas sustainably and to ensure that the ideas are both ecologically and economically viable. A targeted exchange and collection of such examples can significantly increase creativity and efficiency in product development. A general sustainability-related assessment is usually carried out by means of a life cycle analysis. However, this assessment is not carried out in the early phase but only in the downstream processes of product development [7]. Such an assessment has several evaluation criteria, including metrics, the selection of which is extremely important, especially in an early-phase assessment [35,50].

2.3 Integration of Sustainability and Cycle-Orientated Prototypes in the Early Phase

Product development is commonly divided into different phases. A typical classification includes the following stages [13,14,48]: Idea and concept, planning and specifications, draft and design, prototyping and testing, manufacturing and production, launching and marketing, maintenance and evolution. Each stage comprises tasks and steps pivotal to product development. The methods can be roughly divided into two areas: Traditional and agile. The traditional approach is more linear and sequential, and all planning is done at the beginning. The agile approach is iterative and incremental, allowing for flexible planning and adaptation during the process. Regardless of the approach and phases, it is important to generate physical implementations early on and thus integrate sustainability and cycle-orientated early prototypes into the process [10]. These early prototypes, which generate sustainable and cycle-orientated solutions, can be helpful at the early phase.

The findings show that it is immensely important for the development of sustainable and circular products to consider circular strategies and measures in the early phases in order to be able to view and develop the product holistically regarding the circular economy. Particularly in the early phases, the design must be based on circular measures and early prototypes can help to find suitable technical solutions.

Our analysis has led us to the conclusion that a process is needed that involves creating initial ideas and designs with early prototypes and analyzing them in the early phases of product development in terms of their impact on sustainability and circularity. Based on the authors' understanding, this was not covered by the results proposed in the literature so far.

3 Approach for Idea Generation on Sustainable and Cycle-Oriented Products in the Early Phase

Sustainability and circularity are growing in significance in product development and design [16,19]. The objective is to design products that preserve resources and are environmentally friendly throughout their entire life cycle. This entails employing sustainable materials, minimizing emissions and waste in production, and enabling reuse or recycling of the product at its end-of-life. Design-for-environment approaches and life cycle assessments are among the tools that can be utilized to account for these factors in product design.

In the early stages of the innovation process, within the generation of product ideas, far-reaching decisions are made. While management focuses on business figures, developers focus on aspects such as functions and structures, while designers focus on design, materials and features. To link these different bases for decision-making and to promote mutual understanding, an approach is needed that considers the needs of all parties. The approach developed in this paper aims at the early generation of ideas, considering sustainability aspects, in order to secure strategic decisions of all parties.

The following chapter presents the approach developed to support the generation of ideas for sustainability- and circular economy-oriented products in the early stages through early prototypes. This includes a fast innovation approach (Chapter 3.1), the evaluation of early prototypes and designs (Chapter 3.2), the assessment of sustainability and circular economy strategies for prototypes (Chapter 3.3), and the integration of these into strategic decisions during the development process (Chapter 3.4). Figure 1 shows the approach.

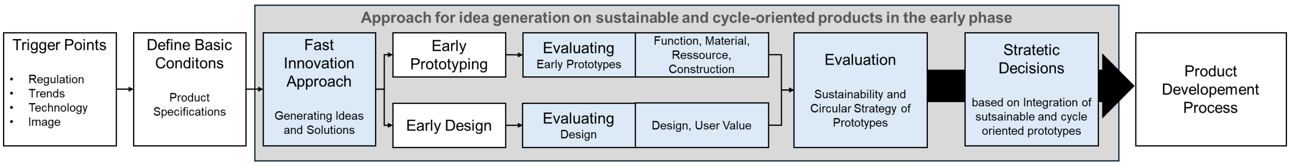

Figure 1: Approach for idea generation on sustainable and cycle-oriented products in the early phase

3.1 Fast Innovation Approach with Sustainability- and Cycle-Oriented Early Prototypes

Many years ago, product ideas were developed using traditional materials and tools, while modern prototyping technologies such as 3D printing and laser cutting were still reserved for specialists. Access to information was limited, and there were concerns about virtual processes. Today, much of the innovation process is virtual, but it is becoming apparent that tangible prototypes are often more helpful in the early phases. Questions arise about the efficiency of the current prototyping process and the best supporting tools. The maker movement promotes a culture of hands-on manufacturing and innovation through traditional and digital tools. Makers are a diverse group of creative minds who work in teams and learn new technologies to develop creative solutions. Early-stage prototyping can effectively address gaps or inaccuracies in sustainability assessments based solely on theoretical data by:

- Design consideration: evaluation of the design and functionality of the individual components and the assembly.
- Real-world testing: prototypes allow for the observation of actual performance in real-world conditions, revealing discrepancies between theoretical assumptions and practical outcomes.
- Iterative feedback: prototyping enables iterative development, allowing for continuous improvement based on feedback from testing and stakeholder input.
- Material and resource insights: prototypes help identify the actual materials and resources needed, which may differ from theoretical estimates, thus refining sustainability assessments.
- User interaction: engaging users with prototypes can uncover practical usability issues and environmental impacts that theoretical data may overlook.
- Data collection: prototypes can gather empirical data on energy use, waste generation, and other sustainability metrics, providing concrete evidence to inform assessments.
- Scenario testing: prototyping allows testing various scenarios to understand potential impacts and optimize designs for sustainability.
- Strategy consideration: prototypes enable an interdisciplinary consideration of future conditions (R-strategies) and corresponding C-measures to ensure the best ecological and sustainable solution.

By integrating practical insights from prototypes with theoretical data, organizations can achieve more accurate and reliable sustainability assessments. When evaluating prototypes in terms of circularity, the developed fast innovation approach focuses on the use of materials and resources, design, and strategic direction.

The fast innovation approach is a process that promotes the generation of early practical prototypes and enables stakeholders to gain a first physical impression of the product idea [32]. Various methods such as brainstorming, synectics, functional analysis, TRIZ and design thinking are used in this process (see Chapter 2) [1,2,36]. In addition to the established methods, there are other approaches, such as the honeycomb canvas or decision-making using the translation canvas, for cooperation with digital talents. Early prototypes offer a way to quickly implement ideas in a physical and creative way.

The Fast Track Innovating Process [32] established at Fraunhofer IAO consists of the phases: ideation, creative excursion, collaboration with digital talent and prototyping. Open-source components are used. Young digital talents are integrated to complement the expertise of the experienced workshop participants. In addition, intuitive prototyping tools are provided. This enables rapid and uncomplicated prototype development.

If all these elements were integrated, the idea generation process would become optimal. Concepts can be made tangible in a short period of time. Traditional decision-making processes, which often take weeks, can be significantly accelerated by rapid prototyping, enabling timely consideration of decisions.

The evaluation systematology has as its subject the circular economy options that arise from the so-called “R-strategies” for a manufacturing company regarding a product to be developed and forms the evaluation framework by means of which the circularity of a product is to be assessed. Based on already identified circularity indicators and with the inclusion of circular economy-relevant norms and standards, overarching assessment dimensions for R-strategies were identified that could be valid for all R-strategies relevant to the project. These include the dimensions of material and energy efficiency, recyclability, durability, repairability, and reusability.

3.2 Evaluating the Sustainability Design, Material and Resource Insights of Prototypes

When prototypes are reviewed in terms of design, materials and resources, the factors considered include practicality, functionality, aesthetics, compliance with regulations, cost-benefit, user feedback and sustainability. Particularly to the design, the extent to which the required quality standards are met with sustainable materials is examined. In most cases, the prototype consists of several components or assemblies that are connected to each other. In terms of sustainability, the joining and assembly technology must be examined, as these are important e.g. repairs or reuse. The implementation of functionality with different alternative sustainable materials is checked on the one hand and evaluated on the other by means of customer feedback.

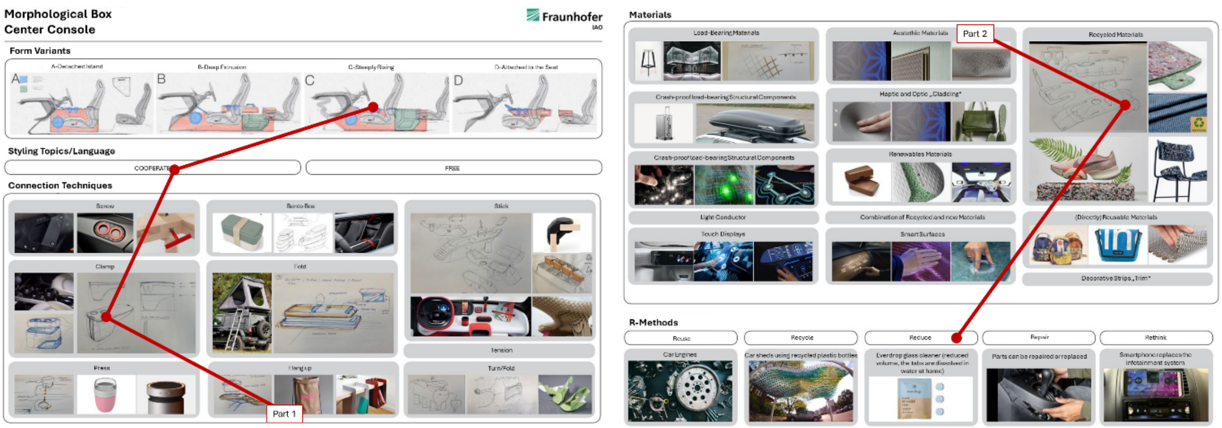

Figure 2: Morphological Prototyping Box (Part 1: left, Part 2: right)

A typological concept is used to define e.g. a target vehicle type and class, for a component as well as ergonomic requirements for the center console could be derived. With the help of a Morphological Prototyping Box (see Fig. 2), various design ideas were developed regarding design, construction/connection/joining concepts, materials and recycling strategies (see chapter 3,3). Finally, three design concepts were identified, which were developed in a further step with experts from companies and science.

3.3 Evaluating the Sustainability Strategy of Prototypes

The evaluation of sustainability requires an overall view of the elements of corporate strategy, product strategy, production and product life cycle. Differentiated evaluations must be provided for the respective decision-makers/stakeholders (figure 3). The procedures differ in several aspects. Each element poses specific requirements that differ depending on the context and objectives. The evaluation methods are based on weighted C-strategies, which serve as the basis for the analysis [53].

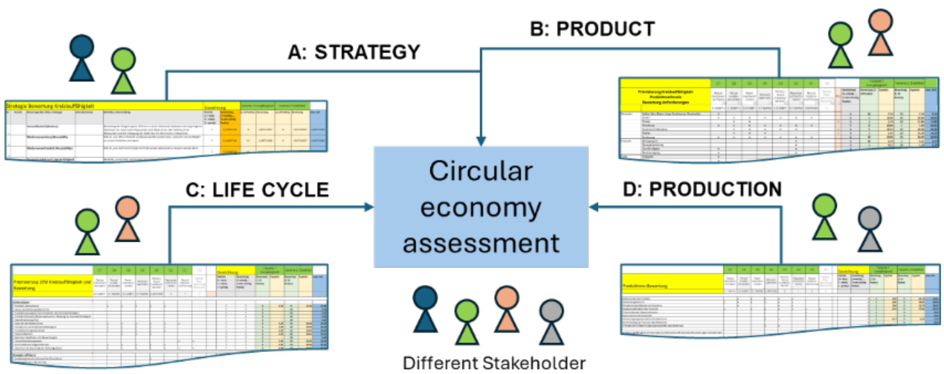

Figure 3: Sustainability evaluation of prototypes

The goal of the circular evaluation system is to make the concept of a product's 'recyclability' measurable and ultimately assessable in the context of product development, which requires a basic framework of metrics. Suitable indicators serve to describe circular aspects within a company and its products. Circular Economy (CE) indicators were considered as potential metrics, indices, variables, or combinations thereof that represent how the circularity of companies or the circular potential of products can be represented and, if necessary, quantified using various descriptive variables. The focus is on the circular economy options that arise from the so-called “R-strategies” for a manufacturing company regarding the product to be developed. It serves as a framework for evaluating the recyclability of a product. R-strategies set a long-term goal and show a possible path, but do not define the specific "circular" measures (C-measures). C-measures contribute to the extension of the lifetime of a product in operation through repair or reuse of parts of the product and they can, individually or in combination, contribute to changing the initial state of the product to an end state. The initial state can be "defective, worn or unattractive" and the end state can be "new, like new or used". The actions taken have an impact on the quality and consumption of resources.

The C-measures form the basis of the circular evaluation system for analyzing the implementation of requirements from prototypes. In the evaluation system, the individual C-measures are weighed against each other to determine the extent to which one measure is more important than another, e.g. whether reusability is more important than repurposing. On this basis, an individual factor evaluation is considered in relation to the elements of corporate strategy, product, life cycle and production. This also leads to a targeted evaluation of prototypes. For example, a product evaluation feature such as connection technology can be important for all C-measures, while the use of materials is mainly relevant for repair, refurbishment, remanufacturing or recycling. The individual factor evaluations provide a common overview and enable the comparison of different prototype variants.

3.4 Integration of Sustainability-Orientated Prototypes in Product Development Process

The basis for adapted product development is a product development process focused on circularity and sustainability. Aspects from the life cycle assessment, strategies and measures of the circular economy, strategies for the end of life and the requirements of a design framework must be considered. Figure 4 shows a few aspects that must be considered.

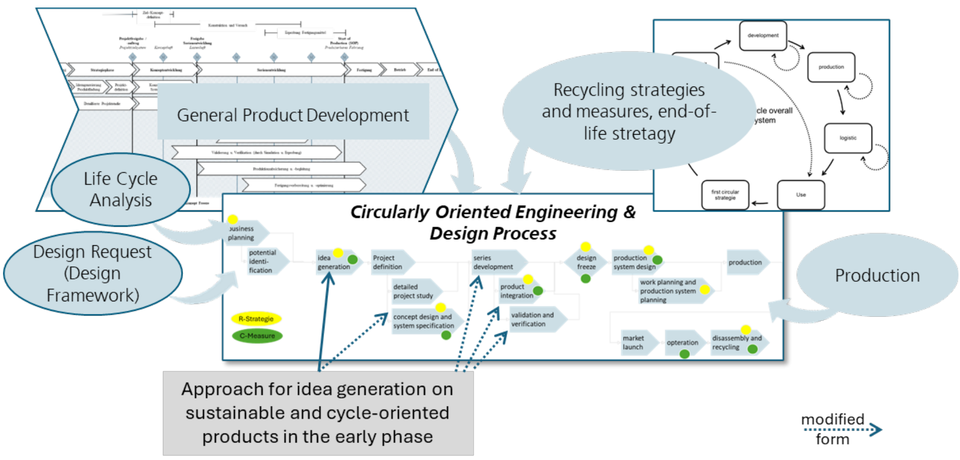

Figure 4: Circularly Oriented Engineering & Design Process

The approach developed (chapter 3) is to be integrated into the product development process and must be positioned at the beginning of the idea generation process. This is because, on the one hand, various goals and data must be considered at an early stage in the idea generation phase, such as business goals, life cycle goals, a derivation of the R-Strategy from the C-Measures, as well as design specifications and functionalities or user requirements. On the other hand, decisions are made that have a huge impact on the direction of later development phases.

In the early phase, sustainable and circular decisions must be made for further planning. The use of circular prototypes is important to make these often-far-reaching decisions in the best possible way. The prototypes combine theoretical assessments with practical considerations of the circular economy. They enable interdisciplinary and cross-functional integration and the formation of a common understanding among stakeholders and experts or employees who are only involved at a much later stage in the product development and production process. Circular prototypes thus become a connecting element on the path to sustainable and circular product development between the early phases, the actual product development process, life cycle analysis, requirements from the design framework, strategies for sustainability, recycling, and end-of-life, as well as production. The approach to creating and evaluating circular prototypes can be revisited in a modified form at a later stage in the product development process.

4 Application of the Approach, Evaluation and Results

The approach described in chapter 3, was applied and evaluated at a sustainable and circular vehicle component (centre console). In the early phase, ideas were generated in several "Fast Innovation Workshops" with different stakeholders and young talents (chapter 3.1). In doing so, previously defined recycling strategies were considered throughout via trigger points and basic conditions. Priority was given to developing joining concepts and functions that enable easy disassembly and thus reparability, replaceability and sort-ability. Based on the ideas generated and considering the requirements of the cycle strategies, initial prototypes were built to test practical implementation. At the same time, initial design variants were created using the newly developed cycle-oriented design pre-process. Figure 5 left shows an early prototype of the assembly concept of a new idea. The special feature is the simple assembly and disassembly of the components, which relate to a clip, plugged into each other, and fixed with a few easily accessible screws. In addition, sustainable materials such as flax and wool were included in the concept. The center console is functionalized using smart textiles such as buttons made out of conductive yarns and a touchpad based on silver paste under the textile. Figure 5 right shows the parts as well as the assembly and material concept for the center console.

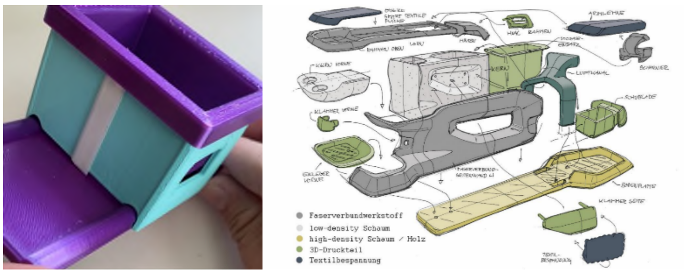

Figure 5: Right: Early prototype of the assembly concept. Left: Parts, assembly and material concept.

In addition, three design concepts were developed in line with the defined user group and implemented using digital prototypes. The digital and physical prototypes provided valuable insights that were discussed during the process. The morphological box (Chapter 3.2) was used to evaluate the design variants and early prototypes in terms of design, function, materials, aesthetics, construction, connection concepts, joining concepts, and R strategies. Based on these results, three design concepts for the sample component (the center console), were defined, which were then further developed and evaluated together with the stakeholders and subsequently contributed to the decision-making process. A life cycle analysis (LCA) of the parts used supported this decision on which variant to implement. Ultimately, a design concept was selected, and a prototype of the concept was created. After that, it was evaluated with the stakeholders to gain insights for later decisions, e.g., for the corporate strategy, product strategy, or product life cycle (chapter 3.3). Figure 6 shows the chosen design concept and the prototype. The developed prototypes helped within the process to make strategic decisions in the early phase and also for planning the product development in downstream processes (chapter 3.4).

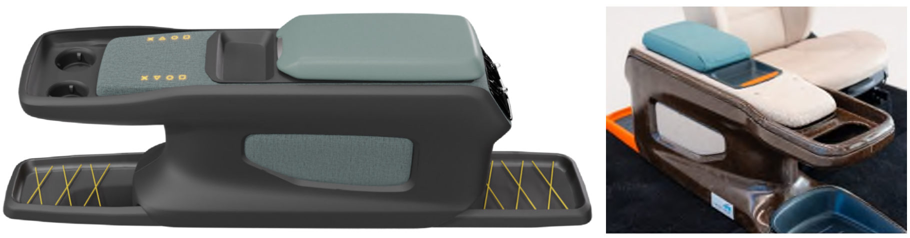

Figure 6: Left: Digital Prototype. Right: Physical Prototype of the Center Console

The approach developed in this paper was successfully applied. It makes a significant contribution to the generation of sustainable product ideas and supports fundamental sustainability- and cycle-oriented decisions during the creative process in the early phases. The combination of the four elements mentioned above, drawn from theoretical approaches and physical implementations, is an excellent way of evaluating the ideas generated in terms of their sustainable implementation potential and carrying them through the entire development process.

5 Conclusion

The article describes an innovative approach to generate ideas for sustainable and circular products in the early stages of the innovation process, particularly in the context of the automotive industry. In view of the increasing importance of sustainability and the circular economy, supported by new EU regulations, the need to consider these aspects in the early phases of product development is emphasized.

Despite the awareness of the challenges of sustainability, there are few effective approaches to solving these problems. The article describes various methods for generating ideas, such as brainstorming, design thinking and SCAMPER, which, however, are often not focused on sustainability. In addition, existing approaches to product development are analyzed in terms of circular economy and sustainability, whereby it is found that many of these methods are not applicable in the early development phase.

Generating ideas for sustainable products requires consideration of circular strategies. The authors propose a process that includes the development of early prototypes and their evaluation in terms of sustainability and circularity. It is emphasized that the use of physical prototypes in the early phase is crucial to finding feasible solutions and ensuring the ecological and economic viability of ideas.

The developed approach consists of a rapid innovation process based on the creation of sustainability-oriented prototypes. The approach is described, which makes it possible to generate and test practical solutions at an early stage. It includes various creative methods and promotes close collaboration between stakeholders. By integrating young digital talents and using open-source components, the expertise of experienced participants is complemented. This enables rapid and effective prototyping that optimizes the ideation process.

As part of the approach, a central component of a vehicle, the center console, was examined. In several workshops, ideas were generated considering circular strategies. Early prototypes were developed to test the feasibility of the ideas. The results show that the use of a morphological box and the early creation of prototypes provided valuable insights that contributed to the decision-making process.

The article concludes that an early integration of sustainability and circular economy into the innovation process is crucial to meet the ecological and economic requirements of modern product development. The proposed approach promotes the combination of theoretical approaches with practical implementations, effectively supporting the generation of sustainable product ideas. The successful application of this approach to a prototype vehicle component shows that the combination of theoretical and practical approaches is crucial for the development of sustainable product ideas and supports decision-making in the early phase.

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M.A. Franziska Braun, is a research associate at Fraunhofer IAO in the Innovation Design team. She studied Industrial Design for her bachelor's degree, Strategic Design for her master's and is currently doing her doctorate in the section of engineering sciences with a focus on interdisciplinary product development processes. Her work focuses on circular product design, market-driven development of innovations in the field of mobility, and research into new development processes and methods for (radical) innovations.

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