# Sustainable product development by means of personalization – paradox or solution?

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**Abstract.** Personalization of products and services entails not only risks but also potentials for sustainability. During the product development process, it is crucial to take into account future usage patterns and their variability. Even if the product itself is not personalized, a user-centered approach during the entire life cycle can unlock many potentials. Avoiding unnecessary functions and tailoring a product precisely to its user's needs can lead to optimized sustainability performance during its use. Moreover, by developing and offering personalizable products that meet the requirements of the respective user, companies can tap into new market opportunities and increase their competitiveness. As a methodological basis, we introduce a combination of the Stuttgart models of personalization and personalized product development with life cycle thinking aspects and circularity strategies. In an interactive workshop the integrated model is discussed and participants can locate their own work and perspective within the broader personalization scheme. Different opportunities of personalization are highlighted from an environmental point of view.

## 1 Introduction and motivation for the workshop

Personalization can have both negative and positive effects on the environmental sustainability of products [1]. For instance, personalized products might have a longer lifetime and potentially use less resources, due to fulfilling user needs more precisely or through adaptivity to changing user needs. On the other hand, additionally integrated functions might lead to a higher resource use in production, and re-use possibilities might be limited for highly tailored products, therefore potentially reducing the lifetime.

In order to make environmentally friendly decisions, product developers need to have relevant environmental information at hand during the development process. For the success of personalized products, especially the potential usage behavior of future users is relevant. Additionally, users often lack information on the sustainability of their decisions when choosing personalized products, despite growing sensitivity and motivation. Thus, in order to integrate sustainability in a user-oriented way and at an early stage in the creation of

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personalized products as well as purchase and usage decisions, it is necessary to develop a systematic approach providing different stakeholders with information in a comprehensible way [1, 2].

In an interactive workshop at the 10th International Conference on Life Cycle Management (LCM 2021), we first presented such a systematic integration of sustainability into the development process for personalized products (see section 2) to sustainability experts from research as well as from industry. In the interactive part, we assessed the practical relevance of this systematic approach and its impact on the circularity strategies [3] using dot-voting on a collaborative online-whiteboard (see section 3).

## 2 Scientific background: Systematic integration of sustainability aspects into the personalized product development process

Based on the Stuttgart model of personalization and the Stuttgart model of product development [4, 5], we integrated the two models into a single architecture. To achieve this, several expert workshops were held with participants from the fields of sustainability and life cycle assessment (LCA) as well as human-machine interaction (HMI) and user experience (UX). Additionally, all experts are experienced in the field of mass personalization and personalized product development. In these workshops, aspects for integrating and communicating sustainability in the process were identified and then iteratively integrated into the model [6]. The final result is presented in Figure 1, depicting an approach of how sustainability and life cycle thinking related aspects can be integrated into the Stuttgart models. The generic model can be applied to many different sectors and industries.

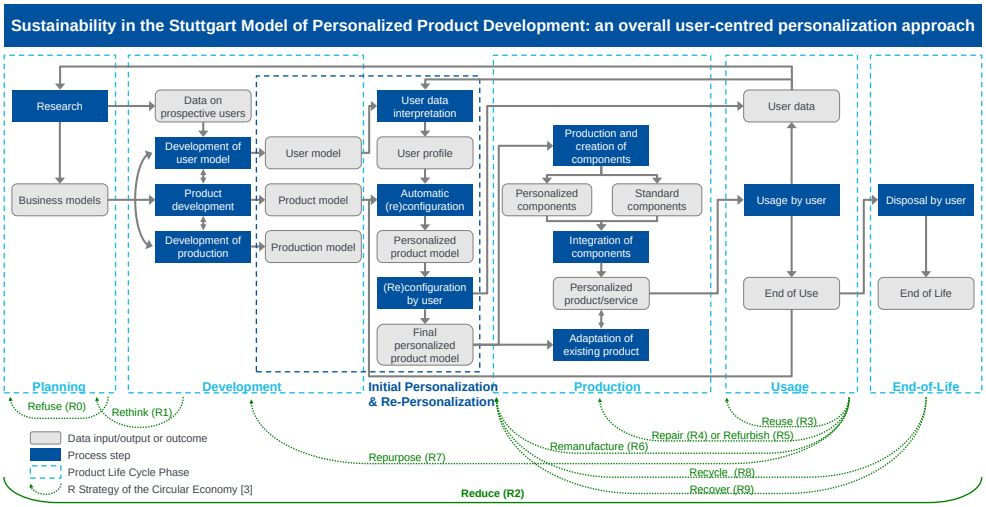


**Fig. 1.** Integration of sustainability and life cycle thinking aspects in the Stuttgart Model of Personalized Product Development [6].

In the following, we describe for each phase key considerations that help to ensure not only a user-centered and personalized sustainable product development process but also a sustainable product life cycle.

### 2.1 Planning

In the planning phase, research should involve the consideration of the sustainability challenges and risks of personalization as well as the potentials for the personalization of

product systems. This involves checking whether the product and all its functions are essential and necessary and, consequently, abandoning unnecessary functions if possible (Refuse - R0). In addition, product design can include circular concepts, such as sharing, multi-functionality and adaptivity (Rethink - R1). Research should also consider the input from current user data for the following user model development (e.g. which data are available or should ideally be collected additionally). Furthermore, sustainability requirements should be considered in business models, in order to develop "green" business models.

In total, the overarching principle of reducing energy and resource demand (Reduce - R2) should be considered for and applied to all processes and phases, respectively.

## 2.2 Development

The design decisions during the development phase are crucial for the personalized product's sustainability impact. They are key to both, the ability to optimize for sustainability during the initial personalization process itself and the realization of circularity strategies in later life cycle phases. Three models including their interrelations must be designed in parallel: the user model, the product model and the production model.

First of all, the defined user model should – besides product specific preferences and individual needs – contain information regarding users' environmental awareness, values and sustainable behavior. When doing so, attention should be paid to potential data collection mechanisms required to actually derive this information.

However, information about prospective users is not just relevant for user modeling. Product development and, thus, product modeling should also take into account the expected user behavior and its variations in order to optimize the resulting environmental impacts [2]. A modular product architecture providing the flexibility required for personalization can also enable the potential reuse of components. Yet, it is crucial that the product model only provides variability that is required (according to research) and decidable (based on the user model or users themselves).

The production model defines the respective manufacturing processes to produce the personalized product variants as defined by the product model. This includes mass production of standard components as well as the production of personalized components. Moreover, the production model should define all relevant information to allow for sustainability evaluations during the personalization and production phases.

## 2.3 Initial personalization and re-personalization

In the initial personalization and (re-)personalization, user data including behavior and individual decisions are interpreted, for example to infer the user's attitude towards sustainability. For this reason, the individual profile based on user data and general user model has to include the personal sustainability preferences. In the automatic (re-)configuration, the user profile and product model are matched and optimized regarding sustainability within the available degrees of freedom. The result is an automatically personalized initial product model or reconfigured product model.

The user integration during the following (re-)configuration by the user is scalable and adaptable to personal preferences, e.g. regarding the number of presented options. Furthermore, the consequences of the personalized product configuration can be communicated individually in a meaningful and understandable way, e.g. by displaying the environmental impacts calculated by means of LCA for different available options to the user. This way, the user can make informed decisions on the personalization of the product leading to the final personalized product model.

### 2.4 Production

For the production of the product, the optimization of the order and the allocation of production processes for the required components towards sustainability is essential. This includes personalized and standard components. For example, Reiff et al. [7] propose a detailed process-planning framework for sustainable manufacturing applicable in the context of (mass) personalization. As a next step, these components are integrated in a way that enables the replacement of individual components up to their complete recombination, resulting in the personalized product or service. Finally, the existing product can be adapted according to changes or additionally discovered requirements to prevent an early end-of-use. This way products re-enter the personalization process and are re-configured for the same or a different user (also see end-of-use options in section 2.5).

### 2.5 Usage

In the use phase, the amount of the collected user data should be minimized. From a sustainability perspective as well as to ensure users' privacy, it should be limited to the extent required for effective interpretation in the personalization step according to the defined user model. These data also provide the basis for the necessary calculations, e.g. using LCA during the product development process and the personalization process.

During usage of the product, users should ideally be guided in their decisions: This includes the option to nudge users to use the product in a sustainable way, to reconfigure the product to prevent an early end-of-use (Repair - R4, Refurbish - R5, or Repurpose - R7), or to hand it over to another user completely (Reuse - R3) or in parts (Remanufacture - R6).

### 2.6 End-of-life

At the product's end-of-life, the user should individually be informed about the optimal disposal or recycling options for the product. Due to its flexible architecture, recycling (R8) of the product's components and materials can save raw materials in the production of new products. Finally, energetic recovery (R9) can contribute to the energy demand.

## 3 Assessing the practical relevance: Summary and discussion of the workshop results at LCM 2021

The workshop was carried out as a remote session during the pre-conference program of LCM 2021. Accordingly, the workshop's participants were a subset of the overall conference audience representing the target group of our work. Thus, they formed a valid group to assess the practical relevance of the presented model in an interactive workshop.

### 3.1 Participants of the workshop

To learn about the participant's background, they were invited to answer a set of interactive polls. Despite the virtual nature of LCM 2021 most of the workshop's participants were from Germany (56 %) and, among this group, from the Stuttgart region (34 %). According to the thematic focus of the conference, all participants work in a sustainability related role, with the majority being sustainability analysts, researchers, or scientists (50 %). The picture diversifies with regard to personalization: While the majority stated that at least a few (22 %) or even many of their company's offerings (33 %) are personalized to a certain extend today, the others stated that they did not know the answer this question (45 %). The types of products

the participants deal with in their company cover consumer products and the mobility sector as well as the construction of buildings, textiles, and packaging.

### 3.2 Sustainability related processes within the Stuttgart models

Based on the Stuttgart Model of Personalized Product Development as presented in Figure 1, the participants were asked to dot-vote for the processes and artefacts they currently focus on in their work from a sustainability perspective.

Two dots were placed in the planning phase, notably on the business models artefact rather than on the research process. The development phase received a total of 8 votes, with a slight emphasis on product development. With regard to the production phase, 4 participants focus on the production and creation of components. Interestingly, 3 participants currently already focus on the adaption of existing products. The usage phase received a total of 5 votes, all dedicated to the usage by users itself. Finally, 7 votes were placed in the end-of-life phase, six of them in the disposal by user process.

While all these phases are relevant for traditional, non-personalized products and services as well, the personalization phase itself is dedicated to personalized product development. This phase, however, also received 3 votes, specifically for user data interpretation and the resulting user profile.

### 3.3 Relation of circularity strategies and personalization

In a second dot-voting session the participants were asked to reflect the influence of personalization on the relevance of the nine circularity strategies [3]. The voting was split into the relevance of the respective strategy in general and for the participants' specific products or services. The results depicted in Figure 2 show that the majority of the participants expect the strategies Reuse (R3), Repair or Refurbish (R4/5), Remanufacture (R6) and Repurpose (R7) to gain relevance from personalization in general, but not for their own products or services. Notably, Reduce (R2) was the only strategy that earned more votes for the specific products or services than regarding the general relevance.

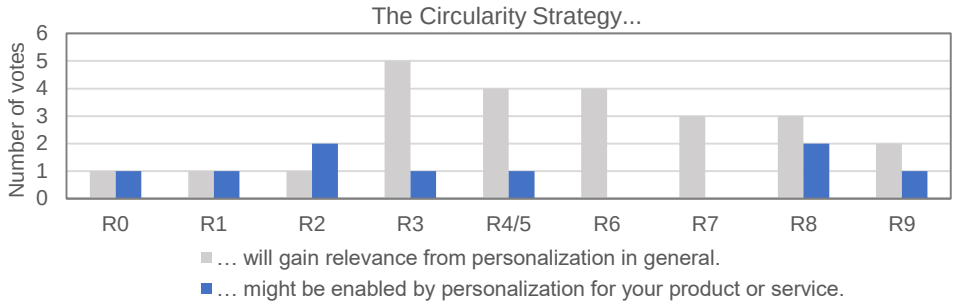


**Fig. 2.** Results of the dot-voting regarding the relation of the circularity strategies and personalization.

## 4 Conclusion

The systematic combination of the Stuttgart Models with aspects of life cycle thinking and circular economy strategies provides a holistic overview of the personalized product development process taking environmental aspects into account. In this work, we visualized how the individual processes during product development from research to the final product can be contextualized within the product life cycle, including the use phase and end-of-life

processes. Especially for personalized products and services, the presented user-centered approach can support creating, improving and maintaining sustainable product systems through the various possibilities during all life cycle phases. Furthermore, the context of the Circular Economy was included in our model by pointing out where the various R-strategies can be localized in the Stuttgart model.

The workshop at LCM 2021 confirmed the relevance of this contextualization. The current focus of participants from a broad spectrum of topics within both research and industry could be located by themselves in our process overview and was emphasized in the oral discussion. Furthermore, over the course of the workshop most participants saw sustainable personalization no longer as a paradox but rather as a solution (see Figure 3).

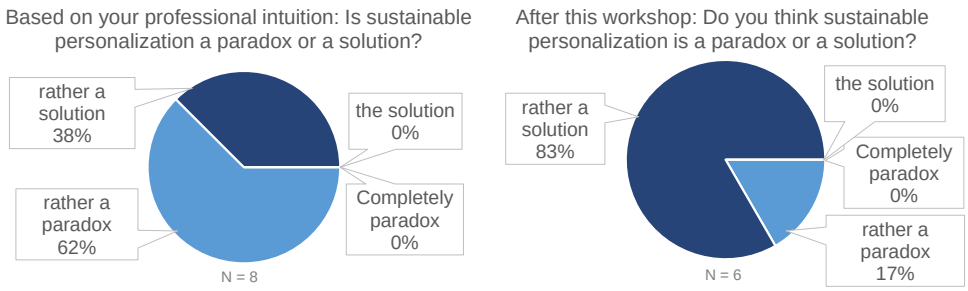


**Fig. 3.** Results of two interactive polls carried out at the beginning and the end of the remote workshop, respectively.

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