User-centered data provision for climate-friendly products development

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Abstract

The development of climate-friendly products is a growing challenge for manufacturing companies facing increasingly serious concerns about global warming and the importance of environmental protection. Design engineers have a shared responsibility to realize sustainable products with the minimum environmental impact as possible. To address this challenge, the engineering perspective was analyzed and described using a systematic methodological approach. This approach is demonstrated in this paper by means of a workshop and a persona description. The outcome enables user-centered analysis and proposed solutions specifically focusing on information perspectives in design engineering.

Keywords: Sustainability, Product Development, User-centered Design

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1 Motivation

The emphasis on sustainability in product development arises from the concerns about global warming and the growing importance of environmental protection. Design engineers have therefore a shared responsibility to realize sustainable products with the minimum environmental impact as possible. The development of climate-friendly products requires smart and forward-looking design decisions, with regard to resource-saving material selection that follows circular economy principles.

Design engineers are faced with numerous requirements in product development and must increasingly take the sustainability of products into account. Gathering sustainability information from various sources is time-consuming and challenging (Kim: 2020, 38). Sustainability experts can help. However, sustainability information and its assessment is often unavailable for designers during the product development process (Delaney: 2022, 16).

The results presented in this paper have been acquired as part of the project “Digitalization for Sustainability” (DigiTain: 2024) that aims to develop processes, methods and models for a fully digital product development and certification of sustainable electric drive architectures. The main objective of DigiTain is the systematic incorporation of sustainability aspects during product development. For this, digital methods are developed that enable product designers to consider sustainability early in the development phase of a product.

2 State of the art

Based on the European Commission around 80% of a product's environmental impacts is determined at the design phase (European Commission: 2022, 11). Hence, Design Engineers make a considerable contribution to the production of sustainable products. Figure 1 illustrates in a qualitative way that decisions made during the development phase have the most significant influence on the product-related environmental impact along production phases and the whole product lifecycle. Later, the possibility for influencing the environmental impact decreases rapidly. Decisions made during the development phase cannot be reversed later, or in some cases only with significant effort. At the same time, the total environmental impact increases steadily.

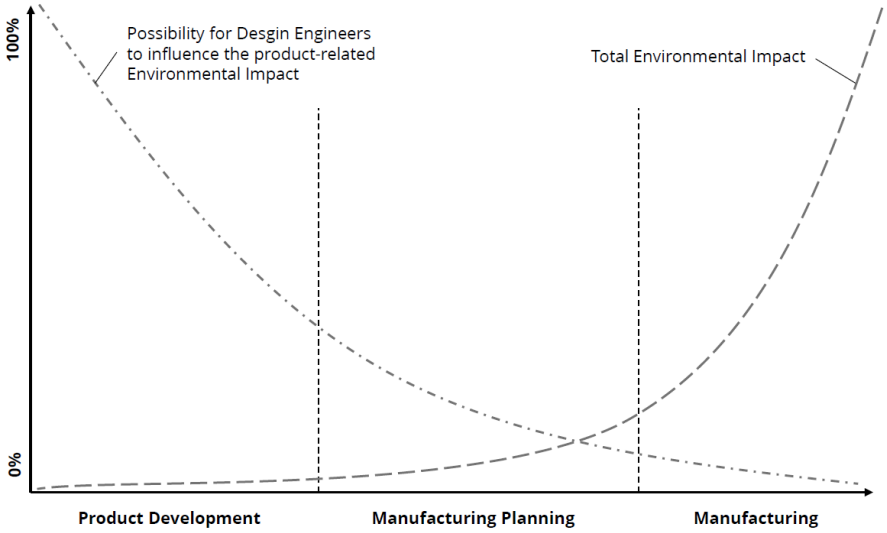

Figure 1: Product-related Environmental Impact along production lifecycle (illustration adapted based on O'Reilly: 2016, 751).

Nowadays, Design Engineers must comply and fulfill multiple sustainability-oriented product requirements that come from different internal and external sources. Knowledge about common production and recycling design rules is usually backed up by internal, company-specific regulations that limit engineers' scope for decision-making. Design manuals in particular provide systematic design guidelines – methods, formal requirements and company standards – for all those involved in product development. The active engagement of sustainability experts in the creation and refinement process of design manuals is considered to be essential. Sustainability experts are therefore able to influence product sustainability at a very early stage (Martínez-Peláez: 2023, 3).

Design specifications can be also often found as digital libraries in development tools like CAD. This provides engineers with a choice of standard parts as well as materials and components. Depending on availability and manufacturing capability these standard parts are permitted as design basis and are therefore to be preferred. Sustainability experts can also contribute to such digital solutions in order to guide the decision-making scope for engineers.

Examples for external sources in the automotive industry are key regulations that address protecting the environment by fuel efficiency regulations and emission standards (e.g. UN/ECE R101 and European Regulation (EC) 715 / 2007). They directly influence vehicle weight, aerodynamics and engine design. Moreover, the European type approval regulation 2018/858 is currently under review by the EU commission and a new draft for it was already published. The proposed regulation will affect how vehicles are built in the future, because it aims to increase circularity in the design, production and end-of-life treatment of vehicles. This includes the use of a minimum amount of recycled plastics, provisioning of replacement and recycling strategies and increased recovery of critical raw materials.

Design requirements from external sources are transferred to design manuals and translated by the sustainability expert. Therefore, engineers must find an optimal solution regarding technical feasibility, costs and in addition sustainability specifications.

3 Aim

To enable Design Engineers to make the best possible design decisions for sustainable product development in line with internal and external requirements, it is necessary to describe and understand their situation – goals, motivation, tasks but also pains and needs – when designing circularity capable and resource-saving products. The analysis of this situation makes it possible to identify improvements and actions regarding whether the information related to sustainability aspects during product design and the access to it might be insufficient. To answer this question in this paper a Battery Designer is explored in detail. The Battery Designer is a representative for the DigiTain project which also focuses on the development of an electric vehicle and its components, such as the battery for the electric drive.

4 Solution and Methods

A persona is a fictional character that represents a crosscut through potential users of a product. It is often used in product management to help understand key traits, behaviors, goals, and needs of a specific type of user. Personas are developed based on market research and personal interviews. In the DigiTain project two project workshops of two hours each have been performed with three project partners. The

interviewees were high-voltage battery designers from automotive suppliers and car manufacturers. To create the persona description, the project partners were interviewed to analyze the engineers' situation. The results were gathered in a template (see Figure 2).

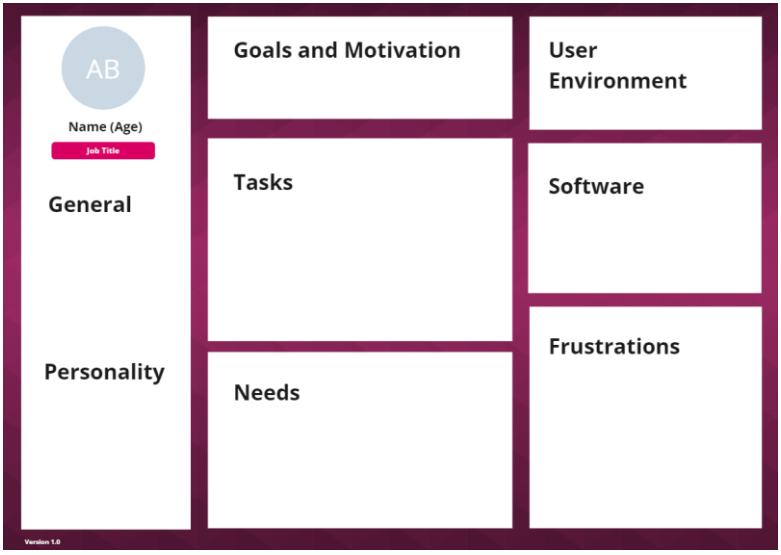

Figure 2: Template for the persona description.

The template contains eight parts. The "General" part consists of name and age, profession or job title, the industry, that the persona is working in (e.g. automotive) and the size of the company for which the persona works (e.g. small, medium, large, OEM, first tier supplier, other suppliers). Additionally, the department of the company in which the persona works is mentioned, the academic education and/or job-related training of the persona, the experience the persona gained while working in the job, particular field or profession and the main responsibility.

The "Personality" part is used to indicate whether the persona is an introvert or extrovert and how the personas thinks – is the persona analytical versus creative. Furthermore, the personality reveals whether the persona makes decisions in a rather thinking or feeling way, is more judging or perceiving and how the persona organizes its environment – structured and clearly regulated or open and flexible.

The "Goals and Motivation" part describes the main working goals and what drives the persona. In the "Tasks" part a list of the top tasks the persona accomplishes in its job are mentioned followed by a part "Needs" that describes the personas' demands to perform its tasks and achieve the goals.

This part “User Environment” describes the working environment of the persona. Here the persona is classified working rather from home or in an office-space, alone or in collaboration with others and whether the persona spends more working time on mobile devices or on desktop computers and laptops.

The “Software” part classifies the persona’s affinity to software and its flexibility to accept new software tools. The software part also lists tools that the persona frequently uses in its daily work.

The last part of the template considers “Frustrations”. These are the problems (pain points) of the persona that it has in its current workflows and daily work. They reveal important insights into improvements and actions.

5 Results

The results of the workshop interviews are summarized in Figure 3 that shows the template filled with the core messages. The persona developed based on the interviews is Peter Volt, a 36-year-old senior battery designer with a master's degree in electrical engineering (see Figure 3 – the detailed interview results are available upon request).

Peter has more than 10 years of experience in high voltage battery design. He works in the product development department of a big sized automotive company. His major responsibility in the battery design process is to focus on the material composition and Bill of Material (BOM) as well as physical and technical properties to achieve his design objectives. He is an introvert with a highly creative and judging character.

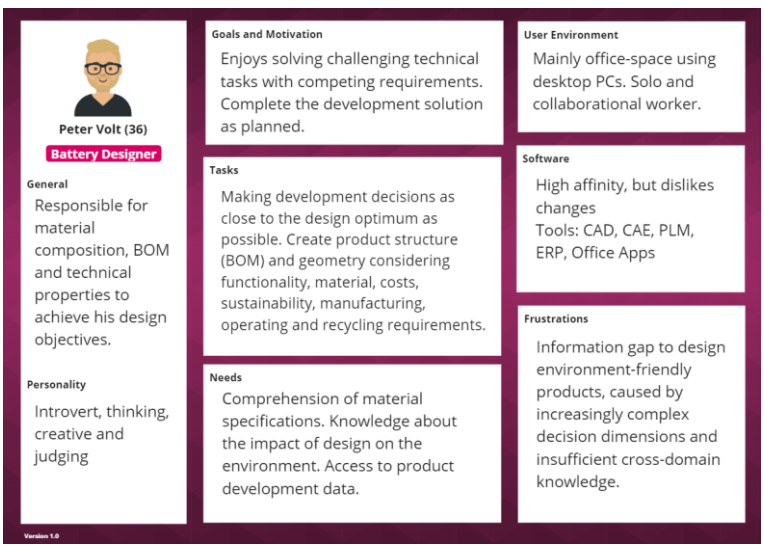

Figure 1: Persona description for a component designer (here: Battery Designer).

Peter typically works with technical specifications that challenge him to find a balance between established and new designs in close dependence with various internal and external requirements (Figure 3, “Goals and Motivation”). His motivation is on the one hand to achieve his goals as planned. On the other hand, designing an eco-friendly battery means to him „contributing to the planet, people and profit“.

Peter's task is to make design decisions and implement them as part of the product model, which is close to the design optimum (Figure 3, “Tasks”). This means making compromises for a technically feasible, economical and sustainable product that takes into account requirements from the entire product life cycle. Peter is increasingly co-responsible for identifying sustainability and circularity indicators and giving them consideration in his decisions.

In the battery design process Peter is dependent on his knowledge and comprehensive access to information about the battery chemistry type, composition, physical specifications and design principles to create a battery pack (Figure 3, “Needs”). Furthermore, he must understand the manufacturing processes and supply chain to deduce production requirements for the battery design. To ensure that the battery is safe and meets legal requirements, he needs information about material compliance for substances that he incorporates in the battery. To meet the increasing demand for sustainable products he requires more and more information about the impact of his design strategies on the environment and must consider resource availabilities, recycling strategies, carbon footprint but also emerging green technologies.

For Peter the consideration of increasingly complex relationships between designing batteries with high circularity, non-toxic materials and high-performance functions combined with safety, quality and low prices is a challenge (Figure 3, “Frustrations”). For him nowadays it is time consuming to estimate the gross environmental impact and life cycle costs quickly by using the software applications available to him (Figure 3, “Software”). For this he is reliant on collaborating with experts (see Figure 4, “User Environment”).

Peter finds himself in a dilemma between his goals and motivation on the one hand and the increased workload by the advanced ecological specifications on the other. With the right information, at the right time and in the right quality, Peter would be able to achieve his goals more efficiently. He would be able to estimate the gross environmental impact and life cycle costs more quickly. This requires an adaptation of the development process and a systematic approach for information provision.

6 Discussion

The need for sustainability-relevant information such as resource availabilities, recycling strategies, carbon footprint but also emerging green technologies is

significant to develop climate-friendly products efficiently. With this in mind, it can be stated that there is a lack of processes and digital solutions for integrating such information into the product development process and the associated tools and systems like CAD, CAE or PLM. Sustainability data must be made available in a way that is comprehensible for non-experts and also user-centered in the designers' information resources and tools to make access as easy as possible. On the one hand, expert tools are, due to their functional spectrum, primarily reserved for sustainability experts with specialist knowledge. One the other hand, some providers of design tools like CAD offer add-on applications for sustainability assessment that are an integral software part. However, such add-on applications are generally limited by their customization capabilities and the integration of external information resources. In particular, the integration of sustainability-relevant product requirements into the processes, tools and systems of product development – even by an integrative or federated information sharing strategy – has great potential to optimize the information flow across domain boundaries. Nevertheless, sustainability experts are and will remain responsible for information sharing. For example, companies often aim to integrate environmental considerations into their product development processes by applying voluntary guidelines. Industry standards and norms such as ISO/TR 14062:2022 help companies to create eco-friendly vehicles that generate fewer greenhouse gas emissions and waste throughout their lifecycle.

As part of the DigiTain project, a prototypic integration between the life cycle assessment software Product Sustainability (PS) and its backbone Umberto and the PLM system Aras Innovator is being developed. So, using PS' software interface adapted for Design Engineers, product and material data can be retrieved from PLM in order to create life cycle assessments. PS provides automated Product Carbon Footprint and Life Cycle Assessment calculations based on the latest environmental regulations and PLM the best basis for product-relevant data like latest development results such as Bill of Material or information on production. The integration will support the objective of the DigiTain project that is about process consolidation for sustainability assessment and the development of digital solutions that address data provision with respect to the needs of Design Engineers. Information about a material's carbon footprint or recyclability enables engineers to apply circular economy principles in an appropriate manner.

References

Delaney, E. et al. (2022). The investigation of environmental sustainability within product design: a critical review. In: Design Science, vol. 8, e15.

European Commission (2022) Proposal for a Regulation of the European Parliament and of the Council establishing a framework for setting ecodesign requirements for sustainable products and repealing Directive 2009/125/EC. https://eur-

lex.europa.eu/resource.html?uri=cellar:ccd71fda-b1b5-11ec-9d96-01aa75ed71a1.0001.02/DOC_1&format=PDF, published 2022, requested on February 27th, 2024.

Holder, D. (2024): DigiTain – Digitalization for Sustainability. https://arena2036.de/en/focus-projects/digitain, abgerufen am 29.02.2024.

Kim, H. et al. (2020). Research perspectives in ecodesign. In: Design Science, vol. 6, e7.

Martínez-Peláez, R. et al. (2023). Role of Digital Transformation for Achieving Sustainability: Mediated Role of Stakeholders, Key Capabilities, and Technology. In: Sustainability 2023, 15, 11221

O'Reilly, C. J. et al. (2016). Life cycle energy optimisation: A proposed methodology for integrating environmental considerations early in the vehicle engineering design process. In: *Journal of Cleaner Production*, *135*, 750-759.

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