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Hide and Seek – a Systemic Approach to Sustainability in Product Development

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Abstract: The size and extend of a product's environmental impact along its life-cycle is mainly determined in the design phase. So far, studies on product design processes show that Design for Longevity criteria such as reparability, maintainability, and upgradeability are only considered secondarily or in exceptional cases. The crucial questions is why available eco-design processes as well as respective tools, methods are not used widely in the industry. To answer this question we conducted a literature review and semi-structured interviews with several product development experts about product development processes, particularly asking about criteria influencing design decision, and the relevance of measures to prolong the lifetime of products. The qualitative data revealed a number of categories for barriers and enablers for the integration of longevity into the product development. Based on that we developed a systemic approach to the conditions facilitating the integration of longevity into the product development process. At system-level, longevity is integrated into the product development process if the relevant strategic and operational knowledge and know-how is available, if "environmental" values are integrated in the company's strategies, processes decisions, culture, and mind-sets, if the production equipment, the infrastructure, materials, and components are available, if a close collaboration across departments and within a partner-network on equal footing can take place, and of course if the political framework supports long living products. Seeing the many "ifs" it becomes clear that it's not only about changing single processes but changing a company's internal practices and culture as well as the external drivers.

Introduction

Environmental impacts are caused in all stages of the product's life-cycle. From overburden during mining, energy and chemical use plus waste production during refining and processing the materials to components and products, emissions during the transport and use phase to landfilling at end of life. Those environmental profiles differ from product to product, but one can say that regardless of the nature, size and time of occurrence of environmental impacts for a product, they are mainly determined in the early design phase (McAloone & Bey, 2009). However, this is usually not considered by product designers. Design practices are mostly oriented towards other criteria such as competitive performance and functionality, costs, and material properties. A consideration of ecodesign criteria such as longevity, reparability, maintainability, upgradeability, and recyclability only happens in exceptional cases (Graulich et al., 2017) This is problematic from an environmental point of view, since these properties cannot be retrofitted once the product is designed. Therefore, ecological sustainability of products starts with the design. Thus, eco-design is a "systematic approach which takes into account environmental aspects in the design and development process with the aim to reduce adverse environmental impacts" (IEC, 2009).

The last 30 years were characterized by a huge increase of eco-design processes, tools and methods that are meant to facilitate the designs and production of eco-friendly products (Ceschin & Gaziulusoy, 2016). Due to their multitude and their complexity the correct selection and use of those requires high prior understanding. One reason why their application is far from being mainstream (Pigosso, McAloone, & Rozenfeld, 2015). What are the reasons that available know-how did and does not find its way into the common design practice? The following paper is tackling this questions.

Research Approach

A master thesis supervised by one of the authors investigated to which extend eco-design criteria are part of the decision process during product development (Maurer, 2018). Seven experts in the field of product development mainly working in the electronics industry were interviewed. The experts were recruited from the authors' and supervisors' professional and private network. It included experts of one large, one medium sized company, two startups and one micro-enterprise as well as one design consultant and one service provider for hardware development. (Maurer, 2018) frames the interviews with a "general" product innovation process, eco-design methods and tools (eco-design methodology), eco-design principles and eco-design strategies. Furthermore, he already collected barriers and advantages of eco-design from literature.

The interviews were transcribed, coded and categorized using a qualitative data analysis software. The interview transcripts were analysed with a focus on the process of product design and innovation management in the electronics sector and those process characteristics that were relevant for eco-design decisions (*process orientation*). Major questions were: What are relevant barriers, enablers, meanings and contexts that shape design decisions – particularly in the development of new products – and what is the role of eco-design criteria?

In a second step the research team embedded the process and the relevant practices identified by (Maurer, 2018) into contexts and settings that turned out to be relevant for them *(systemic perspective*). The question here was: What are contextual conditions that shape practices in providing possibilities for eco-design relevant decisions and actions?

The content of both *process* and *system* analysis were enriched and complemented with results of (Graulich et al., 2017) who conducted a desktop research and interviewed industry representatives from 19 different companies in order to identify triggers, success factors and barriers for eco-design. Besides, insights of expert interviews conducted during the European INTERREG Project EcoDesign Circle (www.ecodesigncircle.eu) were added (Marwede, Paukstadt, Hofmann, Clemm, & Jokinen, 2019).

As a result we propose a systemic framework that describes qualities of an organisational surrounding that support eco-design. This approach helps to understand which conditions can foster the integration of eco-design into the product development.

Limitation of this qualitative research approach is that results cannot be seen as representative for a whole sector or industry or company size and the results present rather the personal opinion and experience of the interviewee than the actual practice in the overall company. However, the in-depths interviews with overall 26 individuals backed-up with literature can give a good understanding of barriers and favourable conditions for eco-design.

Barriers for the integration eco-design into the companies practices

The following subsections represent the major categories of barriers found in (Graulich et al., 2017; Marwede et al., 2019; Maurer, 2018):

- **Knowledge, know-how and competences** of individuals in the company on all levels include the lack of awareness of the benefits, the lack of theoretical knowledge e.g. how to assess environmental impacts of products and the added value through eco-design. Also strategic competences of practitioners are missing how to combine eco-design and business models. Furthermore, the multitude and complexity of eco-design methods hamper the easy selection and use of those. But also data and specifications about alternative sustainable materials might not be available or easy accessible. Even if eco-design knowledge is available, this is not successfully integrated into internal processes and not brought into practice.
- **Organisational and structural barriers** relate mainly to the lack of cooperation and information exchange across departments e.g. the environmental management sector and the product development department do not cooperate. Also strong hierarchies, a high degree of bureaucracy and budgets assigned to single departments hamper eco-design.

  "*As bigger it gets the more difficult it gets because there are so many departments so many hierarchical levels and so and so that makes it challenging to work in that kind of multidisciplinary way of really taking care together and solving the*

problem what you are facing on in the project program" (Anonymous, 2017a)
Furthermore, eco-design requirements are not defined at all or are integrated too late into the product development process when all technical requirements are already defined.

- **Infrastructural and technical barriers (materiality):** The company might not have the required infrastructure, technical equipment or other necessary resources for the realization. Being stuck in **path dependencies** hampers the transition to eco-design, e.g. given production equipment, recent investments taken, or dependency on certain suppliers or components. Furthermore, the **"materiality"** determines the processes and products, e.g. alternative materials, manufacturing processes, infrastructure or equipment are not available – either not at all or not in a sufficient quantity or quality. Furthermore, eco-design criteria might conflict (trade-off) with price, functionality, safety and aesthetic criteria (e.g. dismantlability versus robustness, aesthetics and technical characteristics of recycled or renewable materials versus required specifications reached by current materials).
- **Strategic and managerial barriers:** the management is not aware, lack commitment and do not incentivise eco-design. This means that it does not make resources available to support the process, i.e. avoids investing into eco-design. Furthermore, it does not set long-term strategic goals and does not translate those into operational measures. Besides, a missing innovation culture within the company is hampering eco-design. Furthermore, sales and marketing decides over product innovation cycles in order to push sales which does not leave room and time for more radical innovations.
- **Economic barriers:** the lack of knowledge and competences means that you have to invest in building up this competences or buying external consulting services. Furthermore, the planning efforts increase, i.e. you have to change internal processes, reorganize internal structures and integrate additional steps and methods into the design process which leads to additional costs (personnel, time).

"We can't just impose sustainability on an existing product platform. It would require major changes in the entire platform production and supply chain." (Anonymous, 2017a)
Companies do not know how to get that initial investment back. "*There is a lack of knowledge about how design, particularly eco-design, can benefit companies and how it could be used to their advantage*." (Noor-Ilander, 2016) Moreover, it is tricky to convince partners along the value and supply chain to change their mind sets, processes and behaviour. Furthermore, companies fear lower turn-over in case they increase longevity and reparability of the product, i.e. current linear business models do not support eco-designed products. On top of that, lower economies of scale and a potential increase in production costs through reshoring production to high-income countries may increase overall costs. Also "green" materials might be more costly and the economic benefit of recycled materials is marginal compared to virgin materials.
Overall, "green" products tend to be more costly at the beginning.

- **Customer demand and sales:** Customers are not necessarily willing to pay a higher prices for green products, and might question the environmental benefit. Overall, the demand for environmental sustainable products is low. Furthermore, customers tend to perceive "green" products as of lower functionality, performance and aesthetics or might misinterpret the sustainable features (e.g. lower power is perceived as lower performance and not as lower energy demand). That means single sustainable alternative products or a product range in the companies' product portfolio are tricky to sell and market because the other "normal" products of that company might be perceived as being not sustainable or inferior.
"Even with evidence for a niche market demand [for sustainable products], our developer think and design in global market terms." (Anonymous, 2017a)
- All those aspects make it more difficult to communicate the sustainable features of a product. Furthermore, vendors might not have the relevant information or information is simply not passed on to the

customer. Or, retailers might simply not include environmental sustainable products in the product range, which means that there is no "alternative" available during the purchase decision.

- **Policy barriers:** Complex and fast changing policies as well as unawareness of and uncertainty regarding existing policies hamper sustainable product development. There is limited market surveillance for minimal legal requirements, which gives an advantage to those which not follow the rules. Furthermore, there is a lack of public funding sources for sustainable product development, for example technology development funding schemes do usually not address sustainability. Besides, the multitude of labels are hard to grasp for consumers.

The different categories show that it needs a systemic understanding in order to facilitate and enable eco-design in companies.

The attempt of a systematic understanding – favourable conditions for eco-design

***Figure 1*Fehler! Verweisquelle konnte nicht gefunden werden.** illustrates the variables influencing the integration of eco-design processes into a company, which was developed by the research team on the basis of the results of (Graulich et al., 2017; Marwede et al., 2019; Maurer, 2018):

First of all, relevant agents inside the organisation as well as the production networks (e.g. manager or product developer) has to have the **knowledge** and the **know-how**, in particular

- *strategic know-how*: definition of a eco-design strategy and goals, thorough knowledge of the existing business, good abilities to strategically rethink business models and a good understanding of sustainability concerns which enable anticipation of regulation and public opinion
- *operational know-how* about eco-design tools to use, where to find relevant data, how to engineer technical solutions e.g. for the accessibility of components, and
- system level understanding e.g. life-cycle-thinking, network analysis and complexity reduction.

According to (Jalas, 2016) the skills one would need to have for an integrated eco-design approach are a "*thorough knowledge of the existing business, good abilities to strategically rethink business models and a good understanding of sustainability concerns which enable anticipation of regulation and public opinion*"

Furthermore, the intrinsic **motivation**, **values** and **meanings** of employees and company stakeholder e.g. the willingness to learn and change, conviction to the idea of sustainability and transformation of the company's practices etc. is an important prerequisite for the integration of sustainability into the company's practices, i.e. to take risks, invest, translate barriers into challenges and chances, find new solutions, and to be eco-innovative. It is especially important to communicate the values internally to the employees and externally to your customers, partners and stakeholders.

"*I think that it (eco-design) can be definitely a tool to bring competitive advantages to products today it is seen for many project owner as a constraints more than a business driver so they think about that as cost which is a shame but we need to change we need to make the people change*" (Anonymous, 2017b)

To conclude, if the individual has the know-how, the resources and the legitimacy, s/he has the **power** to alter practices and **processes** within her or his sphere of influence, such as

- *Strategic processes:* Decision processes are fast and flexible and environmental responsibility is built into the decisions making. Development of an ambitioned environmental management strategy together with internal and external stakeholders and translation of this strategy into clear operational goals and definition of performance indicators to measure the level of success which go beyond pure economic indicators, for example development of new skills, creating new contacts, increase of employee or customer satisfaction, or environmental and social benefits for stakeholders. Business developers are able to create a business case, e.g. by developing new business models such as product-service-systems. The business case behind the product is crucial, which means that it is fit to market, i.e. eco-

design does not stand in conflict to the customer demand, that the total-cost-of-ownership or the life-cycle-costs are reduced, or that a higher price can be asked due to a better performance or image.

- *Operational processes:* eco-design criteria are integrated in the early phase of the design process and are of equal value to other criteria such as performance, aesthetics, customer preferences, costs, legal and standards. Procedures are available how to deal with design conflicts, e.g. make compromises, align criteria with strategic goals, or escalate decisions to a higher level.

Those processes are taking place in a certain "**setting**". The setting comprise the entire properties of a certain social or socio-cultural environment in which something takes place or is experienced. The setting in a company is amongst others the organisational culture, the organisational form (e.g. family business or corporation), the product portfolio, the equipment, the buildings etc. The "setting" should give for example the time and space for cooperation between different departments. Is the setting flexible? Is the supporting infrastructure given? It is for example easier for a family owned business to change the business model compared to corporates, which have to resolve more external factors and are dependent on their shareholders (Graulich et al., 2017).

Besides the setting, the **"materiality"** (technical, mechanical, physical and chemical characteristics) of components, products and equipment determines the space of possibilities, i.e are for example more sustainable materials, manufacturing processes, infrastructure or equipment available – in sufficient quantity or in sufficient quality. R&D capacity, resources, funding and partners can help to overcome technical barriers.

Moreover, you need to look for new suppliers and create strategic partnerships – even with competitors – to create the market demand for economies of scale, exchange information on how to eco-design and create common standards for an equal playing field. The latter means a change in how to deal and manage your partner-**networks**. It's a collaboration on an equal footing instead of a buy-sell relationship. They are partner in the value creation process. Engaging with stakeholders such as policy makers, NGOs, customers and scientists can help to solve many technical, legislative and brand issues.

Of course, the companies and stakeholder act in a certain political **framework** which regulates the market. Here several political instruments are available: measures such as (see (Winzer, 2015)):

- Laws and directives, which set minimal environmental requirements on product and process level (e.g. ban of hazardous substances or limits for emissions)
- Financial and fiscal policies such as taxes, duties and subsidies e.g. tax reduction for repair services, subsidies for renewable energies or tax on emissions
- Normative support (standards) define eco-design requirements such as reparability or recyclability.
- R&D funding and grants for the development and realization of eco-design
- Green public procurement linked to norms or labels (e.g. the EPEAT label or the blue angel) creates a market, which can also increase transparency for other purchasers. Also independent product tests and benchmarking can increase transparency.
- Exhibition and awards reward forerunners and increase public awareness.

Last but not least, important actors within the **market**, the customers and distributors, play a crucial role. First of all, the distributors has to have green products within his portfolio, s/he is placing those strategically, and sales staff guides and informs customers specifically about those. Of course, private customers also need to demand greener products. In a business to business market the customer can set certain environmental friendly purchase criteria such as energy efficiency or reparability criteria. But also the OEM can offer certain after sales services such as maintenance or repair services especially in the B2B market – at the same time increasing the lifetime of the product and the turnover (product-service-systems).

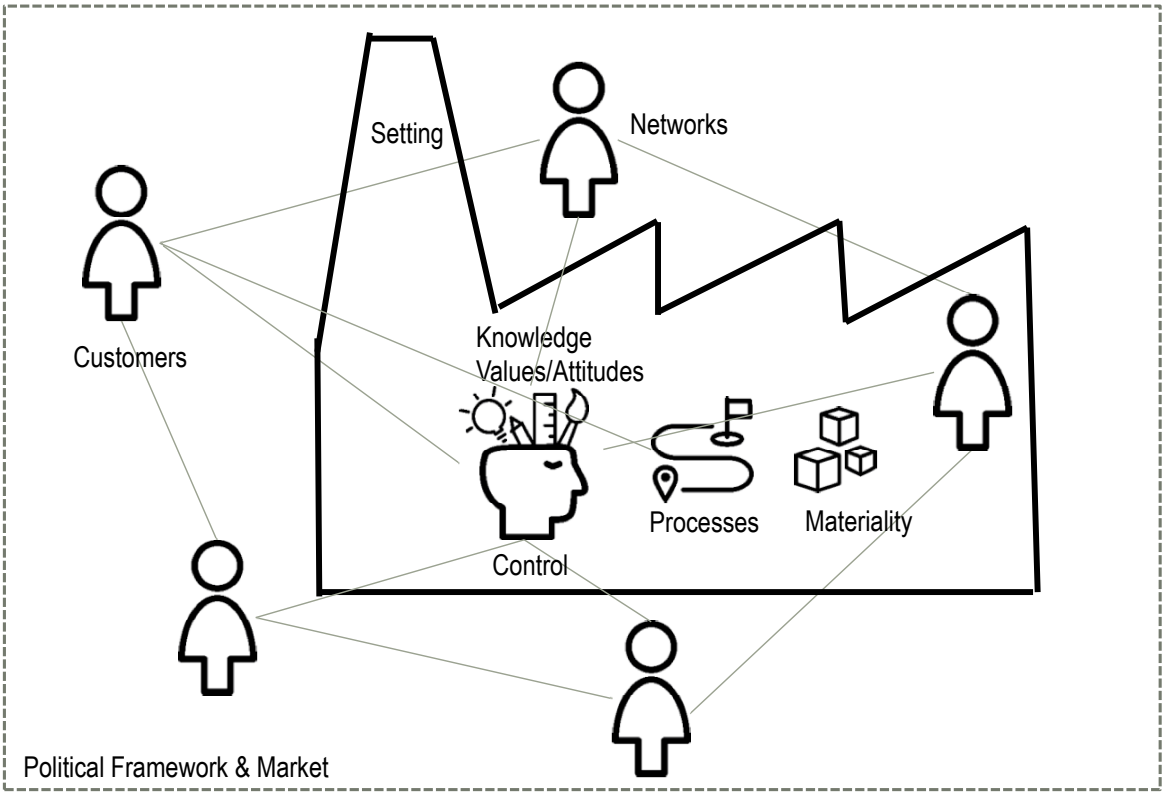

Figure 1. System view on conditions for the integration of sustainability into the product development.

Conclusions: Implications for companies' processes and practices

One cannot deny that eco-design increases the complexity of product development. On the other hand the authors are convinced that implementing eco-design process and practices in a company will make the company more innovative, competitive, resilient and future proof in a global fast changing world.

As (Edman, 2016) states: "*We can´t continue and stay competitive if we are not in balance with the Earth's ecological systems. Ultimately it is about quality of life – for everyone – now and in the future.*"

There are few good practices which can support the implementation of eco-design in companies:

- User centric design: understand the users' expectancies, needs, motivations and problems, their repair and maintenance practices while reflecting on why they buy and discard products. Design the product so that they like to take care and keep the product in use and alive (design for sustainable behaviour, design for product attachment and trust).
- Focus on providing a service instead of selling products: dematerialize by making full use of one product (share products, pay-per-service or pay-per-access).
- Combine product and circular economy business model development: the business model has direct implications on the product design. For example, in case you create a product for short use (disposable product) it should be easily recyclable or biodegradable. In case you "just" use the product to provide a service (pay per service) you want the product to be reliable and easy to maintain.
- Keep the product at high utilization through maintenance, reuse, repair, remanufacturing and cascade use of the product, components and materials. Keep in mind that through recycling you will destroy most of the value you created during the product development and production.
- Design the system (life-cycle thinking) besides the product: which partners, services and costs/benefits do you have to

integrate in order to keep the product alive?

- Create strong partnerships and integrate the network including the user in the value creation process. Open up the design and the value creation process and let partners (e.g. repair centres) and users take part in the development, manufacturing and maintenance of the product and distribute the benefits fair to your collaborators.
- See your company as part of the environment the company relies on. Think about how you can restore that environment instead of how you can exploit it.
- Think about the purpose and the values of your company, your employees and your stakeholders. Integrate those values and your long-term strategy. Balance environmental, social, technical and economic decisions.
- Identify the benefits you create through eco-design within your company and translate environmental improvements on a product level as benefits for your clients.
- Support self-organization and thus enable fast decisions, agile processes, participation and creativity.

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