Environmental Product Optimisation: an integral approach

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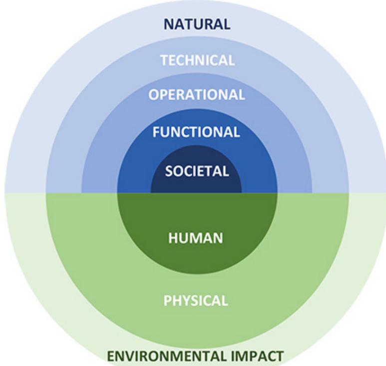
ABSTRACT

For environmental product optimisation, an interdisciplinary design team needs to mutually align and assess the physical- and human impacting factors of a product system. This paper argues that this optimisation can be supported by a fast 'back of the envelope' recurring inventory- and analysis based intervention strategy that timely aids team members adequately document, present, and mutually align and assess interrelated product aspects among relevant stakeholders from within and beyond the team. Various distinguished design phase related environmental activities and -contribution types can further aid tailor the strategy. The use of natural and uninterpretable language and methodical concepts, as well as support of non-designers in creation, visualisation, and selection endeavours are suggested for improving interdisciplinary collaboration. Additionally, design team assistance is requested in verifying the full environmental potential of a design brief and illustrating its potential corporate gains, as to stimulate clients too to aspire to environmental product impact minimalization.

Keywords: product system analysis, environmental product optimisation, design process, lifecycle approach

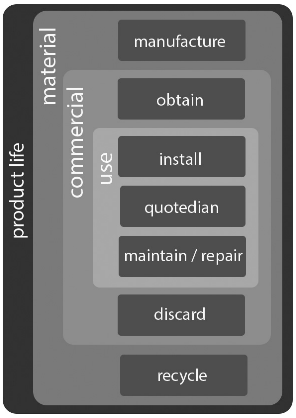
INTRODUCTION

This paper proposes additions to product design activities with the intent to improve the integration of environmental considerations. In order to illustrate the scope, the introduction initiates by addressing how, why, and when the product's environmental impacts are generated and destined. The introduction ends with the demarcation of a search area on which the following presented research is based.



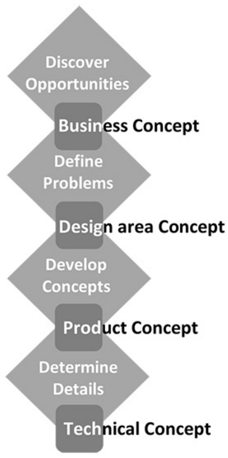
[Figure 1] *product system levels*

A product's environmental impact originates from five product system levels ([Figure 1). The technical level concerns the artefact and the thereto related up- and downstream auxiliary means, like, for instance, for manufacturing and logistics (Ullman, 2009). The operational level adds the auxiliary products and services needed for product functioning, like power and maintenance equipment (Vezzoli, Ceschin, Diehl, & Kohtala, 2015). At the functional level the consumer behaviour is integrated, comprising the use interactions between man, product, and use context (Wever, van Kuijk, & Boks, 2008). The societal level is where the customer makes decisions, for example, about why, what, and how to obtain and discard the product (Shove, 2004). The natural level, or the environment, encompasses the previous levels (McKinney & Schoch, 2003). From this product system level systemisation can be gathered that although the actual environmental impact is physical, the corresponding technical and operational physical impacting factors often originate from functional and societal human impacting factors ([Figure 1) and that environmentally optimal design requires regard for the product system, which includes corresponding auxiliary technical and operational means.



[Figure 2] *product lifecycle*

For any product, each system level can contain multiple product aspects. For example, for an electric coffee machine the operational level contains product aspects like electricity, coffee, water, and possibly even Wi-Fi. These product aspects can directly and indirectly interrelate within a system level or over various system levels, either concurrent or with other lifecycle phases [Figure 3). For example, during use the environmental product aspects wear and tear are directly related to the user's behaviour on a functional level, auxiliary means on an operational level, and construction on the technical level, as well as indirectly related to the product's lifespan. A concrete situation from the coffee machine example is that boiling (functional) water (operational) causes vapour immediately (functional) and calcification over time (natural). Decreasing its environmental impact due to that calcification can be done by, among others, using decalcified water (operational), making relevant parts of non-stick material (technical), as well as improving, or even enabling, possibilities for maintenance and repair (a technical aspect with implications for aspects on other levels).



[Figure 3] *generic product design*

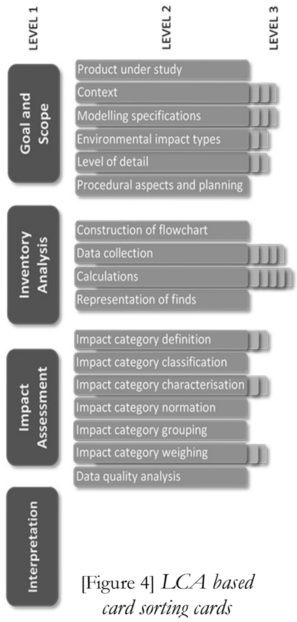
The reason for focussing on design is because a product's environmental impact is mainly destined during the design process (Rebitzer et al., 2004). The earlier illustrated interrelatedness of product aspects illustrates that environmental product optimisation requires interdisciplinary collaboration throughout the design process ([Figure 2) (Young, 2010). Although there are many adopted, adapted, and dedicated methods and models for addressing environmental product aspects, a strategy that aids design teams align product aspects across product system levels, hence interdisciplinary, and throughout the design process is lacking (Fiksel, 2007; Senge, 2008).

This paper presents a research on the possibility to create an environmental product optimisation strategy which fits current design practice. In order to explore both possibilities and challenges for creating interventions, the methodologies of the two main domains, product design and environmental sciences, were researched on existing lingual, cultural, and political similarities and differences for founding a so-called boundary object on (Kimble, Grenier, & Goglio-Primard, 2010). The lifecycle assessment approach (LCA) was chosen as common ground because of its existing application in product design, the overlap in terminology with design, and an overlap in activities with other design involved research orientated domains (Baumann & Tillman, 2004; Guinée et al., 2011; Roozenburg & Eekels, 1998). Another choice which is meant to increase the likeliness of adaptation is the precondition to suit the strategy to the generic, well founded, design process (Joore & Brezet, 2015).

METHOD

As to explore the possibilities and challenges to imbed the lifecycle assessment protocol into product design, expert interviews with a card sorting session were performed. Card sorting (Spencer, 2009), with the lifecycle assessment approach steps (Baumann & Tillman, 2004) presented on the cards ([Figure 4), was introduced in order to challenge respondents beyond their existing convictions and maximize the likeliness of obtaining concrete results. The respondents were asked to link the cards to phases of the design process on an underlay of a generic product design process ([Figure 2). Along with the card sorting procedure, respondents were stimulated to reason aloud.

For establishing common ground within design, the majority of the respondents had a product design background with environmental product design experience. The inclusion of an equal number of respondents from domains that link to the various product system level was chosen to ascertain overlaps and differences with the results from the designer group. The results were analysed by enumerating similar cards per phase and abstracting outings from the corresponding interview.



[Figure 4] *LCA based card sorting cards*

RESULT

General remarks

Many general remarks were made about suiting the design context. For one, investments will be more easily justified in case an intervention is designed to demonstrate financial and imago gains. And since it is not uncommon that environmental optimisation requires a lengthy process of successive system changes in order to overcome the lock-in effect of existing production facilities and product systems, roadmaps and long-term planning are said to be needed too. One respondent added that for convincing clients and managers, it is also important to keep the intervention's overview model easy to pitch and memorise. As approach for suiting a variety of project objectives and investment possibilities, was suggested to offer an essential, medial, and extensive version of the intervention. To increase the likeliness an EPO strategy will get imbedded in design, it was suggested to offer an easy, professional, and expert version, as well as include alternative gains, like efficiency improvement.

Another often addressed aspect was managing the effects of product complexity. Respondents mentioned and illustrated many intricate dilemmas, like, for example, the increase of environmental e-waste burdens of LED and electronic cars versus their respectively energy- and CO_2 savings. In order to make comparisons and trade-offs between incompatible impact aspects, there was a difference of opinion about how to handle this best; some respondents proposed transferring all impacts to a common unit like restoration costs, while others preferred mutual analyses and debate over the risk of 'oversimplifying' decisions by obscuring possible effects. In support of affronting complexity, respondents prefer using guidelines, checklists, and brokers over rules, not only because of better suiting the 'design way', but, more importantly, as to not hinder innovation. To 'ensure a considerable overall improvement at the end' of a design process, the need for a 'factor 2 to 3 design margins' on any particular environmental aspect was repeatedly mentioned. Even higher margins are said to be needed for new-to-the-world products.

Also, interdisciplinary collaboration issues were a recurring topic. Where the design's creative culture was characterised with statements like 'collaboration by walking around' and 'back of the envelop decision making' and 'educated assumptions', the environmental sciences' culture was characterised with the precautionary principle's notion to 'avoid unintended effects'. To support full interdisciplinary design activities, both designers and assessors mentioned that support is needed for non-designers in creation and selection endeavours. Also, the 'language of design', the use of visualizations, is mentioned as a compulsory skill for which non-designers could use support. On the other hand, designers need encouragement to improve documentation, both for managing interdisciplinary considerations and eliciting shared responsibility. Regarding linguistic aspects, the use of neutral, understandable, and uninterpretable language and methodical concepts was advised, as to avoid misunderstandings and domain preferences.

An unexpected emphasis was placed on the limited extent to which design teams are able to carry out the optimisation. The lack of involvement for setting the design brief, as well as the design team's dependency on a client's or superior's support for optimisation are seen as grave derogation risk. Respondents agree that the designers' leeway will stay limited as long as companies fail to see financial gains and customers are satisfied by mere 'greenwashing'. It was also mentioned repeatedly that the execution of subsequent corporate alterations by all involved stakeholders is necessary in order to avoid losing environmental improvements along the production process. As an example was mentioned how optimisation gets annulled if allied departments are separately assessed on mere finances.

Design process

Then about the design process. According to one respondent 'the exercise is to see if postponing is possible', since, as someone else stated, 'the curve for determining the environmental impact is steepest at the start'. These remarks characterize many discussions and doubts during card sorting, as to where lifecycle protocol cards could best be represented on the product design process underlay. Another overall aspect is the repeated explicit mention of recurring inventory- and analysis activities; first exploring of possibilities for pinpointing opportunities, then comparing possibilities for selections in various design stages, and finally assessing possibilities for optimization.

Under the first phase, discover opportunities, many cards that fall under *goal and scope* were placed. Quite some respondents remarked a distinct difference between redesign and innovation. For redesign, environmental benchmarking of similar products' business- and product characteristics can offer immediate insight and, therewith, be used for the development of the business concept. For innovation, trend explorations are first needed in order to establish a business niche, before benchmark studies on products with similar functions and functionalities can be deployed. In either case, redesign and innovation, environmental trends were mentioned as an important means for setting the conditions of the other product system levels. Because design teams are often given the business concept, hence not involved in its development, respondents see any interventions for this stage as a welcome additional means for verifying the design brief.

The second pre-product phase, define problems, is seen as the phase for further concretizing the *product under study* and the therefore applicable criteria. *Functional units* are expected to become evident as a result of ongoing product system's *flowchart*- and *system outline* development. These environmental outlines can be made alongside readily made benchmark inventories of similar products or products with similar functions and functional aspects. It is noteworthy that the card '*context*' was either interpreted or relabelled as the product context and not the project organisation's context. As a result, the cards under *modelling specifications* are contributed to the card *context*.

The first design phase, develop concept, initiates 'design', which respondents consider to be iterations between creating, analysing, selecting, and researching. Respondents state that at this stage *inventory analyses* for benchmarking ideas and concepts are omnipresent. Emphasised is that thorough pre-design research should assure that at this stage the *goal and scope* requires marginal changes at most. The *impact assessment* cards are placed most often here as well. These cards are remarkably often placed as a stack, accompanied by a remark of how this is mostly done 'with the push of a button' by the use of software programs. *Interpretation* during this phase is seen as an integral part of idea and concept selection, as fact-based decisions are neither desirable due to budgets nor feasible because of design's earlier mentioned inherent unfamiliarities.

In the second design phase, determine product, the 'intricate relation between product and production dictate contemporary development'. This is where design 'turns on the calculation road' and 'sense making flips towards assessing'. Here too, most decisions will be based on relative comparison of alternative solutions. The need for assessments is said to start here, and the amount of assessments to increase for and due to the final decisions for all not yet determined product aspects. Along with placing of the cards was said that in this phase merely optimisation of physical details, like material, construction, and production, take place. Despite the fact that 'only marginal room for improvement' remains, respondents from design practice acknowledge that most design practices only here start making environmental considerations.

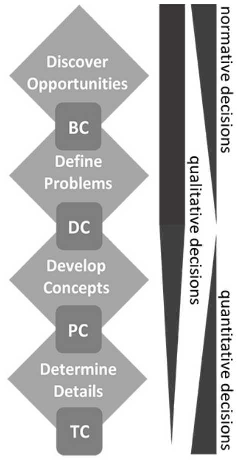
The phase 'implement market' was added to the design process for absolute completeness, since it is present in some design process models. Under this phase little cards got placed, because, as respondents pointed out, at this stage there are no design activities regarding the physical product left. Respondents did, however, stress that here an all-encompassing assessment becomes possible, now that the product is actually in use. The relative worth of the usual use assessments was debated, by design and environmental orientated respondents alike, since these assessments are usually based on statistics, like amount of battery recharges, rather than actual behaviour driven use scenarios.

Interpretation: Guided design iterations

Indirectly deduced results are presented under five additional denominators: environmental considerations from the outset onwards, a motivation for documentation support, the assignment of phase specific environmental contributions, the recognition of environmental contribution types and their positioning, and the use of domain transcending inventory and analyses recurrences.

Environmental considerations from the outset onwards

Throughout the sessions the interviewee illustrated how business concept decisions influence the entire design process. A given example is for the design of a car. Selecting car lease as part of the business concept is more likely if during discover the following is considered; the increase in material prices due to depletion (operational and natural), people's less defined expectancies regarding work and relations (societal) as well as their decreased ability and interest in DIY (functional), and the readily available network of car workshops (corporate). The premise of car lease, then, ensures setting criteria and creating concepts for, for example, minimizing the costs of customer service aspects as, for instance, maintenance and repair, and for optimising corporate benefits from the altered car ownership, such as reclaim, reuse, and recycle strategy. Without the lease concept in mind, so without the idea for the producer to stay proprietor of the car, it is unlikely that product imbedded maintenance and disassembly 'scripts' get optimised or the use of expensive materials can be made worthwhile.



[Figure 5] *contributions types and their position*

Documenting lateral, chronological, and anachronical product development

As endorsed earlier, EPO requires alignment of interrelated product aspects throughout the product design process. The thereto performed design iterations are not only related to a particular instant in the design process and in a chronological order, but also in a contra chronological order, or anachronical. An example of anachronical iteration expressed in one of the interviews is that the idea for incapsulating CO_2 in order to avoid CO_2 exhaust, leads to researching the results and effects of incapsulating CO_2 relative to earlier researched option in case encapsulating was not considered an option in an earlier stage. As the example illustrates, anachronical alignment of product aspects is needed in case new ideas fall outside the earlier design scope, in order to establish the idea's effects on the overall product system and compare these effects to those of other ideas. The need to reconsider the design scope increases with the idea's degree of innovativeness, since a lack of comparative products inhibits direct benchmark studies. In support of anachronic research, structured documentation for monitoring of earlier found product aspect interrelatedness is proposed. In other words, in support of lateral, chronological, and anachronical iterations, EPO requires structured documentation for monitoring interrelated product aspects throughout the design process.

Phase specific environmental contribution

The interview outcomes clearly marked specific environmental contributions for each design phase. For the <u>discover opportunity</u> phase, environmental trend research firstly and environmental aspects benchmark studies of comparable value propositions secondly improve the likeliness that, respectively, the proposed search area and business concept support later environmentally optimisation activities. For the <u>define problems</u> phase, benchmarking the environmental side of both comparable product systems and product systems with comparable purpose and product aspects leads to setting the core criteria that demark the design area concept. For the <u>develop concepts</u> phase, it is possible to actively participate by contributing and aligning environment driven physical and human product aspect ideas and to aid make environment proof educated selections. In the <u>determine details</u> phase, environmental knowledge can again be used for proposing alternative ideas and for the selection processes. Incorporating this insight into the intervention can aid participants realise a design phase related contribution.

Environmental contribution types and their positioning

The type of environmental contribution and its positioning relative to the other domains vary during the design process ([Figure 5). To start with environmental targets. These can proactively be positioned for establishing the design goals. This environmental contribution has a <u>normative</u> character towards other domains and is indispensable during the pre-product phases. Then environmental designs and -considerations. These can actively be proposed alongside other creation and selection activities. The environmental contribution to cross-disciplinary creative and reflective alignment has a <u>qualitative</u> character and can be found throughout the design process. Finally, environmental assessments of concepts for determining compliance with conditions and constraints is a reactive activity. Here the environmental contribution has a <u>quantitative</u> character and will increasingly take place during the design phases. In short, the environmental contribution can have a normative, qualitative, and quantitative character and over the course of the design process the positioning of that contribution changes from leading to following. Incorporation of this insight into the EPO strategy can stimulate participants bring forth an appropriate contribution, at an appropriate instance, and in an appropriate way.

Domain transcending inventory and analyses recurrences

Respondents acknowledged the earlier premise that similarities among domain dependent inventory- and analysis methods can be used to base an interdisciplinary approach upon. The inventory and analysis activities, which progressively outline the product system's parts and -interactions, can be made for exploring the physical- and human environmental impact aspects and effects, as well as arranging and ranking these mutually with the corresponding product aspect. For this, the research indicates that the lifecycle assessment protocol offers a rich and specific domain transcending basis. In summary, in support of interdisciplinary collaboration, design involved inventory- and analysis methods, among which the lifecycle assessment, can be used for constructing a neutral domain transcending commons.

DISCUSSION

What is open for debate regarding the card sorting procedure, is keeping the lifecycle assessment protocol cards in one particular order, since other orders, or a random order, would most likely have led to different outcomes. Taking into consideration that it is an explorative research, intended to find logical connections between the lifecycle assessment approach and the design process, the applied order has consciously been applied, with the motivation to support logical reasoning and avoid misinterpretation.

CONCLUSION

It is feasible to create a domain transcending environmental product optimisation strategy from a merger of the lifecycle assessment approach with the product design process. This research's outcomes suggest a stern inventory- and analysis foundation and provides ample suggestions and requirements for developing and assessing such a strategy. Hence it provides a search area for further study into creating an actual environmental product optimisation strategy.

By offering design teams a strategy that runs throughout the design process and suits interdisciplinary product aspect alignment, the participants are offered a means to reduce or, ideally, eliminating its environmental impact destination. As such, it has the potential to become a hands-on way to decrease the product system's generated technical-, operational-, but also behaviour-, and decision- environmental impact.

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