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Challenges and trends within eco-design

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Abstract

Despite years of research and other activities in society the anthropogenic impact on nature still increase. Eco-design has a potential to reduce this impact, but yet a minority of companies practice it. The aim of this paper is to identify current challenges and trends within eco-design. In addition, the paper further aims to disclose important eco-design related research gaps. Eco-design challenges and trends have been studied in 22 selected papers, out of 52, found in ScienceDirect during April 2015. In addition, four snowballed papers from the same database and one standard were included. Challenges and trends are revealed and structured into four categories; 1) system and success level; 2) strategy level; 3) action level; and 4) tools level. Most challenges and least trends are found within the first category: systems and success level. An implication from the result is that research and other activities should more than today be supported by a system and success level. Future research should focus on understanding the industry’s perspective, help set requirements in product specifications, create low economic risk implementation roadmaps, understanding how to map knowledge and information to aid eco-design implementation. It is also preferable to facilitate an efficient inclusion of social and economic aspects when practicing eco-design.

Keywords:
Eco-design, ecodesign, sustainable, product development, product design, engineering design

1 INTRODUCTION

The increase of anthropogenic Greenhouse gas (GhG) is according to IPCC [1] the reason to the highest concentration of carbon dioxide, methane and nitrous oxide since at least 800 000 years ago. Therefore, some decision makers in the society want companies, consumers etc. to act upon this and emit less GhG. Some companies change their way of develop and manufacture products by practicing eco-design, e.g. ABB [2]. That is a step forward, but if the goal is to make serious reductions of today’s increase of GhG on a global level, too little is yet accomplished [1]. Even though there are a lot of eco-design tools (tools and methods) developed and research done by academia, the majority of companies have yet not established eco-design practice in their principal product development activities [3]. There seem to exist several reasons to this. Lindahl [4] mentions that developed eco-design tools do not fit the purpose well enough and they are therefore not used as much as intended. According to Bey et al. [5] customers in general do not value the sustainable characteristics of a product enough, compared to other characteristics. The search for reasons why there still is a little, and efficient eco-design practice in the majority of companies seems to proceed. Other research, like development of new tools and ways of working, seem to proceed too. Together with the mentioned IPCC statements [1] this calls for more research on how to reduce the environmental impact from products.

2 AIM

The aim of this paper is to identify current challenges and trends within eco-design. In addition, the paper further aims to disclose important eco-design related research gaps.

3 RESEARCH METHODOLOGY

To meet the aim of this paper a literature study was performed. It was based on 22 papers, selected out of 52, found during April 2015 in ScienceDirect using the following search word combination: eco-design AND (“product development” OR “product design” OR “engineering design”) AND (method OR tool), also illustrated in Fig 1.

![Fig. 1: An illustration of the search word combination.](image)

Only research papers (no books) from year 2000 until 2015 were searched for, and the search fields were Title,
Abstract and Keywords. A relevant paper in this study is considered to be a paper that describes challenges of eco-design, and/or trends of eco-design and/or several eco-design tools and perhaps also how they work. The 22 papers were selected by using the following evaluation steps:

Step 1. Evaluation regarding the title. If considered relevant -> Step 2

Step 2. Read the abstract and after that do an evaluation of the abstract regarding the whole paper’s potential of being relevant. If considered to have a potential -> Step 3

Step 3. Read the whole paper

The selection process and which literature that was included in the study is described in Fig 2.

Fig. 2: A visual description of the selection process and which literature that was included in the study.

In this study words that mean roughly the same as “eco-design” has also been used. Those are e.g. Environmental Product Development (EPD), Sustainable Product Development (SPD). In addition to the selected papers described above, four more papers and one standard (ISO14006) were included. Two of the snowballed papers were received from ScienceDirect’s own recommendation pop up function. The other two snowballed papers were commonly referred to in the selected papers. The ISO14006 standard [6] was also included in the study since it was used as a reference several times in the selected papers and seemed relevant for the aim of the study.

When the authors have been looking for challenges within the selected papers we have included expressed challenges, barriers, needs, problems and calls for improvements. Regarding trends we have included expressed trends and areas where focus of interest seems to be changing.

4 CATEGORIES OF CHALLENGES AND TRENDS

The challenges and trends identified in the selected papers were categorised into four categories. The categories are based on Robèrt et al [7] as referred to by Byggeth and Hochschorner [8]. These categories derive on their definition of sustainability [7].

Category 1: System and success level

The system is the human society acting within the ecosystem. The goal is that society shall be sustained. To achieve this nature must be sustained, since in the long run society is dependent on the nature. People must also be able to meet their needs. To be successful in this work, the nature must not be exposed to:
1. Increased concentrations of substances extracted from the earth’s crust;
2. Increased concentrations of substances produced by society;
3. Degradation by physical means;
4. In that society people are not exposed to conditions that systematically undermine their capacity to meet their needs.

These four principles are called the system conditions [7].

Category 2: Strategy level

At this level the strategic guidelines for planning towards success on a system and success level are described. One can also say that this level shall be informed by the system and success level. There are two overarching strategic guidelines within this level and they are;
1. Make sure investments can be further developed and being in line with the system conditions described above,
2. Make sure the investments are economically sound so that the process does not stop due to lack of economic recourses.

Category 3: Action level

The activities which are planned and actually done towards being successful on a system and success level. There are several times in the selected papers and seemed relevant for the aim of the study.

When the authors have been looking for challenges within the selected papers we have included expressed challenges, barriers, needs, problems and calls for improvements. Regarding trends we have included
problems on a tools level can hamper efforts towards a sustained society.

5 CHALLENGES FOUND WITHIN ECO-DESIGN
In this chapter the 16 challenges found in the covered literature is presented.

5.1 Challenges on a system and success level
1. Lack of tools which are built for achieving goals on a system and success level
Byggeth and Hochschorner [8] describe that none of their 15 analysed tools are built on any theory of sustainability, theory as the system conditions described in the earlier section. The authors interpret this as: Existing tools helps taking decisions that more or less reduce the sustainable impact. But, that is not enough if the goal in a systems and success level shall be achieved.

2. To better understand and/or influence end-user’s behaviours when performing eco-design
End-users decide the life time of a product and consequently they affect the result on a systems and success level (([9] as referred to in [10])). That means that even though a company put a lot of effort to fulfil e.g. an environmental requirement, and succeeds according to the measure they use, on a systems and success level where an end-user is included the requirement might not be fulfilled. The important challenge is here interpreted to be the difficult task of making correct assessments of end-user’s behaviour. This is somewhat in line with the more overarching discussion by Baumann et al. [11] where they describe that there is a lack of people in companies which are responsible for a product in a “product system” perspective. The “Product system” is interpreted by the authors as the whole product life cycle including the whole supply chain.

3. To complement eco-design with social-and economic issues
It seems to be a challenge, but important, to include all three dimensions (the environmental, economic and social dimensions) of sustainability together with a life cycle perspective in a company’s product development process. Such tool or way of working would support possible trade-off situations that might occur on a system and success level [8].

4. Confusion about what a sustainable business is, and the scope of eco-design compared to other approaches
According to Short et al. [12] there seem to exist different definitions and comprehensions of the scope and goal of the similar approaches that exist, e.g. eco-design, Design for Environment (DfE) and sustainable product development (SPD). The interpreted challenge is that it is difficult for consumers to do the best choice for environment, since a consumer might believe a product, or companies activities, are better for the environment than it actually is. In line with this, Baumann et al. [11] point out that available eco-design tools are not equally sustainable, since the scope they cover differs.

5. How to create effective legislation that makes an improvement on a system and success level
It is mentioned by Baumann et al. [11] that more research should be done on how to create policies that makes a difference in a life cycle perspective where the whole value chain is included. The authors interpret this as that it is a challenge today for policy makers to fully understand how to create legislation that affect the whole value chain, rather than individual parts, and thereby create a legislation that makes a bigger effect in total. If this is not fully understood by them there is a risk of sub optimization.

6. Possible future hazardous materials/substances are not banned often enough
One challenge discussed by Byggeth and Hochschorner [8] is that many eco-design tools include materials that are not yet considered hazardous, but in the future they will. A related challenge is also that the precautionary principle seems not being applied as often as it should. The authors interpret this as that even though there are doubts about that a material has low environmental impact, it can still be used. Both these challenges are by the authors considered giving problems in a system and success level perspective.

5.2 Challenges on a strategy level
7. Overcome barriers when implementing eco-design
There seem to be many barriers to overcome when implementing/start performing eco-design. It is a challenge to understand how to avoid or handle those barriers. Several barriers are listed by Bey et al. [5] and they describe that lack of information about the environmental impact, lack of expert knowledge and lack of allocated man hours are the biggest. In addition, socio-psychological factors can become very big barriers and this is pointed out by Boks [13] to consider carefully.

8. Knowing how to implement eco-design in a company
This challenge is described by Pigosso et al. [14] and they also create a maturity model that shall guide a company in its implementation. The authors’ opinion is that the challenge still exist since it is unclear if this maturity model can fully solved the problem.

9. Lack of expert knowledge in how to implement eco-design
Bey et al. [5] found that one big barrier for implementing eco-design practices is that “too much specialist knowledge” is needed. Here interpreted as knowledge in management of eco-design implementation, eco-design processes and tools.

10. Lack of time and other resources for implementing eco-design
This challenge is described by Bey et al. [5] and resources are there defined as man power and time. The authors
interpret this as difficulties of getting the management level prioritising the investment in eco-design implementation.

5.3 **Challenges on an action level**

11. **Eco-design practice is still limited**

Despite there are companies practicing eco-design [2] or other similar ways of working, it is still considered to exist a challenge in a system and success level perspective, since eco-design does not seem to be implemented into enough number of companies and their activities (see e.g. [3, 4]), like product development and management processes (see e.g. [14]). According to Brones et al. [15] eco-design is not integrated enough in project management yet.

12. **Lack of environmental (or sustainability) oriented requirements in product specifications**

Without any environmentally oriented requirements and goals on a product or project, nothing will happen. Since not much seems implemented yet, one reason is a lack of this type of requirements and goals in the product specifications, see e.g. [13] and [16]. SME enterprises have been studied by Lee-Mortimer and Short [3] and based on preliminary results from their studied segment they suggest that a lack of structure and management of the formal product development process could be a root cause to the little number of environmentally related requirements in the product specifications. They especially point on this lack in the stage where product requirements are set.

13. **Including the whole life cycle and value chain of a product**

This challenge is related to both the assessment and creation of solutions [11]. Companies might need to create and share information that earlier has not been available, which can be a barrier and a challenge.

5.4 **Challenges on a tools level**

14. **Tools do not fit the purpose well enough**

It is a challenge that available tools sometimes does not seem to fit their purpose well enough, for the product developers, designers, purchasers and people in other involved functions. This is one of the reasons, mentioned by Lindahl [4], that cause eco-design being difficult to implement in industry.

15. **Clearly understand why a tool might be needed**

Some research (see [11] and [13]) suggest that tools, or at least concept tools made by academia, might not be needed for developing more sustainable products, Management and organisation seems more important. The authors interpret this as that is seems to be too much focus on tools, since the root cause to for instance an implementation barrier might be on a strategy level, e.g. difficult to understand how to understand how to get profit out of an eco-design implementation, instead for at a tools level. The challenge here, interpreted by the authors, is to steer the focus a bit away from the tools towards management visions, goals, strategies to reach the goals, selection of relevant KPI’s and information flows when practicing and plan for implementation of eco-design. The authors perceive a similar challenge seem to be present in some cases when Lean manufacturing starts being implemented.

16. **Lack of environmental impact information**

According to Bey et al. [5] there is a lack of environmental impact information. Here interpreted as information related to material, products, components of a product, manufacturing processes and other stages in a products life cycle.

6 **TRENDS FOUND WITHIN ECO-DESIGN**

In this chapter the 11 trends found in the covered literature is presented.

6.1 **Trends on a system and success level**

1. **Improved inclusion of end-user’s behaviour when assessing impacts and develop new products**

To be able to make decisions which supports a system and success level the behaviour of end-users of the products will have to be considered when making decisions. The reason is that all end-users cannot be expected to act as intended or estimated by the producing company. The end-user is the one that decides when the use phase of a product is over. The topic is discussed by van Nes and Cramer [9] as referred to in [10] and [17]. Vallet et al. [17] point out that future eco-design tools must more than today push for product solutions that are developed from a thorough insight of how the tool is used. Vallet et al. [17] also write that research has been done within this field during recent years i.e. a trend.

6.2 **Trends on a strategy level**

2. **A better inclusion of the economic dimension into eco-design and related ways of working**

Many researchers speak about the necessity of complementing environmental and/or social considerations with the economic aspect, e.g. [8, 10, 18-20]. Some try to solve it [18]. An economic risk will always be there even though it is low [10]. Since the industry in general has not yet implemented much of eco-design or similar approaches (see e.g. [10, 15, 21]) an interpretation by the authors is that the industry still feel the economic risk of implementing and/or practicing eco-design is too high and the basic reason can be that they do not have efficient tools aimed for estimating that risk in a more correct way than exist today. The authors’ opinion is that a possible lack of this type of tools might be the reason to that industry seem to ask for some kind of roadmap (see e.g. [12], [22]). The authors thinks therefore that future focus from research and industry will be an increased or improved inclusion of the economic dimension of sustainability into eco-design in general.
(implementation included) so that the industry can better than today estimate the economic risk, and through that try to reduce or pass the risk.

3. **The search for knowledge on how to increase eco-design practice will continue**

There seem to be a need for understanding why tools and related ways of working are not implemented in a greater amount than seems to be expected. Implementation models are being developed by researchers to aid implementation of eco-design at companies (see e.g. [14] and [23]). There are also different reason behind the little utilization of tools and implementation of eco-design, described in the literature. For instance, the lack of guidelines of how project management shall be integrated into eco-design practices is mentioned by Brones et al. [15]. The tools must according to Lindahl [4] better fit the purpose than they do today, and that the follow up of the utilization of tools must be better than today if they shall be utilized more. The soft sides must be better considered to make sure the implementation works well [13]. According to Byggeth and Hochschorner [8] all three dimensions have to be considered, otherwise sub optimization on a system and success level can happen. The authors’ opinion is that a sub optimization might be risky for companies due to that the brand name might be hurt if a holistic view is not present and media use this fact to criticize the company. It is not clearly described in the literature, but an interpreted trend by the authors is that the search for how to increase eco-design practice will go on for a while.

4. **Companies integrate environmental considerations within their sustainability management**

This is a trend mentioned by Karlsson and Luttropp [10]. The consequence according to them is that eco-design activities will have to be related to ethical and social aspects and other interdisciplinary considerations.

6.3 **Trends on an action level**

5. **To integrate eco-design into product development processes**

The authors’ opinion is that it seems to be a trend to focus on, and thereby increase, the inclusion of eco-design into the product development processes. By doing so, Poulkikidou et al. [21] conclude the potential of environmental aspects being considered is increased. The topic is also discussed by Short et al. [12] and they describe a desire in northwest of England to introduce “environmental concerns” into the formal product development process.

6. **Increased interest of applying remanufacturing**

This is a trend expressed by Pigosso et al. [20]. Remanufacturing is related to eco-design since design for remanufacturing in general gives a lower environmental impact from products, compared to manufacturing new products or products manufactured out of recycled material [24].

7. **Human powered products**

A trend expressed by Karlsson and Luttropp [10] is human powered products. The description is interpreted as that the interest for these type of products is increasing at year 2006.

6.4 **Trends on a tools level**

8. **Integrate environmental (or sustainability) aspects into the daily work of product developers and designers**

This is a trend perceived by the authors and it is based on the desire of researchers to integrate eco-design, and/or other aspects, like cost and other sustainability aspects, into the daily work of product developers and designers. This desire is e.g. described by Karlsson and Luttropp [10] where they state “we think eco-design tools ought to be made for the product designers and for the working situations in product development processes”. A software platform is by Dufrene et al. [22] believed to be a way to aid communication with environmental expertise, in a well-defined PDP-process where eco-design is included. In [25] a platform consisting of optimization algorithms together with LCA is described. The authors believe that necessary information, information flows and knowledge should be included when discussion platforms.

9. **More focus on communication and information flows**

There is a trend in more focus on communication and information flows as an important “tool” for making things really happen, e.g. Poulkikidou et al. [21] describe that internal information about eco-design and its use, the communication in the company about eco-design strategies and goals and more clear information flows, will all aid implementation of eco-design. Something similar is described by Dufrene et al. [22] which say that, along with more complex supply chains more information and knowledge than today will have to be communicated between suppliers.

10. **Tools aimed for (or possible to use) in the early stages of product development**

Some researchers describe the importance of considering sustainable aspects early in the product development process, e.g. [10, 16, 18, 19], where Luttropp and Lagerstedt [16] also have created the tool “Ten Golden Rules” aimed for this stage. Since this seem to be an important finding a perceived trend by the authors might therefore be that more tools in the future will more expressively be made for, or at least being able to use in, this early stage. It could be to aid finding requirements and help create the product specification.

11. **More focus on the role of project management to make eco-design work**

There is a trend to focus more on the role of project management in the product development process and the extra knowledge and different way of working that might be present when doing eco-design. It can for instance be which new decisions the role need to take and new stakeholders and experts that need to be communicated
The project management’s role for increasing the success of integrating eco-design into the product development projects is a quite new thought, and would enhance the integration of eco-design into the product development process [15]. This is also touched upon by Dufrene et al. [22] which describe that all stakeholders of the eco-design tool and way of working are identified and have a role when reaching a successful implementation.

7 ANALYSIS OF THE RESULT

The challenges and trends are grouped into four categories to see where most challenges and trends seem to exist, see Table 1. In the categories strategy level, action level and tools level there are roughly the same amount of challenges and trends found. The distinguishing category is the system and success level which holds more found challenges than the other categories. The least trends are also found within this category. One implication from this is that more research and other activities which are supported by a system and success level should be done.

Challenges and trends which are closely related to implementation aspects (challenges 3, 7, 8, 9 and 10 and trends 2, 4, 5, 8, 9 and 11) are considered related to each other and can after being merged together be described as: To create trustworthy profitable low economic risk implementation roadmaps for companies to use when trying to implement eco-design.

Some challenges and trends might be different sides of the same coin. It is therefore recommended to not make a clear distinction between them. For instance, the trend “A better inclusion of the economic dimension into eco-design and related way of working” may be a reaction to the challenge: “Lack of time and other resources for implementing eco-design”.

8 METHODOLOGY DISCUSSION

In due to the perceived confusion about what is covered by eco-design, challenges and trends related to other approaches which are similar to eco-design have been included, e.g. Sustainable Product Development. All papers but one which are found and selected in the literature search use eco-design in their keyword list. The one which did not use the word “eco-design” used it in the abstract instead and therefore it was found.

There are few expressively described challenges and trends in the papers. The majority of these are interpreted by the authors from how needs, barriers and statements are described. For the purpose of this study the authors’ opinion is that the methodology to reveal challenges and trends works well.

9 CONCLUSIONS

The aim of this literature study is to identify current challenges and trends within eco-design. In addition, the paper further aims to disclose important eco-design related research gaps.

The study reveals challenges and trends within eco-design and structure them into four categories: 1) System and success level; 2) Strategy level; 3) Action level; and 4) Tools level. Most challenges and least trends are found within the category Systems and success level. The other categories holds roughly the same amount of challenges and trends. An implication of the result is that more
research and other activities shall be done which is supported by the system and success level.

In line with this implication future research is recommended to include a system and success level perspective when defining the aim or research problem to solve.

The authors believe the following five research gaps, integrated with a systems and success level perspective, are important to focus future work on. All research gaps are derived from the found challenges and trends that were summarised in Table 1.

1. How can the environmental (or sustainability) knowledge, information and information flows that is needed for a company to proceed its ambition to develop more environmentally (or sustainable) products be mapped in an efficient way? (derived from challenges 6, 12, 13, 14, 15 and 16 and trends 1, 2, 8, 9, 10 and 11)
2. How can industry in a most efficient way make trade-offs between different aspects, especially aspects where all dimensions of sustainability can be included, together with a life cycle perspective? (derived from challenges 3, 12, 13 and 14 and trends 2, 4, 8, 9 and 11)
3. How can industry in a most efficient way find environmentally (or sustainability) oriented needs, prioritize them and set profitable requirements on them? (derived from challenges 12, 14 and 16 and trends 2, 5, 9 and 10)
4. How can a low economic risk road map for implementing eco-design practices in a company be developed? The roadmap shall induce profit (attractive enough) both in a short and long term. (Barriers which are important and how to avoid or handle them shall also be described, and which drivers that must be in place to succeed) (derived from challenges 7, 8, 9 and 10 and trends 2, 4, 5, 8, 9 and 11)

Since this study is a literature review it would be interesting to reveal more about industry’s opinion about eco-design. An additional research gap is therefore:

5. How to develop and communicate more knowledge than exist today about how different companies do eco-design and their needs? Examples of research questions that could be interesting for this gap are:

- What do companies think about modern state of the art sustainability tools like the ones from Solid Works [26]?
- Which requirements would make them start developing more environmentally (or sustainable) products?
- Do they consider eco-design to be a good way to reach sustainability and in a system and success level perspective? If that is not the case, what is?
- What values are required to be delivered from eco-design to be considered a competitive strategy by a company?
- Does eco-design fulfil company needs?

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