HEURISTIC GUIDELINES IN ECODESIGN

Sarnes, Julian; Kloberdanz, Hermann
Technische Universität Darmstadt, Germany

Abstract

Guidelines, in the form of rules and instructions, are a commonly used support for analysis and synthesis in the field of ecodesign. This paper considers the heuristic nature of ecodesign-guidelines and argues for the necessity to gain a deeper understanding on this subject-matter and the potential of a method to support the formulation of new heuristics by ecodesign experts. Based on the theory of heuristics and literature concerning guidelines a new approach for a formalized guideline-documentation is proposed, which uses additional information to increase the usability and effectiveness of ecodesign guidelines.

Keywords: Ecodesign, Heuristics, Guidelines

Contact:
Julian Sarnes
Technische Universität Darmstadt
Fachgebiet Produktentwicklung und Maschinenelemente
Germany
sarnes@pmd.tu-darmstadt.de

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1 INTRODUCTION

Heuristics are tactics that simplify problem solving in specific and complex contexts. In their internalised form they are an extremely common human behaviour. This paper will look at guidelines in ecodesign as externalised heuristics: instructions or rules that can be communicated and used to achieve goals. In design, the use of heuristics, i.e. the communication of experience with specific design decisions, has a long history. The form that heuristics take in ecodesign is manifold, e.g. simple rules, guidelines and examples. The terms used to denote them are even more diverse, e.g. *guidelines*, *rules*, *instructions*, *measures*, *practices*, etc. This paper presents a look at literature concerning heuristics and heuristic guidelines, and argues the need for a deeper theoretical engagement with these subjects.

One common example of a heuristic guideline in ecodesign is "Reduce the mass of the product". The connection between the mass of a product and its environmental impact during its life cycle is not obvious. For moving systems, a higher mass will usually increase the amount of energy needed for the movement. The processes of producing and using energies (or energy carriers) are always directly (e.g. fossil fuels) or indirectly (e.g. solar power) associated with environmental impacts. A reduction in normal forces associated with a part caused by a reduction in mass can often reduce friction in a system and thus energy demand. There are many other connections between the mass of a product and the amount of energy needed to move that product, e.g. inertness, potential energy, etc. Additionally, there are many paths from product mass to environmental impacts. For example, as shared with stationary systems, a reduction in mass may lead to a reduction in the amount of materials used, which might reduce the number of processes needed to provide the material for the product. This depends on the manufacturing techniques employed in the production of parts. To reduce the amount of material needed to produce a milled part from a round bar steel, the largest external diameter of the part has to be reduced. Other geometric changes to reduce the mass of the part will not influence the amount of material produced nor the environmental impact of the product life cycle. Another way for a designer to achieve a reduction in mass is to exchange one material for another, less dense material. However, the lightweight material chosen by a designer ignorant about the environmental impacts of the two material-production processes can have a much higher environmental impact than the material used previously. The application of this ecodesign heuristic can, under certain circumstances, cause an increase in environmental impacts over the product life cycle; the example above of a heuristic is not absolutely robust.

Under the assumption that guidelines used in ecodesign can be viewed as heuristics, the nature of heuristics is relevant when thinking about guidelines. (Gigerenzer 2007) states that heuristics have certain characteristics, like an inherent relation to the evolved and learned capabilities of the user. It is inherently simple to use a heuristic because it matches the existing capabilities of the user. A second characteristic of heuristics is the exploitation of "structures of environment" (Gigerenzer 2007), where heuristics capitalise on structures, patterns and general principles within a particular context to achieve the goal. From this, it follows that a heuristic is only effective in specific contexts. The given example about reduction in mass is most effective in the context of movable systems, while its effectiveness decreases in stationary systems. A further narrowing of the scope of application, using more specific categories than *moved* and *stationary*, can increase the effectiveness and robustness of the heuristic guideline. To use a heuristic the user does not need to fully understand the systems they are interacting with. In the example, the user does not need to be aware of all connections between mass, energy consumption and environmental impact.

Additionally, heuristics have to be viewed in the context of a *bounded reality* (Todd and Gigerenzer 2000): resources that play a role in solving a problem or completing a task, like time and information availability, are limited. Setting up and solving differential equations may be a learned ability of most engineers, but it is not usually a skill that can be employed in a fast and easy manner. As such, a heuristic that helps to avoid the need for an engineer to solve differential equations reduces the time to create a design. A design based on such a heuristic does not necessarily match the design derived from an analytic process, which is the third characteristic of the heuristics described by Gigerenzer (2007): Heuristic are not *"as-if" optimization models.*

Bakker et al. (2012) report a surprising lack of attention to ecodesign heuristics in academic literature. There are a lot of authors who present guidelines in their work, but the methods to choose and access

the guidelines are usually much elaborated, while the nature of guidelines and methods to obtain and document them are neglected.
A more formalised model of heuristic guidelines, especially in ecodesign, might be advantageous. There is potential to improve the usability of heuristics by understanding the subject matter better and providing a methodology or framework for formulating and documenting new and existing heuristics. In software engineering, a formalisation for the documentation of heuristics was published in (Gibbon 1997). The motivation in this case was the possibility of teaching learners better using the experience of practitioners, "as the ratio of learners to experts increases" (Gibbon 1997). The situation in ecodesign is different, which leads to a difference in motivation for a formalisation. This in turn causes differences in the form heuristics should take in the field.
Experience shows that the environmental impact of their products is a relevant topic for companies, beyond mere compliance with legislation. An inherent sense of responsibility and the conviction that environmental friendliness is a requirement of customers and consumers seems to motivate them. It also shows that reduction of environmental impacts is usually a lower priority than economic, technical and other requirements.

2 HEURISTIC AND ANALYTIC APPROACHES IN ECODESIGN

To establish the particular role and the consequential relevance of heuristics in the field of ecodesign, this section contrasts heuristics with analytic approaches in ecodesign. An additional dimension discerning analysis and synthesis steps in the design process is used to further distinguish different kinds of heuristics.
The first dimension used regards the approach to a given task, which can be characterised by the following dichotomy: A problem can be approached with heuristics, using past personal experiences or externalised experiences and insights from others, in a solution-oriented manner. Such an approach depends on commonalities between different product systems, which can be viewed as "structures of environment" in the field of technical products. The potential of using such commonalities to analyse probable environmental impacts of a product based on similar reference products has been shown by Collado-Ruiz and Ostad-Ahmad-Ghorabi (2010 and 2013) under the name *LCP families* (LCA-Comparison Product families). The alternative to heuristic approaches is to work analytically, modelling system behaviours using universally valid (or at least generally accepted) principles to derive the desired results (Grünig and Kühn 2013). These are just two types of human behaviour. Real human behaviour will usually be somewhere between these two extremes. For example, during the analytical process of conducting a Life Cycle Assessment, the practitioner may base a cut-off decision or a decision about system borders on past experiences and preconceived notions. Such heuristics are usually internal but can be externalised for use by other potentially inexperienced practitioners.
Two of the main activities when designing a product are analysis and synthesis of technical systems (Weber 2011). The categories *analytic* and *heuristic* can be related to these activities. Both activities can be approached in a heuristic or in an analytic fashion. In design, especially in ecodesign, heuristics are mostly for synthesis, but there are also instances of analysis heuristics, such as the use-phase heuristic ("Frequently used electric and electronic products usually have, over their life span, a dominant impact in the use phase." (Bakker et al. 2012)).
This rough categorization is comparable to the more thorough classifications of ecodesign methods presented in (Bovea and Pérez-Belis 2012) and in (Ramani et al. 2010). The dimensions "Difficulty level/ Time required" in (Bovea and Pérez-Belis 2012) and the categories "Qualitative knowledge intensive" and "Quantitative/Data intensive" in (Ramani et al. 2010) correlate (but are not equal) to the distinction between heuristic and analytic approaches used in this paper due to the characteristics of these two concepts described in Table 1. Both (Bovea and Pérez Belis 2012) and (Ramani et al. 2010) use a categorization based on phases in the design process as a second dimension. This paper uses a similar approach, but in a more abstract manner to describe the context of heuristics.
The path from Life Cycle Assessment to the identification of ecological levers to derive strategies for ecological improvements to a product (Birkhofer et al. 2012) is primarily analytical. Besides its obvious strong points that are common to analytic approaches, it has a couple of severe disadvantages. Even conducting a shortened life cycle analysis is an activity that requires some theoretical knowledge and exercise to be used effectively (Bakker et al. 2012). In life cycle assessment, considerable time and a much larger body of theoretical knowledge and experience is needed for successful application.

Alternatively, a company can hire consultants who specialise in the assessment of environmental impacts of products. For the company this process is still time-consuming (because of the effort needed for data gathering and communication) and associated with considerable costs.
Table 1 contains examples from the field of ecodesign. It also shows some advantages and disadvantages of heuristic and analytic approaches, based on (Grünig and Kühn 2013), and characterises cases of both approaches in the field of design. Heuristics are most relevant where the effects of *bounded reality* are most visible, for example, in the earlier steps of the supply chain, where information on environmental impacts during the entire product life tends to be low (Sarnes und Kloberdanz 2013). The relevance of heuristics, compared to analytic approaches, increases, with a decrease in valuation of environmental requirements of a product. In cases in which environmental aspects are more important than other requirements, for example, niche products that cater to an environmentally conscious group of customers, analytic approaches are most appropriate.
Quantification of relevant phenomena, like environmental impacts, which are usually found using analytical analysis methods, suit modern business culture, which tends to value it as a basis for rational decision making. In this regard, heuristics are at a disadvantage compared to analytic methods.

Table 1. Analytic and heuristic approaches - examples of their use in ecodesign, advantages/disadvantages (Grünig and Kühn 2013) and criteria for use

		Approach	
		Analytic	Heuristic
Activity	• Analysis	• Life Cycle Assessment (LCA)	• Checklists • Analysis Heuristics (e.g. LCP-families)
	• Synthesis	• Deriving environmental levers based on LCA	• EcoDesign Heuristics (Guidelines, Rules)
• Advantages		• guaranteed to find solution (if one exists) • guaranteed to find optimal solution (for well-defined problems)	• low effort • no formal conditions for use
• Disadvantages		• problems need to be well-defined • high effort	• no guarantee of finding a solution • no guarantee of found solutions being optimal
• Criteria for Use		• High priority tasks • high information availability • well describable systems • areas of competence in a company	• low priority tasks • low information availability • no need for optimal solutions

3 HEURISTICS IN ECODESIGN

This section focuses on heuristic synthesis, rather than heuristic analysis, as it seems more relevant and prevalent in ecodesign. Heuristics are as common in ecodesign as they are in other fields of design. Yet in current ecodesign literature there is a multitude of different terms used by authors for similar concepts (heuristics, guidelines, rules, instructions, measures, practices, etc.).
While in other areas (e.g. design for corrosion prevention, design for manufacturability), heuristics usually take the form of a mixture between short instructive statements and sketched examples of good and bad designs (e.g. the examples given in (Feldhusen and Grote 2013)). In ecodesign, short instructive statements are the predominant form.
The *Ten Golden Rules*, developed in 1996 (Lutropp and Lagerstedt 2006), can be characterised as a set of extremely broad heuristics. The authors state that the rules have to be customized to be used. Some of these rules contain recommendations that limit the kinds of products to which they should be applied, for example, number five: "Promote repair and upgrading, especially for system-dependent

products (e.g. cell phones, computers and CD players)." (Lutropp and Lagerstedt 2006). Some of the other rules do not make distinctions concerning the system they should be applied to, like number seven: "Invest in better materials, surface treatments or structural arrangements to protect products from dirt, corrosion and wear, thereby ensuring reduced maintenance and longer product life." (Lutropp and Lagerstedt 2006).

Dahlström (1999) mentions a method called the IVF method, which can be used to derive guidelines from LCA data, and a source described as "Advice Banks". In a second step, the guidelines are transformed into company-specific guidelines by correlating them with constraints that exist in the specific company.

Wimmer and Züst (2001) present a tool called "Ecodesign-pilot", which supports the designer in analysing a product system, choosing appropriate guidelines and implementing them. The analysis step is semi-quantitative and leads the user to a set of guidelines appropriate to the specific product in question.

Vezzoli and Manzini (2008) use the terms *guidelines* and *design options*, which are categorised by *strategies*. Products are classified into *durable goods (reusable goods)*, which are subdivided into *products that consume resources in usage and maintenance* and *goods that don't consume resources in usage,* and *consumer goods (throw-away goods)*, which are further divided into goods *that can be used up* and *throw-away goods that can be reused, recycled or substituted*. The strategies chosen have to be related to the class of the product. For each guideline, a very tangible example from an existing product is presented.

Birkhofer et al. (2012) describe an ecodesign methodology that consists of two steps, which correspond to the design activities analysis and synthesis. The first step is an impact assessment, which is used to identify *ecological weak points* and *ecological levers* of a product system, and derive ecological requirements. In the second step, *ecodesign measures* (which equate to heuristics) are used, based on the results of the first step.

Zhao (2012) presents a couple of *guidelines* (categorised by life cycle phase and strategies) with appended annotations as output for a method based on measures-properties matrices. This method is based on a table that describes the influence of characteristics on properties (in the terms of (Weber 2011)) and another table that describes the connection between measures and characteristics. The characteristics properties table is supposed to then be customized to better represent the range of product systems on which it is used. The combination of the two tables can be used to select a set of measures that influence a chosen set of properties. The connections in the tables are weighted for a more distinctive selection.

Pigosso (2012) uses the term *practices*, as distinct from *operational practices*, which concerns the technical aspects of a product, and *management practices*, which concerns the development process itself. An example of the latter is "Make ecodesign tasks a part of the daily routine for the relevant employees" (Pigosso 2012), while operational practices equate guidelines.

Quella (2013) mentions *rules of experience*, which are basically heuristic guidelines. He points out that the presentation of a great number of rules can overwhelm a designer, especially a beginner in the field. According to him, a reduction in the number of rules by selecting only a few might enable the designer to use each rule more effectively. Bringing order to the rules, for example, by ordering them according to life cycle phase, might also improve usability.

Fakhredin et al. (2013) argue that *heuristic guidelines* are often both too generic and too product specific. They infer that another kind of support has to be developed to follow up impact assessment. Guidelines like "Do not use elastomers", an example from (Fakhredin et al. 2013), are not helpful, because they do not present a simple path to an environmentally sound solution - they put a problem in front of the designer, which is not easy to solve, depending on the context. As in the characteristics of heuristics described by Gigerenzer (2007), this guideline would potentially just be a bad heuristic. A better heuristic guideline would propose one or several solutions that could be used to avoid the use of elastomers. The solutions may well depend on the function that the elastomer part fulfils. This shows the need for conditions that describe the areas of applicability for specific guidelines, which is related to the "environment exploiting" characteristic of heuristics. A condition for applicability reduces the instances in which the statement of such an analysis heuristic has to be true, enabling much more accurate statements.

Bakker et al. (2012) describe an analytic heuristic, the Use Phase Heuristic, frequently used for active products: "Frequently used electric and electronic products usually have, over their life span, a dominant impact in the use phase"(Bakker et al. 2012). Bakker et al. (2012) question the validity of this heuristic for products that are designed for energy efficiency. This is again a case in which the proper setting of conditions could help to increase the usefulness of a heuristic.

A common theme in many methodologies in ecodesign is the provision of support that enables designers to choose a set of heuristics from a larger collection based on some kind of analysis step. The selection can be based on heuristic analysis, like the product categories in (Vezzoli and Manzini 2008); based on semi-quantitative heuristic analysis, like the ecodesign-Pilot; based on other aspects, like the situation of the company in which the design process takes place, like that used in (Pigosso 2012); or based on an analytic method, like life cycle assessment (LCA) or its shortened variant (SLCA), which is used to select guidelines, as in the approach described in (Birkhofer et al. 2012).

In some cases, heuristic guidelines contain rudimentary heuristic analysis steps. "Arrange and facilitate disassembly and reattachment of easily damageable components" from (Vezzoli and Manzini 2008) refers in its instruction to *easily damageable components*. This specifies the cases in which the application of the heuristic will lead to the heuristics goal.

It could be argued that some of the examples found in literature are trivial or not helpful enough to be called a heuristic as per the meaning presented in the first section, and yet, arguably, they all fulfil the role of heuristics: to enable the designer to implement changes to reduce environmental impact where this was not possible previously without the guideline. Guidelines that are not able to support the designer in this way (for example, because they are too generic), can be considered poor heuristic guidelines. A guideline has to be tailored to the learned and evolved capabilities of the designer who is using them to be useful. Addressing a product designer's special knowledge in a guideline (for example, by referring to design parameters known by the designer), is one way to achieve this. The guideline "Don't use toxic substances", though common in literature, is, on its own, not a very good guideline, because most designers are not familiar with all of the relevant toxic substances and lack the expertise to fully inform themselves in a timely manner. If the guideline is accompanied by a list of usually relevant toxic substances and their (relative) toxicity, or, even better, several lists, each dedicated to particular conditions, like product categories or classes, following the guideline becomes more possible for the average designer. If the average designer cannot even assess whether the substances on such a list are contained within the product (or are used during its life cycle), other kinds of information should be provided to increase the heuristic value of the guideline.

4 APPROACHES FOR FORMALIZING HEURISTICS

4.1 Approach from software engineering

Gibbon (1997) presents an approach for the documentation of heuristics in software engineering. As mentioned earlier, the motivation for this differs slightly from motivation to use heuristics in ecodesign. In software engineering, heuristics are used to teach prospective specialists in the field of software engineering by documenting and communicating the experience of seasoned experts, providing a lot of background and contextual information. Ecodesign heuristics, on the other hand, are mostly used by engineers without a specialisation in that field. Ecodesign is more application-focused than teaching-focused. From this follows a different orientation of the proposed elements for the documentation of heuristics. There is a lot of overlap between the kind of information needed for teaching software engineering novices and the kind of information needed to use heuristics in ecodesign. The elements proposed by Gibbon (1997) can be found in Table 2. The documentation of heuristics in this approach tends to contain more information than most ecodesign guidelines.

Table 2. Formalised documentation of heuristics in software engineering (Gibbon 1997)

Field	Field description
Name	Description of the heuristic
Intent	Aim of the heuristic
Rationale	Outline of the problem
Consequences	Things to be aware of when applying the heuristics
Contextual Information	Important design-specific details that affect heuristic behaviour
Inter-heuristic dependencies	Heuristics that have a direct bearing on this heuristic
Suggestions	Things to be considered in light of the heuristic being breached.

4.2 Ecodesign-Pilot approach

Wimmer and Züst (2001) describe formalised guidelines that consist of six elements. Table 3 shows the elements used by Wimmer and Züst (2001) for the support tool *Ecodesign-Pilot*.

Table 3. Formalised documentation of guidelines in (Wimmer and Züst 2001), translated

Field	Field description
Name	Description of the guideline
Relation to environmental aspects	What is the relation of the guideline to environmental impacts?
Example	What would an implementation of the guideline look like?
Inter-heuristic dependencies	What is the relation between this and other guidelines? Are there amplifying or mitigating effects between the two?
Additional information	Where to find additional information on the guideline
Assessment questions	How can fulfilment of the guideline be assessed?
Additional questions	What additional considerations are relevant?

4.3 Approach of Vezzoli and Manzini

Vezzoli and Manzini (2008) present a collection of guidelines. The formalisation of the documentation is not, contrary to the last two approaches, the topic of their publication but their presentation of the guidelines can be put into the same form (Table 4) to show the differences and similarities.

Table 4. Formalised documentation of guidelines in (Vezzoli and Manzini 2008)

Field	Field description
Name	Description of the guideline
Introduction (per group of guidelines)	What is the relation of the guideline to environmental impacts?
Example	Concrete example of product with guideline applied
Further information (for some guidelines)	Additional information that can be used to implement the guideline

4.4 Proposed approach

Most guidelines seem to be derived in an unstructured process, based on expert knowledge. It seems beneficial to work towards a methodology that supports the process of finding, formulating and documenting new heuristic guidelines. The following approach to the elements of guideline documentation, based on literature sources presented here and the understanding of guidelines as heuristics is an initial step in this direction.

It is not a contradiction to have a collection of heuristic guidelines with different grades of specification. If an ecodesign expert is very active in a particular branch of industry, it might be useful to formulate specific guidelines for products in that industry. Dahlström (1999) uses company-specific guidelines, however, similar products in different companies have more in common than different products in one company.

The heuristic guidelines examined in this paper mostly focused on design decisions on products in one design project. In the case of components, two or more design projects are relevant when describing all connections between the projects and environmental impacts (Sarnes and Kloberdanz 2013). Components are developed to be used in higher level products and, in many cases, change of the component is not the most effective way to reduce environmental impacts. Game rules that are passed on as additional information to the designer of the higher level product, that describe the most eco-efficient use of the component, are a suitable means to achieve environmental soundness. In many cases, such rules might overlap with the content of normal technical documentations and selection tools provided by the supplier, but a new dimension can still be added to support decision making. These heuristics of information provision directly concern the synthesis step and therefore should be considered heuristics for synthesis.

Table 5. Proposed Structure of heuristic guideline documentation

Field	Field description
Name	Description of the heuristic guideline
Intent	Goals to be achieved by using the guideline
Conditions for applicability	Defining the product systems in which the guideline is effective
Instructions	Detailed instructions for the guideline
Additional Information	Additional information needed to implement the guideline, like substance lists, impact factors for relevant processes, calculation factors, etc.
Examples	(Preferably concrete) examples of products that show use of the guideline
Goal Conflicts	Relevant goal conflicts with other areas of design and typical requirements of products
Interdependencies	Description of the interaction between the guideline and other ecodesign guidelines
Rationalisation	Short description of the way the implementation of the guideline is supposed to reduce environmental impacts
Sources	Origin of the heuristic guideline

The following paragraphs present some considerations concerning the proposed elements of guideline documentation:

Name: Heuristic guidelines in literature tend to be formulated as short sentences. These are used as a denomination of the guideline. If a collection of guidelines has multiple levels of specificity, the denomination may have to be tuned, for example "mass reduction for movable systems" and "mass reduction in vehicle systems". When very specific conditions are used a different kind of identification system may become a necessity.

Intent: Heuristics usually have a specific goal to be achieved with their use. In ecodesign, this goal is mainly the reduction of environmental impacts over the whole life cycle of the product in question (or an increase in ecoefficiency). However, a given heuristic is not necessarily limited to one goal, e.g. in many cases of ecodesign heuristics, there is a goal mix between environmental and economic goals.

Conditions for applicability: The applicability or robustness of any heuristic or game rule is related to particular conditions. In extreme cases, a heuristic is applicable to all products. For most heuristics, a narrowed down area of validity will lead to more specific instructions, leading to higher usability of the heuristic. Some authors argue that very specific heuristic guidelines will still be useful, if they are formulated well. Categories must fit the intended area of application.

Instructions: While guidelines tend to be presented as short sentences, it will often be necessary to give more elaborated instructions to maximize the usability of a guideline. A user will not usually implement a very large number of guidelines in their design project, so there is no need to economise on the instructions provided for a guideline. The easier the user can relate the instructions to their design activity or design parameters that they know, the simpler that implementation will be for them.

Additional Information: As shown in the example about the "toxic substances" guideline, in some cases additional information has to be provided to make a guideline a good heuristic.

Examples: As can be seen in (Vezzoli and Manzini 2008), concrete examples of guideline implementation can be a great way to communicate the intent of a guideline, especially in cases in which a guideline is difficult for the average designer to grasp. An example can clarify the intention of a guideline. The use of examples will depend on the specific heuristic. Examples must match the conditions for a guideline.

Goal Conflicts and Interdependencies: The instruction given by a heuristic that is supposed to achieve a certain goal (improving eco-efficiency or reducing overall environmental impact) may be in conflict with another goal (or requirement) of the product system. As often as there are cases in which a heuristic achieves environmental and economic goals, there are goals that are in conflict with each other.

Interdependencies: The issue of guideline interdependencies is described well in literature. Some guidelines might be mutually exclusive while others benefit from the implementation of particular guidelines. For the purpose of documenting large collections of guidelines, interdependencies between heuristic guidelines pose a problem because there is a need for information completeness to ensure that every relevant interdependency is presented.

Rationalisation: In most cases, the connection between a heuristic and environmental impact is not obvious. Due to the nature of heuristics, the designer does not need to know these connections to successfully use the heuristic guideline. From a psychological perspective, this may be problematic, especially in ecodesign. Due to the nature of environmental impacts, there is no feedback from a description of the causal chains that connect a design parameter to an environmental impact, preventing the designer from rationalizing the effects of a given heuristic.

Sources: Confidence in the effectiveness of a heuristic is important, especially in the case of ecodesign, where there is less direct feedback than in other cases. To ensure confidence, the sources for the heuristic guideline should be documented. In some cases the source might be a specific LCA or a couple of studies, in other cases, the guideline may be deeply rooted in ecodesign literature, in which case the relevant publications can be cited. This increase in transparency might be helpful for the user of guidelines and ecodesign experts alike.

5 CONCLUSIONS AND OUTLOOK

While guidelines are commonly referred to in ecodesign literature and methodology, heuristic guidelines in ecodesign are not. The guidelines identified by experts in the field of ecodesign are valuable assets, but there is potential to increase their usability and thus their value by refining the theory of heuristic guidelines in ecodesign.

Advanced heuristic approaches will not supersede analytical approaches in EcoDesign. However, they may be able to help spread ecodesign in practise by supporting designers in situations in which the more time-consuming analytic methods do not match the requirements of design projects.

To utilise the potential of heuristic guidelines to the highest degree, a method to enable new heuristics to be articulated in a formalised form should be developed, as described in Section 4. Before this can be tackled, a deeper understanding of heuristics (and guidelines, design rules, etc.) has to be developed. An analysis of existing guidelines and design rules in ecodesign might reveal patterns and categories of these items. The data sources relevant for the formulation of heuristic guidelines have to be identified, and their role needs to be characterised.

An evaluation of the proposed approach has yet to be conducted. One first step towards an evaluation is testing the proposed approach by providing student teams in product development projects with heuristics that are documented in the proposed manner and comparing their experience and results with the experience and results of student teams that were provided different but comparable resources, like heuristics documented in a different fashion or SLCA-tables. The most important elements of the experience, which should be determined are the subjective ease of use and the confidence of the user in regards to the effectiveness of the results. The results can be evaluated by ecodesign experts by conducting a LCA-study in regard to the environmental properties and by rating the technical properties of the developed products in regard to its requirement-list. By using different teams that work on the same product, a meaningful comparison can be achieved. Yet there are several big limitations for such an evaluation. Engineering students are not the target group for design support, the transferability of the results to engineers is questionable. The amount of suitable development projects that are conducted is quite limited, which reduces the significance of the results. The low number of different products that are available to be used for such an evaluation put the generalisability of the results in question. In spite of these limitations such an evaluation will be conducted in the future.

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