THE CONCEPT OF ECOLOGICAL LEVERS – A PRAGMATIC APPROACH FOR THE ELICITATION OF ECOLOGICAL REQUIREMENTS

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ABSTRACT

This paper uses the concept of product properties to analyze three different dimensions a product development process has to cope with: technical, cost and ecological requirements. Objective is to highlight the problems when managing ecological product properties as well as to provide the basis for the elaboration of a pragmatic approach for eco-design practice. Pragmatic means securing the feasibility as to day-to-day work of product developers. The paper focuses on the early phases of a product development which constitute the most important ones in terms of task clarification. The full integration of ecological aspects in these phases is therefore promising and needs more methodical support. In this context, the concept of ecological levers is presented: Based on the ecological weak points of a product, the relation to functional areas and components causing these weak points is displayed by means of so called effect chains. Having identified the constructive improvements that can lead to a better ecological performance, their significance and feasibility is analyzed in terms of a potential analysis. By doing so, only the expedient improvement measures are identified and formulated as requirements: these are the ecological levers.

Keywords: Eco-design methodology, product properties, defining ecological requirements

1 INTRODUCTION AND MOTIVATION

Nowadays, eco-design is an integral part of design methodology research. Various methods and approaches have been presented on how to develop environmentally sound products: Product developers can choose between a wide range of checklists, design guidelines and IT-tools. However, it seems that eco-design has not exploited its potential yet. Besides in companies and industry branches which face corresponding environmental legislation or remarkable public attention, most of the product developers do not integrate environmental aspects in a regular and goal-oriented way claiming that available eco-design methods are too complex, not applicable to their specific products and given the limited resources barely feasible in day-to-day business [1]. Hence, new approaches are needed in order to provide methods for developing environmentally friendly products that are user-friendly and pragmatic in terms of allowing for restrictions given in each product development project. These restrictions can result from the technological state of the art, manager and customer input or from time and cost limitations. In order to do so, a deeper analysis of the ecological dimension in a product development process can be worthwhile: To fully understand the ecological dimension is crucial for further developing eco-design methodology.

The early phases of the product development process play a decisive role in each development project; this also applies when ecological aspects are integrated [2]. In this sense, ecological aspects need to be taken into account when clarifying the task. This paper provides insights for supporting the elicitation of requirements from an ecological point of view. For this purpose, the concept of product properties is applied for analyzing ecological product properties. The concept has proven useful for analyzing products and product development in the past. In this paper, it is used to highlight different categories of product properties and the special role of the ecological category as well as how to deal with it in a pragmatic way.

2 THE CONCEPT OF PRODUCT PROPERTIES

Hubka & Eder [3] describe technical systems as the entirety of the product representing objects and processes as well as the relations between them. In this paper, only tangible products shall be subject to analysis; for the description of intangible product see [4]. Thus, a product can be described by

means of its properties. A property consists of an attribute and a corresponding value, both related to the object being described [5]. For example, when describing a shaft, the following property can be useful: the length (attribute) of the shaft (object) is 300 mm (value). Of course, besides its length, the object has a lot more attributes as material, diameter or type of profile (hollow or solid). In this sense, products differ in terms of at least one differing property which means that one product either features one additional or differing attribute or it has a differing value for the same attribute compared to another one.
The concept of product properties provides various levels of analysis, for example the description of product models [6]. For the purpose of this paper, it is sufficient to focus on those aspects which are helpful to fully understand the ecological dimension of a product development: the differentiation between independent and dependent properties.

2.1 Independent and dependent product properties

Product properties can be distinguished between independent and dependent properties: *Independent properties* are directly defined by the product developer. They are material and geometric (macro- and micro-geometric) properties as these are the only ones that a product developer can assign to a product model in a 3D CAD parts list. It is evident that by defining the material and the geometry of a shaft e.g., many other properties are influenced, such as its weight or maximum deflection. Those properties, which cannot be directly fixed by the product developer, are called the *dependent properties*. They constitute the impact of design decisions.
The linkage between independent and dependent properties is given by physical or chemical models, the basis for technical knowledge [7]: The connection between the maximum deflection on the one side and material and geometric properties on the other side is associated with knowledge in technical mechanics. Basically, the knowledge on the linkage is part of the essential engineering basic knowledge. In case the connection is not clear, the product developer has to acquire the corresponding knowledge or estimate the impacts of the design measures. Based on these considerations, a product development process is nothing else than the definition of independent properties in anticipation of the resulting dependent properties in order to fulfill the customer requirements. Figure 1 represents the relation between independent and dependent properties in a property-relation-chain:

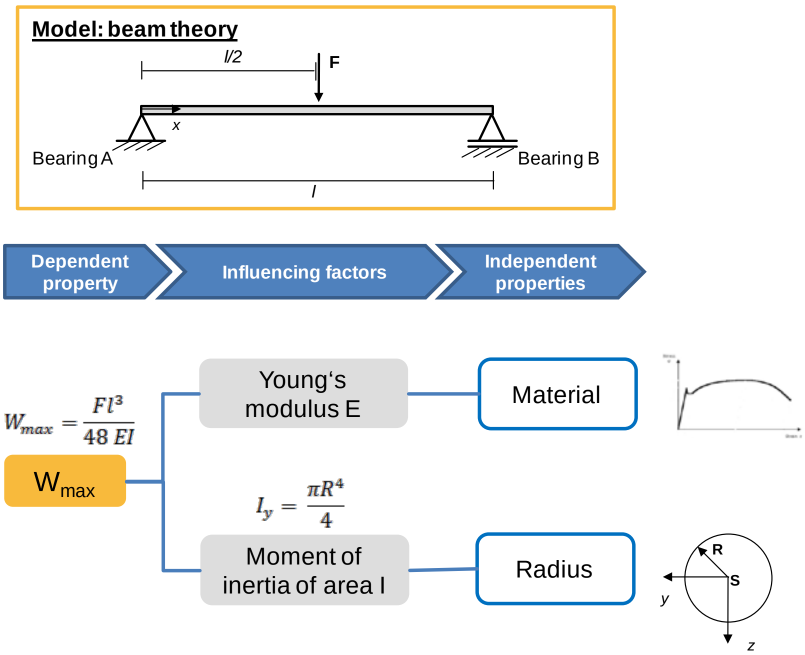

Figure 1. Relation between the dependent property "maximum deflection" and the corresponding independent properties of a shaft

The example of the shaft is one in which the product to be developed consists of just one component. In case a product is composed of more functional areas and components, dependent properties can relate to the product level as well (for example "fuel consumption" of a car). In this case, the depiction of the relation to the independent properties contains more steps including the influencing functional areas and components as well as the dependent properties of these components. The latter constitute the starting point for the relation shown in Figure 1.

Figure 1 reveals another determinant besides the independent properties: The maximum deflection is also influenced by the applied load, a factor which is not directly fixed by the product developer. Generally speaking, most technical products can only create a functional benefit when they are part of a (usage) process. Within those processes, there are external factors that are not inherent in the product itself but defined by the user or other boundary conditions: The fuel consumption of a car is also influenced by the driver behavior; the voice quality of a mobile phone surely depends to a certain extent on the location of the user and the resulting signal strength.

2.2 Product requirements as target-properties

Primary source for requirements to be fulfilled in the product development process are the customers. This not only includes the explicitly articulated requirements but also all latent wishes that are not communicated or even those that the customers are not even aware of. It is especially the innovative enterprises that employ research and development resources for identifying new business areas or creating new customer needs.

Dependent properties can be perceived by the customer. Therefore, most of the customer requirements are dependent: The customer may not be interested in a certain material but just needs the product to be within the weight limit. Of course, this does not apply in all cases. Supply components, for example, underlie certain material or geometry specifications due to their function in an overall technical system. For consumer goods and end products in general, however, most of the customer requirements are dependent target-properties.

Furthermore, requirements can refer to other sources such as legislation, particularly in the field of product safety and environmental protection, as well as constraints given by the development project itself in the center of the triangle of time, cost and quality [8]. Quality can be measured by customer satisfaction whereas time and costs constitute two sources for further constraints resulting from development and manufacturing resources. No matter where the requirements stem from and what kind of product is to be developed: requirements are target values for certain attributes.

2.3 Product property categories

A product has a large number of dependent properties, not to say an infinite number. But only a limited number of those properties are relevant in terms of the requirement to fulfill a certain value. All properties can be classified in different property categories which can have any granularity. For the purpose of this paper, it is sufficient to consider the basic dimensions of a holistic product development process, these are: technical, cost and ecological properties [9]. All relevant (dependent) properties can be assigned to these three categories. Style properties serving prestige utility shall be excluded in this paper: The impact of product properties on the perception by the customer as to style is complex and needs other models to describe the relation between independent and dependent properties than are used in this approach.

2.3.1 Technical properties

Properties contributing to the functional performance or referring to other technical customer requirements are aggregated in this category. Thus, this includes all properties (respectively: requirements) in the fields of functionality, reliability, safety, durability and ergonomics. Technical properties serve the purpose of utility in the widest sense and therefore take effect in the use phase. The level of conformity of the attributes with their target-values determines the quality of the whole product: in contrast to the common usage of the term “quality”, there are no “high quality products” per se but only ones fulfilling the customer requirements best. Therefore, quality is always based on a comparison and evaluation of the properties by the target group of the product [10].

As described in section 2.1, the impact of design decisions in terms of defining the independent properties on the dependent properties is captured in the basic knowledge of product developers and is the basis of the engineering work. This applies particularly in the category of technical properties.

2.3.2 Cost properties

Properties which can be expressed in terms of monetary units are classified in this category. Assessing products by means of their manufacturing costs certainly is most common, considering the range of

methods in the field of cost calculation. In this sense, the traditional comprehension of costs refers only to the production phase. Lately, life-cycle-thinking is being taken into account for cost calculation as well: Evaluating products according to the costs caused by them during the whole life cycle (including development and manufacturing, operation, maintenance, as well as disposal) is gaining importance, especially for capital goods such as manufacturing machines. In this sense, a product's life cycle costs serve as a selling point along with other properties [11].
The knowledge on the impacts of design measures on the cost properties is nowadays part of a product developer's education (at least for the manufacturing costs). But the link between each independent property and the costs it causes is not methodologically secured yet. Nevertheless, in most cases, the product developer is able to estimate the dimensions or some kind of ranking as to which design decisions will lead to which costs. Principle solutions, when available, provide the basis for calculating the costs and comparing them with the given requirements.

2.3.3Ecological properties

In the broadest context, the environmental impacts of a product can be interpreted as a property category as well: Each decision on an independent property has an impact on the environment including the human beings within this environment. Of course, not the product itself causes these impacts, but the processes during the whole life cycle: materials production, manufacturing, use and disposal or recycling processes as well as transports. The resulting impacts such as climate change or eutrophication can be regarded as dependent properties being perceived either by the environment or the customers themselves (e.g. noise). They take effect during the whole life cycle, and therefore, life-cycle-thinking is mandatory in this category.
The linkage between independent and dependent properties in this category is also stored in knowledge: The models linking the used materials to the resulting processes and displaying the environmental impacts caused by those processes are nothing less than the life cycle impact assessment (LCIA) methodologies of a life cycle assessment (LCA). This knowledge is not captured by the product developers' field of activity and the associated know-how.
Just like the technical and cost properties, there are an infinite number of properties in the ecological category, but only a limited number of those can be taken into account. This corresponds to the impact categories in the life cycle assessment: By choosing a LCIA methodology, a selection of impact categories and indicators is determined, based on which the product will be assessed. The description of the properties in terms of attribute and value is possible only in the characterization models by means of the category indicators which are very complex. The so-called endpoint impacts and the unit used for describing the aggregated results, such as [mPt] in the LCIA methodology "Eco-indicator 99", are difficult to interpret. Also, it is not common that a product development process faces the requirement of a certain endpoint value. All these considerations indicate the difficulty when trying to cope with the ecological dimension in a product development process. In the next section, the relation between independent and dependent properties is used to further highlight this major problem.

3 RELATION BETWEEN INDEPENDENT AND DEPENDENT PROPERTIES WITHIN THE PROPERTY CATEGORIES

Section 2.1 discussed the linking between independent and dependent properties by means of elaborating property-relation-chains. The same model can be used in order to analyze properties of different categories as presented in the previous section. For this purpose, the relation is displayed in a reverse way: by using the independent property as the starting point, the impact of a design decision (which is the determination of an independent property) on the product in terms of its dependent properties can be described. In this case, the property-relation-chain can be interpreted as some kind of effect chain. Furthermore, the three categories technical, cost and ecological properties are integrated in the effect chain.

3.1 Impact of a design decision on the property categories

Defining one independent property influences the product in regard to each of the three categories, to different extents though. For example, if the product designer decides the material of the shaft to be steel E295, this does have an impact on the dependent properties in all categories:

- In the technical dimension, the material of a shaft is an influencing factor on properties such as durability (lifetime), weight, transmittable torque, and many more.

- In the cost dimension, effects are given by the fact that steel has a monetary value which influences the manufacturing costs. This could be material costs and production costs due to the manufacturing processes needed to process the steel so that it can serve its purpose as a transmission element. Moreover, as in all products underlying mobile or dynamic utilization, the weight of the shaft might have an impact on the operational costs, too, due to the fact that it turns during operation but also because it might be installed in a car for instance.
- In the ecological dimension, this design decision has an impact as well: All processes needed to process the steel have ecological impacts. Its weight as an operational factor also determines the environmental impacts during the use phase: The heavier the shaft, the more energy is needed for its dynamic application, as a transmission element as well as part of a mobile product.

This example reveals more interdependencies: Given the shaft made of steel E295, other design decisions are needed such as the dimensions (macrogeometric) or even the surface treatment (microgeometric). All these decisions lead to properties within each of the categories and are interrelated to a certain extent. As described above, only those properties with the need to fulfill requirements are focused on.

Figure 2 presents a simple effect chain for this example with an extract of properties in each category. To simplify matters, the detailed link between the independent and dependent properties is not shown and the sources for the corresponding knowledge as well as the requirements are referred to instead.

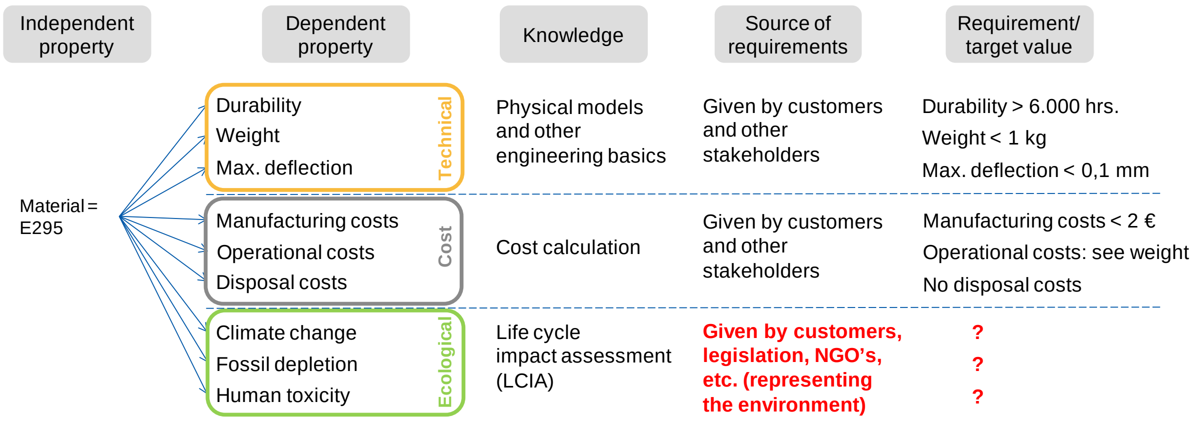

Figure 2. Effects of the independent property „Material = E295 (steel)" on related dependent properties

3.2 Problems managing product properties of the ecological category

Figure 2 discloses a major problem when analyzing the product development process by means of product properties: Unlike in the other dimensions, the ecological requirements do not correspond with the actual dependent properties within this category; they do not constitute target values for the dependent properties. A product developer may face requirements concerning the lifetime, weight or the transmittable torque of the shaft. Also, it is thinkable that requirements for the manufacturing costs are formulated. These requirements all correspond with the dependent properties which are influenced by the product developer by defining the independent properties. In the ecological dimension, however, it is unlikely that the requirements list contains target values for fossil depletion or human toxicity. The demand for minimizing the CO_2-emissions which enterprises currently face is misleading: Besides production plants, in most cases, the requirements relate to products during the use phase such as airplanes or automobiles. According to the life-cycle-thinking, the target CO_2-emission should in fact relate to the whole life cycle which is actually done only in rare cases. Also, CO_2-emission itself is not a dependent property: It cannot be perceived by the customer or the environment but has an effect on the impact category "Climate change". In LCA terms, CO_2-emission is a category indicator [12] contributing to the impact category "Climate change".

But even if the ecological requirements were formulated in a way that they correspond to the dependent properties, it is still not manageable for product developers without knowledge on the relation between the independent and dependent properties of this category. A life cycle impact assessment could provide this information but it is surely not feasible to assess each concept solution that detailed during the development process.

Summing up the results, the ecological dimension is not manageable for product developers. The relations between independent and dependent properties are not clear during the development process. A new approach for an eco-design methodology needs to overcome this obstacle and provide clear and distinct requirements which product developers are able to handle. In addition, a pragmatic approach must take constraints into consideration which are given in the development project: It has to provide possibilities to identify the feasible ecological requirements. The next section presents a first approach for managing the ecological dimension during the early phases of the product development process which takes these prerequisites into consideration.

4 DEFINING ECOLOGICAL REQUIREMENTS – THE CONCEPT OF ECOLOGICAL LEVERS

Based on the problems described when facing ecological requirements, this section provides an approach for integrating ecological aspects in the product development process, focusing on its early phases. The motivation lies in the fact that early phases, such as task clarification and formulation of requirements, are the most important ones: A successful product development fulfills the customer requirements best and this is only possible when the requirements were elaborated in a detailed way. Furthermore, the analysis of ecological product properties has shown that the complexity of the relations between independent and dependent properties and the resulting difficulty formulating ecological requirements constitute a major part of the problem.

4.1 Ecological aspects in the early phases of the product development process

The identification of ecological requirements always has to be based on an ecological assessment of a predecessor product or the benchmark of a competitive product with similar functions. The reason is self-evident: a target-oriented development needs to be aware of the deficiencies which are to be eliminated in the new product, from the technical as well as ecological point of view. There are various ways to analyze a product ecologically: checklists or assessment methods as life cycle assessment can display the materials or processes of a product with the highest environmental impacts. However, a complete life cycle assessment is costly and not always feasible during a product development process, but is also in many cases not necessary: the ecological weak points of some products are evident and easy to determine, for example the energy consumption of active products such as refrigerators, mobile phones and other electric devices.

Given the ecological weak points of a product, a pragmatic approach needs to question the feasibility, that is, to identify those deficiencies that can be eliminated or minimized by means of feasible constructive improvements. For example, an ecological weak point can be based on a technology given by the state of the art, so it cannot be substituted without a loss of functionality. The search for alternative forms of fuel in the automobile and aviation industry reflects this problem: As long as the availability of alternative fuels with the same power is not secured, the weak point “emissions (due to burning of fuel)” can only be minimized in terms of efficiency considerations but never be totally eliminated. Also, it is possible to influence the consumer behavior by displaying the process parameters in order to raise the awareness of the consequences of the actions taken during product usage. The measures which can be taken in this field are not in the framework of this paper.

In summary, an ecological weak point has to fulfill two requirements in order to be taken into consideration for the further product development process: Its improvement has to be feasible and must also result in a significant decrease of environmental impacts caused by the product. Weak points meeting these requirements lead to the so-called *ecological levers*. Ecological levers are the results of assessing the potential of ecological weak points. They help the product developer to decide on the constructive improvements which can be carried out in order to minimize the ecological impacts. Having defined the ecological levers, the ecological requirements are then formulated by specifying them in terms of a quantification of the changes needed.

The first step, however, is to link the weak point to the product: Depending on the product, ecological levers can relate to product properties, functional areas or components and their properties. In any case, ecological levers are always related to the product: If the ecological weak point is not product inherent, the relation to the product has to be elaborated first. The reason is as follows: Ecological levers enter the requirements list as additional requirements that must be met when developing the product. Section 3.2, however, has shown that ecological requirements cannot be formulated according to ecological dependent properties. In order to make sure the product developer is able to handle the

ecological requirements, it is necessary to express them in terms of properties that are understood by developers. As the allocation of environmental costs is not elaborated in detail yet, the technical dimension shall be objective: All ecological requirements need to be converted to technical requirements. In this sense, an ecological requirement is understood as a technical requirement which has a positive impact on the environmental performance of the product, that is, leads to less environmental impacts. By linking the ecological weak point to the product and its functional areas and components, the expression of ecological issues in terms of technical improvement possibilities is secured.
Hence, ecological requirements in a pragmatic approach are characterized by two aspects: They are formulated as technical requirements and were subject to a potential analysis in order to identify those with the highest potential.

4.2 Identification of ecological levers – a first approach for the elicitation of ecological requirements

The ecological assessment provides weak points in terms of the processes or materials with the most environmental impacts. Based on these results, the identification of ecological levers is conducted as follows:

1. Convert ecological aspects to technical ones by relating the ecological weak point to the product and its functional areas and components.
2. Identify the ecological levers by analyzing the corresponding constructive improvements in question in terms of significance and feasibility (potential analysis).

The ecological levers are then formulated as requirements, that is, assigning target values for the attributes.

4.2.1Relating ecological weak point to the product

It is obvious that a certain material is easy to assign to product components; in this case, the weak point is product inherent. It is the processes, such as transports or processes within the use phase, which gain informative value only when they are linked to corresponding product properties or the components which cause them. One possibility to do so is to use effect chains: They link a certain (use) process to the product and its functional areas and components by systematically depicting the influencing factors of each level [13]. Starting with the process itself, the next step is to highlight all factors that influence its environmental impacts. If those factors are not product inherent, they need to be further linked to the product by analyzing the correlation (see Figure 3). Given the aspect of the product that has an impact on the starting process, it is easy to depict the contributing functional areas and components and, if necessary, even their dependent and independent properties.

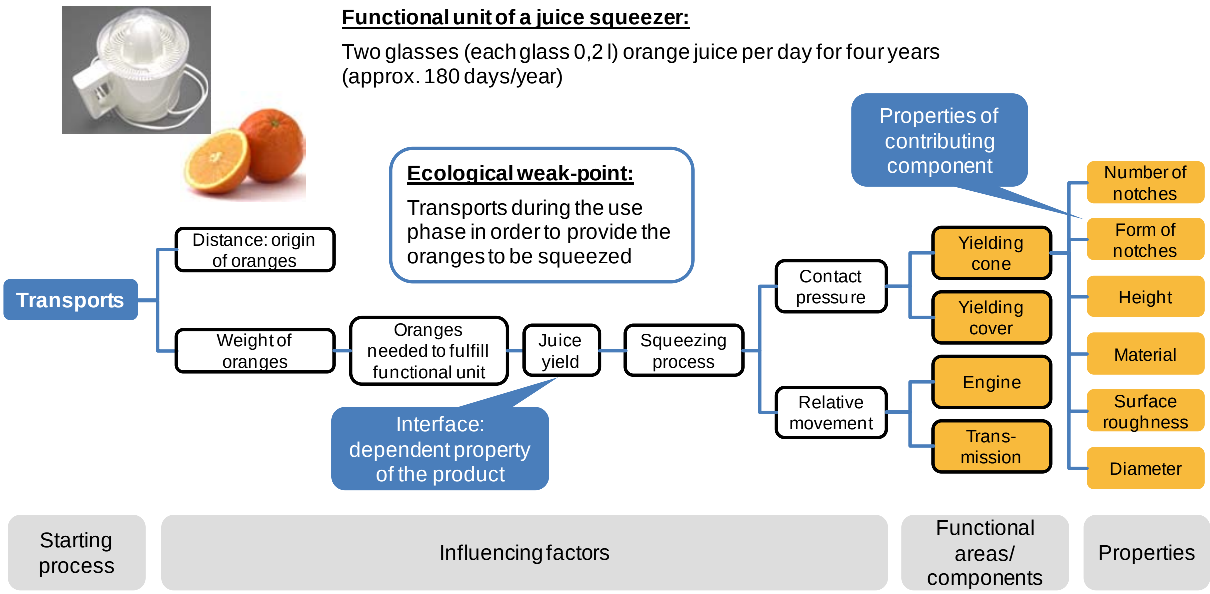

Figure 3. Effect chain analysis – example of an electric juice squeezer

It is not possible to provide a detailed and yet generally valid approach that applies on any product. Thus, the description of the effect chain analysis steps is consciously kept simple. In some cases, a functional area or component is a starting point for further effect chains, but needs not to be further analyzed as it is a supply part that is purchased by choosing specific data. In the example of the juice squeezer in Figure 3 this could apply to the engine or the transmission, for example. The effect chain, however, can surely help identifying the requested values for those data in order to minimize environmental effects caused by the starting process. Also, the analysis on the component level is not always necessary: It is likely, that for the product developer of the juice squeezer, it is sufficient to know that the juice yield as a dependent property of the product is the major influencing factor of the environmental impacts. The fact that the yielding cone, which is described by its independent properties, has a huge impact on the juice yield is probably stored in the know-how of a product developer working in this product field. However, the level to which these effect chains are displayed surely depends on the product being analyzed and the person conducting the analysis.

The knowledge on the relation between the starting process and the product and its functional areas and components contains the information on the direction of change needed in order to decrease environmental impacts. For the example of the juice squeezer, that would mean that the juice yield is to be increased.

Based on this information, it is possible to analyze the expected benefits and feasibility of the constructive improvements in question. Although all following considerations also hold for functional areas, to simplify matters, only the components will be referred to.

4.2.2 Analyzing significance and feasibility of constructive improvements

As to the ecological benefits of a constructive improvement, the question of how much less environmental impacts can be achieved by focusing on a certain component is to be answered. Of course, the elaboration of a complete new solution concept as well as a re-assessment could provide according information. As this is in most cases not feasible, the benefits have to be roughly estimated: For this approach, the possible benefits by realizing a constructive improvement are assumed to be proportional to the share of the environmental impacts the corresponding component is responsible for. For instance, in the example of the juice squeezer, if the yielding cone has a huge influence on the juice yield and therefore influences the environmental impacts due to transport processes during the use phase to a great extent as well, its constructive improvement can lead to a significant environmental benefit. The relation between the yielding cone as a component and the juice yield as a technical property of the product is equivalent to the analysis by means of a Quality Function Deployment [14]. In case the ecological assessment and the following effect-chain-analysis reveal several components in question, the analysis of the significance is even more important as it is surely not possible to focus on each and every component to the same extent. An ABC-Analysis could provide useful information: In many cases, a large share of the environmental impacts is caused by just a few components. The identification of these components corresponds to a significance analysis as it prevents the product developer from focusing on relatively unimportant components.

The feasibility of a constructive improvement can be evaluated in various ways. One possibility is to analyze the efforts for realizing a certain improvement: If the realization is only possible with enormous efforts, then the improvement of the component concerned can be regarded as less feasible compared to the constructive improvement of other components with lower efforts needed. In order to estimate the efforts of a constructive improvement of a component (in terms of the needed direction of change of its properties), representing criteria can be useful. The following considerations shall help to clarify the approach: Hypothetically, any constructive improvement can be realized, the only constraints are given by the resulting costs: Even technologies can be scrutinized and improved when enough development resources are available such as time and financial resources. All restrictions a product development project faces result from time and cost boundaries given by the specific development project environment. Likewise, one could argument that the given constraints determine the efforts for a certain constructive improvement. In this sense, the efforts can be approximately evaluated by criteria such as state of the art, available development and production resources in enterprise, time limits for development project, and others. They all are indicators for the efforts for finding an alternative solution that decreases the environmental impacts of the material or process concerned.

Especially in product development projects which are based on the improvement of an existing product, such an evaluation is not necessary as the product developer knows the product very well being aware of the restrictions given. Therefore, in practice, the feasibility has to be taken into account in a more appropriate way: The specification of the ecological levers lead to the ecological requirements. Basically, the feasibility can be regarded as restricted when the ecological requirements conflict with other (customer) requirements. So all the factors named above can be narrowed down to existing requirements and their interrelation to additional requirements given by ecological considerations. As a result, the impact of the realization of the identified ecological requirements on the requirements in the other categories (technical and cost properties) has to be elaborated. As to the technical dimension, the impact of the ecological requirements on the requirements and properties within this category can be assessed by the product developer and does not need any methodical support. The reason is as follows: Due to the considerations of a pragmatic approach, all ecological requirements were converted to technical ones by linking the ecological weak points to product components and identifying the constructive improvements needed to eliminate those weak points. In this sense, they can be considered as additional product requirements: Just as in a regular product development process, additional product requirements can take effect any time and it is a product developer's day-to-day business to check on their interrelations to already existing requirements. This holds for the interrelations between the ecological requirements and cost requirements as well. Still, there is a slight difference: Whereas the technical dimension constitutes the main goal of a product development project, costs can be interpreted as boundary conditions. Hence, the objective is to develop a product which meets the customer requirements best with the lowest costs possible. In a pragmatic approach, the ecological dimension, even if formulated in terms of technical requirements, can probably only be considered an additional boundary condition: The product to be developed has to fulfill the technical requirements best with the lowest costs and ecological impacts possible. In this regard, the joint consideration of both dimensions seems useful when trying to implement ecological aspects into product development: When cost and ecological requirements both constitute boundary conditions, why not tackling both dimensions in an integrated way so as to minimize the complexity for the product developers?

5 CONCLUSION AND FURTHER STEPS

The concept of product properties helps to fully understand the product development process and therefore has a significant value for engineering design research and practice. In this paper, it was used to analyze the three dimensions technical, cost and ecological product properties. The analysis showed that the ecological dimension is hardly manageable for product developers as the requirements given by the customers or other stakeholders do not correspond with the dependent properties in this category. Moreover, the relation between independent and dependent ecological properties is not clear. Based on the early phases of the product development process, the concept of ecological levers was presented: Constructive improvements having a positive impact on the ecological performance of the product. In addition, a pragmatic approach was chosen: In order to provide methods that can be used in day-to-day business, the feasibility of design decisions was consciously taken into account in terms of a potential analysis. A first approach for this was introduced in section 4.2: Both significance and feasibility can be assessed without having a complete solution concept and carrying out an ecological assessment. Only by identifying those constructive improvements with the highest potential, an expedient solution for the problem can be found and the feasibility in eco-design practice is secured.

However, this paper could only provide a first approach; there is still a lot to do in order to provide a complete methodology: The concept of the ecological levers in general and especially the integrated management of the cost and ecological dimension for identifying the feasible requirements have to be further elaborated in detail. More and detailed case studies need to be conducted. The challenge is to provide a procedure that is valid for different kinds of products. The phases besides the task clarification need to be analyzed: The methodology must enable product developers to take into consideration ecological concerns in each phase of the product development process, including the phase of embodiment design.

Also, an eco-design methodology needs to take all interrelations into account: Interrelations between the ecological requirements and other requirements as described in the previous section, as well as those between the requirements and measures within the ecological dimension. They all must be part of the methodology later on in order to achieve the objective: to provide methods that are expedient and feasible.

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