ECO-EVALUATION OF TECHNICAL SYSTEMS IN THE CONCEPTUAL PHASE

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Abstract

In conceptual design phase, description of the final product solution is abstract, and there is the lack of information on product's environmental performance throughout its life cycle. Quantitative environmental assessment methods are used in the lesser extent during conceptual design due to lack of knowledge about future life cycle of the product and embodiment design. Qualitative approach to eco-evaluation is needed in early design phases and support for original design concepts. Novel eco-evaluation approach is proposed for comparison of environmental friendliness of technical system's conceptual solutions. The approach is demonstrated by establishing effects and technical processes of laundry cleaning concept variants. Proposed eco-evaluation criteria are based on adopted concepts of energy transformation quality and waste management hierarchy.

Keywords: Ecodesign, Conceptual design, Evaluation

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1 INTRODUCTION

The research described in this work addresses the topic of eco-evaluation of conceptual design of technical systems. Product's life cycle and environmental profile are imprecise or vaguely known in conceptual design phase. Usually, environmental profile is described in a quantifiable way (e.g. in environmental impact units) to enable quantitative evaluation of product's environmental performance. During the conceptualization, it is hard to perform an assessment of product's environmental impact without assumptions regarding future product's life cycle and embodiment design made a forehand.
Environmental assessments assist in the identification of product's specific features and properties that need to be optimized for a more environmentally sound product to be developed.
From a practical point of view, environmental assessment is performed when product's description is final, and primary product's features are defined. Assessments are conducted after embodiment design solutions are decided upon and in detailing design phase. Which environmental improvements to perform, how to implement them and how to measure the effectiveness of environmental improvement propositions are still open questions for Ecodesign practitioners and researchers alike.
From a theoretical perspective, environmental improvements (as otherwise in cost and quality) are limited in later design stages (Bhamra et al., 1999). For some researchers, significant environmental profile improvements require that fundamental design changes include a change in the design concept and a shift in the transformation system's paradigm (Quist and Tukker, 2013). However, change in product's concept, functions, working principles or principle solutions at this point of the design process can lead to additional product development costs and delays. All the work performed until that point would be obsolete (Ullman, 2009). All in all, researchers propose that the environmental assessment is conducted earlier, for example in the conceptual design phase, and more often in the design process.
Environmental assessment, environmental impact assessment and eco-evaluation are used synonymously in eco-design literature to describe methodologies, approaches and methods for assessing and evaluating environmental friendliness of products. When product's environmental friendliness is expressed in units like for example eco-efficiency and environmental impact, it is implied that the capacity of the solution is assumed a forehand. In early product development, product or solution as such can not be described by capacities (Andersson, 1996). Rather, it is product's capability that can be considered in early phases, since the solution at this point is still open. Following on that premise, some objective measure of environmental (ecological) quality is required to evaluate environmental friendliness of the product during conceptual design phase, e.g. conceptual design of the product.
Research aim is introducing environmental quality measure that can be asserted in early conceptual design phase and criteria used for environmental evaluation and comparison of concepts.

1.1 Problem formulation

According to Straton (2006), the concept of value (eco-value) is to be associated with capacity (ability to contribute to the value) and quality (measurable in some objective evaluation unit).
It is widely accepted that the environmental impact is the only valid measure of product's environmental friendliness (Bevilacqua et al., 2012). Eco-evaluation in conceptual design phase can be either dominantly qualitative or based upon quantitative data on predicted future product's capacities. Quantitative data that is needed for calculation of product's environmental impact is technically not available in conceptual design phase. Quantitative environmental assessments require that 'functional unit' is defined, so that products with the same functions could be compared (O'Hare and McAloone, 2014). Qualitative environmental criteria such as environmental relevance (Jones, 2003), environmental burdens and gains of greenhouse gas reduction options (Bocken et al., 2012) are more suitable for product planning phase that precedes conceptual design development.
Pahl et al. (2007) provide a clue that energy conversion quality factor can be an important indicator of environmental friendliness. They implicitly state that more environmentally friendly products are products that save energy and that energy can be saved by minimizing the number of energy conversions. Rath et al. (2011) introduced the energy efficiency tool. Their approach to evaluating energy efficiency of the product in the use life cycle stage consists of list of guidelines and concrete measures of efficiency factors (such as minimizing the number of energy conversions and energy transmissions) which are defined for the transformation process.

1.2 Approach

Andersson (1996) explained that capability would be the proper term when early design phases are considered. Hubka and Eder (1996) define the function of the product (*technical system*) as a capability to deliver *effects* necessary for transformation of *operands* into the desired state. Effects exerted from the *technical system* (or other *operators* like humans or management systems) and *operands* that assist the technical process. Technical system's function structure is deduced from the main operand transformation process (technical process), *technological principles,* and effects.

Transformity effectiveness and *waste eco-quality* eco-criteria proposed in this work qualitatively describe environmental friendliness of: 1) effects supplied by the technical system that guide the technical process, 2) operand transformations in the technical process and 3) secondary outputs from individual operations in the operand transformation process. Eco-evaluation approach and criteria are demonstrated in an example where three conceptual solutions for laundry cleaning are analyzed (Table 1). The problem addressed is comparison and eco-evaluation of technical systems with different technological principles in the conceptual phase (Midžić and Marjanović, 2013).

Table 1. Laundry washing and cleaning conceptual variants

Warm water and powder detergent laundry washing 	**Ultrasonic laundry washing with water and liquid detergent** 	**Laundry cleaning with polymer beads** 
Washing is performed warm water and detergent, powered by electrical energy, and enabled by mechanical centrifugal agitation effect.	Washing is performed with liquid detergent and water, powered by electrical energy. Dirt is mechanically removed from the fibers due to cavitation effect (Gallego-Juárez et al., 2010).	Cleaning is performed with polymer beads, a small amount of detergent and water, powered by electrical energy, and enabled by mechanical centrifugal agitation effect (Xeros, 2015).

Hypothesis defined is that eco-evaluation of a particular technical system's functional structure can be managed by assessing properties of operands (*energy*, *material* and/or *information*) which are transformed in the technical process. The idea is to eco-evaluate intermediate transformation states of operands in the technical process according to eco-criteria for each operand type.

Although environmental friendliness of products (technical systems) is in most cases evaluated according to different life cycle aspects, properties defined in the conceptual phase may be major influencing factors of the environmental impact (Zhao et al., 2011) and the useful (operational) life phase (Hubka and Eder, 1996).

2 MOTIVATION, BACKGROUND AND KEY CONCEPTS

During each development phase, product's description and solutions are considered and evaluated from different aspects (such as technical, ergonomic, economic, environmental). There is uncertainty regarding final product's features and properties in conceptual design phase since the decision on final product's concept is not made yet. It is harder to change some product characteristics that may be crucial for product's environmental performance after product's specifications are decided upon (Bhamra et al., 1999). From there on, most technical properties are defined.

Motivations for performing eco-evaluation in conceptual design phase are:

- Decisions made in conceptual design phase significantly affect the environmental impact throughout the product's lifecycle, its future performance and properties (Bhamra et al., 1999),
- Potential for environmental improvements is large at the beginning of product development when ideas and conceptual solutions are open (Bevilacqua et al., 2012),
- Solution space (degree of freedom to choose solutions) is wide in early design phases and needs to be narrowed down. By identifying the fittest or excluding the worst concepts, engineers can focus on developing more prosperous concepts (Derelöw, 2009).

2.1 Eco-evaluation approaches and methods for conceptual design phase

Evaluation methods are used to avoid biases, stereotypes, and personal preferences when deciding upon preferable solutions for further development (Byggeth and Horschorner, 2006). Evaluation criteria are defined first and then evaluators agree upon how much concepts or specific attributes of the concepts satisfy each and overall criteria. Eco-evaluation in conceptual design phase can be either qualitative or based upon quantitative data on predicted product's environmental impact.

Eco-evaluation proposed by Jones (2003) is based on using a single qualitative environmental friendliness criterion called 'environmental relevance'. Only product ideas are assessed in the evaluation process. Environmentally relevant concept is defined as the concept, idea or solution with the potential to reduce environmental impact (in comparison to some other product or process).

Bocken et al. (2012) developed a tool for assessing implementation difficulty and benefits of product's concepts and ideas regarding greenhouse gas emissions. Product ideas are eco-evaluated according to the rebound effect potentially occurring during product's useful (operational) life phase.

Eco-evaluation of product's functional structure in conceptual design phase can be enabled by assessing environmental friendliness of product's components and using environmental impact approximation methods. Coatanéa (2005) and Medyna (2013) use dimensional analysis to compare concepts during early design phases environmental analysis of an energy conversion system using LCA. In that way, most important components with the highest environmental impact can be identified. Fitch and Cooper (2005) investigate life cycle modeling and simulation of environmental impacts for conceptual design phase. They report that data collection and life cycle modeling require many efforts, and there is uncertainty arising from lack of knowledge about product's final attributes and properties. They conclude that those might be the reasons for the lack of environmental impact approximation methods for conceptual design phase for original design concepts (Pahl et al., 2007).

Environmental criteria to be used for product eco-evaluation in the conceptual design phase are not agreed upon among different methodological approaches to environmental evaluation. Environmental evaluation requires assessment of the different embodiment and life cycle aspects of the product, which are not explicitly defined in the conceptual design phase. Future product's life cycle, embodiment design solutions and environmental profile are imprecise or vaguely known (Lindahl, 2005). There is a lack of support for qualitative multi-criteria environmental evaluation in conceptual design phase and lack of guidelines and methods for assigning scores and importance weight factors to each environmental criteria while assessing concept attributes and properties (Byggeth and Horschorner, 2006). In order to support the hypothesis that eco-evaluation of technical systems in conceptual design phase can be managed by evaluating operand transformations in the technical process, environmental criteria for different types of operands and operand transformations are developed and presented in this work.

2.2 Eco-criterion 1: Energy transformity effectiveness

In the field of energy system and ecosystem analysis, energy quality is considered to be a property of energy. There are two methodological approaches to describing the quality of energy in an energy conversion process. Exergetic and entropy-based methods take into account the heat content of energy to measure energy, and do not differentiate the quality of particular energy form to convert to other energy forms. D. Scienceman and H. T. Odum introduced a different approach to energy quality to describe the capacity of particular energy form to feedback and control conversion to other energy forms, and produce goods and services. Energy transformation quality values calculated by Odum (1988, 1996) are used in this work to define ecological criteria of operand transformations in the technical process.

The concepts of *emergy* and *transformity* are used for systems-oriented environmental analysis and modeling. *Emergy* is the available energy that is utilized in direct and indirect transformations into sustaining a product or provide a service (Odum, 1988). Emergy is measured in *emjoule* units to allow for comparison between different energy, material, and monetary flows. Energy *transformity* or energy transformation quality is defined as *emergy* of one type (form) of energy required to make a unit of *emergy* of another type (energy form). By using transformity values, different types, levels, and not comparable energy forms are converted into the same measurement standard (Cai et al., 2004). Odum (1988, 1996) and Ohta (1994) specified levels of energy quality for different energy forms. Odum defined *solar transformities* (unit: *solar emjoules per joule*). Ohta composed qualitative energy quality hierarchy based upon abundances of energy forms in nature. Odum's and Ohta's energy quality hierarchies can be used to compose one unified energy quality hierarchy. This energy quality hierarchy is used to define environmental criteria of central effects energy transformations of two laundry washing concept variants in the work of Midžić et al. (2014). Revised table of transformity values for different energy forms is composed to calculate transformity effectiveness values and demonstrate eco-evaluation of operand transformations.

Table 2. Energy transformation quality values

Sunlight (solar energy): 1 sej/J (Odum, 1988). Wind kinetic energy: 620 sej/J (Odum, 1988). **Energy from unconsolidated organic material**: 4 400 seJ/J (Odum, 1988). **Heat**: 10 000 sej/J - estimation of energy position according to Ohta (1994), approximation of the value according to the interval specified by Odum (1988). **Chemical energy**: 15 000 see/J - approximation of the value based on 'chemical energy in dispersed rain', interval specified by Odum (1988). Wave and tide energy: 19 000 sej/J - average of interval values after Odum (1988). **Mechanical energy**: 29 000 sej/J (approximation of the value based on interval specified by Odum (1988), estimation of energy position qualitatively defined by Ohta (1994). Energy from consolidated fuel: 38 000 sej/J - average of interval values specified by Odum (1988). **Energy from consolidated organic or non-organic material**: 110 000 sej/J - average of interval values specified by Odum (1988). **Electromagnetic energy**: 140 000 sej/J - estimation of energy position according to Ohta (1994), approximation of the value according to the interval specified by Odum (1988, 1996). **Electricity**: 170 000 sej/J - average of interval values specified by Odum (1996). Services (human services): 2 500 000 000 sej/J (average of interval values after Odum (1988). Information: 5 000 000 000 000 sej/J (average of interval values after Odum (1988).

2.3 Eco-criterion 2: Material waste eco-quality

Eco-criterion for evaluating material operand transformations that are non-intended secondary outputs from technical process, (e.g. waste and pollutants) is defined according to the waste management hierarchy established by EC Waste Directive (European Commission, 2008). Waste hierarchy is a list of options to treat waste of which the top waste treatment practices are preferred, and the bottom should be avoided. Waste eco-quality hierarchy is composed of levels of waste toxicity degrees and end of life treatment, which are adopted from the work of Hill (2004) and Allione et al. (2012).

Table 3. Waste eco qualities of operand secondary outputs from the technical process

<table>
<tr><td rowspan="2"></td><td colspan="3">Eco-quality of waste outputs</td></tr>
<tr><td>High</td><td>Medium</td><td>Low</td></tr>
<tr><td rowspan="4">Waste attributes</td><td>No waste or inert waste (small volume and toxicity)</td><td>Potentially recyclable (with low and medium effort)</td><td>Energy recovery (high effort)</td></tr>
<tr><td>Biodegradable or biocompatible renewable resource</td><td>Biocompatible and compostable (bio gasification, biofuel production)</td><td rowspan="3">Landfill disposal:
- Toxicity: Low, medium, high
- Waste Maintenance: low, medium and high
- Resource: renewable or non-renewable</td></tr>
<tr><td>Re-use</td><td rowspan="2">Energy recovery (low and medium effort)</td></tr>
<tr><td>Recycle</td></tr>
</table>

3 ECO-TRANSFORMITY APPROACH TO ECO-EVALUATION

The proposed approach is demonstrated by analysis of three conceptual variants for laundry cleaning. The conceptual variant A represents the conventional laundry washing conceptual solution implemented in most household washing machines. Laundry is first soaked so to loosen the dirt from the textile fibers. Then, by using detergent or soap, chemical energy is released to dissolve the dirt. Laundry is rinsed off with new water or is drained by using centrifugal force of the drum (Figure 1).

The technology of ultrasonic cleaning is utilized in laundry cleaning conceptual variant B. Cavitation effect is produced by the ultrasound wave in the liquid medium and assisted by the vibrating plate. Laundry is guided on the conveyor. The described laundry washing system is patented and results from prototype testing are published (Gallego-Juárez et al., 2010).

Polymer beads perform the conceptual variant C implements laundry cleaning solution where mechanical action is produced by the centrifugal force of the drum and laundry cleaning. Only small amounts of detergent and water are required to aid the process of cleaning, so laundry is cleaned, not washed as in concept variants A and B. This conceptual variant is implemented in a commercially available product of the company Xeros (2015). Polymer beads are reusable and recyclable.

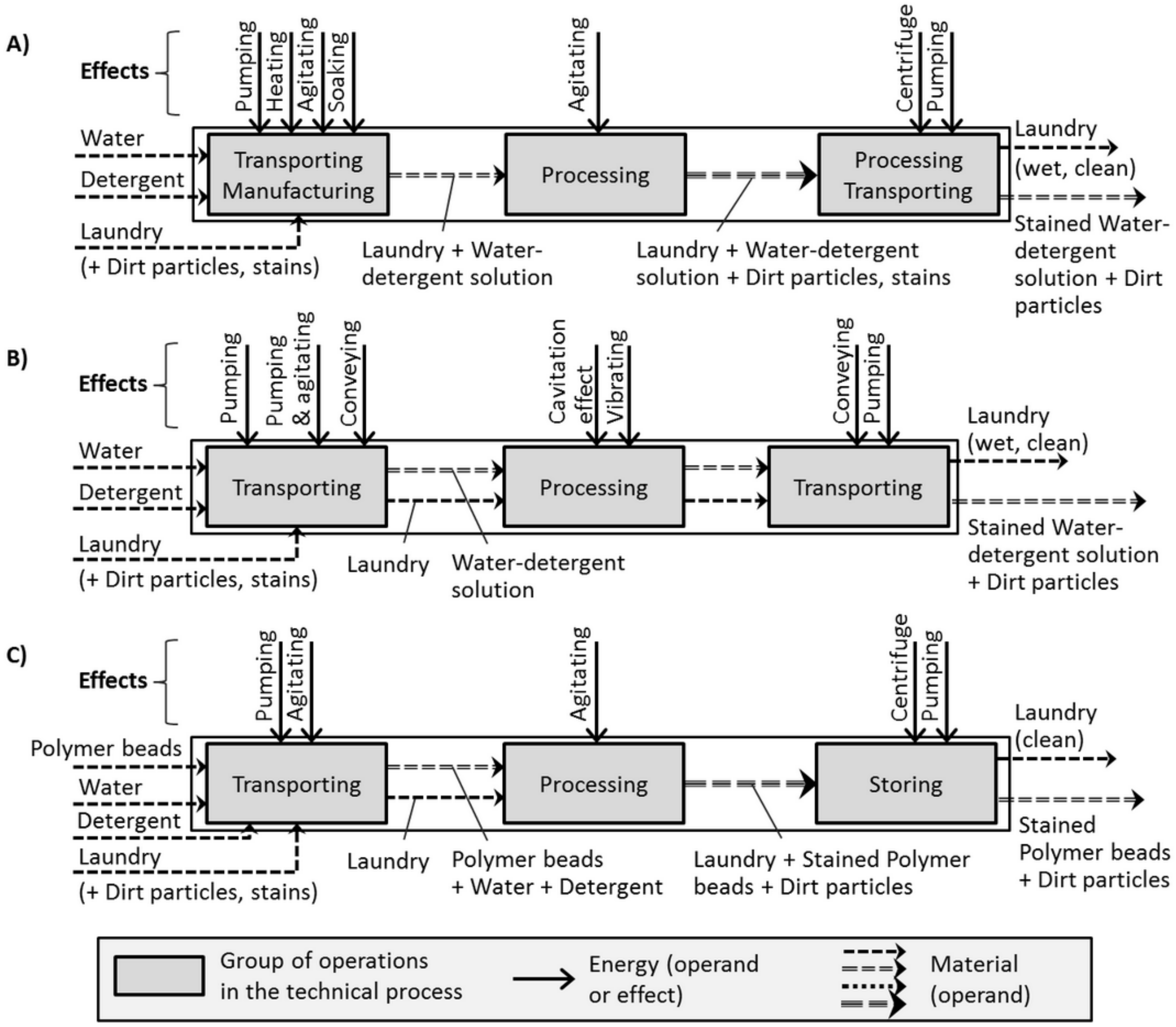

Figure 1. Technical process of laundry cleaning: concepts A, B and C

The structure of the technical process consists of partial processes (*operations*) and intermediate states of *operands*. Characterization of technical processes can be performed according to the type of operations: transformation of structure – *Processing*, transformation of form – *Manufacturing*, transformation of space coordinate – *Transporting*, and transformation of time coordinate – *Storing*. Technical system supplies the effect via it is internal transformation process. Energy conversions, thus the chains of energy conversions resulting in the final effects, are subjected to eco-evaluation.

Table 4. Energy form conversions performed by the technical system for acquiring effects, transformations of operands and waste outputs from the technical process

Concept A
Pumping water (EE → ME → ME) **Heating** water (EE → EM → TH), latent effect: heat (TH) **Agitating** water with detergent (EE → ME → ME), *operand state change* (detergent: solid → liquid) **Soaking** laundry with water-detergent (EE → ME → ME)
Mechanical agitation of laundry (EE → ME → ME), detergent → CH (ECONM → CH)
Centrifuge, draining laundry (EE → ME → ME) **Pumping** dirty water-detergent solution (EE → ME → ME)

Waste: water-detergent & dirt (landfill disposal: low toxicity)	
Concept B	
Pumping water (EE → ME → ME) **Pumping** liquid detergent & **agitating** with water & laundry (EE → ME → ME) **Conveying** laundry (EE → ME → ME)	
Cavitation effect (EE → ME → ME to laundry), latent effect: cavitation noise detergent → CH (ECONM → CH), latent effect: effect of sonication on detergent **Vibrating** laundry (EE → ME → ME to laundry)	
Pumping dirty water-detergent solution (EE → ME → ME), *Waste*: water-detergent & dirt (landfill disposal: low toxicity) **Conveying** laundry (EE → ME → ME)	
Concept C	
Pumping polymer beads (EE → ME → ME) **Agitating** with detergent and water (EE → ME → ME)	
Mechanical agitation (EE → ME → ME) Polymer beads → ME (ECONM → ME), detergent → CH (ECONM → CH)	
Centrifuge, draining laundry (EE → ME → ME) **Pumping** dirty polymer beads (EE → ME → ME) *Waste*: polymer beads (reusable, recyclable), water-detergent & dirt (landfill disposal: low toxicity)	
Legend: EE – Electrical energy, ME – Mechanical energy, EM – Electromagnetic energy, TH – Thermal energy, CH – Chemical energy, ECONM - Energy from consolidated organic or non-organic material.	

Transformity effectiveness is defined in this work as a ratio of transformity value of output energy form (of the corresponding energy, material, information operand or effect) and transformity value of input energy form (of the corresponding energy, material, information operand or effect).

$$\eta_{TR} = \frac{TR_O}{TR_I} \quad (1)$$

where η_{TR} is the transformity effectiveness of energy transformity conversion process. TR_I is transformity value of input energy form of the energy, material, information operand or effect that is transformed into the desired energy form (TR_O), e.g. the output energy form of the energy, material, information operand or effect. Transformity effectiveness is defined as energy, material or information conversion eco-quality and is based upon theoretical ecological quality of energy forms – solar transformity. Transformity values in Table 2, expressed in units solar emjoules per joule are used for calculating transformity effectiveness of: a) energy form transformations supplied by technical system to acquire the effects to the technical process, and b) energy form transformations of operand transformations in the technical process. Transformity effectiveness calculations are noted in Table 5.

Table 5. Transformity effectiveness of energy conversions

Energy conversions	Transformity effectiveness (%)
Electromagnetic to thermal	7
Energy from consolidated organic or non-organic material (detergent or water-detergent solution) to chemical	13
Electric to mechanical	20
Energy from consolidated organic or non-organic material (polymer beads) to mechanical	26
Electric to electromagnetic	64
Mechanical to mechanical	100

According to the maximum power hypotheses about maximizing useful emergy flow (emjoules per time), alternatives with higher transformities are more desirable (Odum, 1996). Inspired by that claim, chains of energy form transformations with higher transformity effectiveness are considered to be more desirable alternatives to requiring the desired effects. Transformity effectiveness is low in the cases when higher transformity input energy forms are used to attain lower transformity energy forms that comply to the theoretical assumed preferable energy form transformations described by Odum's (1988) and Ohta's (1994) hierarchies of energy form quality. Transformity effectiveness relates to theoretical geological and biological capacity of the Earth to drive the transformation processes and support energy conversions. Environmentally favorable energy conversions are those with higher values of transformity effectiveness.

Waste eco-quality criterion is composed according to waste management hierarchy 'reduce, re-use, recycle, energy recovery, treatment, disposal' (European Commission, 2008). Waste hierarchy and the approach does not allow for detailed analysis of waste treatment options and costs, but are defined as a qualitative criterion and a list of guidelines for assigning scores.

There are several limitations of the proposed eco-evaluation approach:

1. Eco-transformity approach to product concept eco-evaluation lacks holistic life cycle perspective. The proposed approach is not purposed for product eco-evaluation, but eco-evaluation in conceptual design phase. Factors that significantly influence product's overall environmental friendliness and that are not addressed in this work and by the proposed approach:
   - Key aspects of product's environmental impact in the use phase (e.g. energy and water consumption throughout operational life phase, impacts due to transport and maintenance).
   - Environmental impacts from the supply chain, material production, and product manufacturing life phases.
   - Environmental impact at the end of life (disposal, remanufacturing and other)
2. No support for identification of product's environmentally critical life phase and the appropriate ecodesign strategy.
3. Limitation regarding using the approach for eco-evaluation of products with the majority of environmental impact expected in material acquisition life cycle phase. Environmental impact for those products is revealed in embodiment design phase.
4. At the moment, there is no support provided for eco-evaluation of latent side effects from the technical system or latent side effects and disturbances from the technical process.
5. The proposed approach to eco-evaluation does not take into consideration possible environmental, cost or other trade-offs and do not provide solutions for resolving the conflicts. Instead, the approach can be used for identifying environmental hotspots of conceptual solutions and their technical processes.

4 DISCUSSION AND FUTURE WORK

Detailed information is required for calculation of product's environmental impact; information about product's life cycle (material and energy flows in material acquisition, production, transport and distribution, use and end of life phase), embodiment solutions, product's features and properties. Re-designed products share crucial characteristics with their predecessor products, which makes them easier to compare and eco-evaluate in conceptual design phase. Similarities between re-designed product and its predecessor can be found on many aspects such as costs, life-cycle performance, and environmental impact. Performing environmental assessment and evaluation of those product's concepts does not bring extra challenges, as is the case with comparison and eco-evaluation of original design concepts and their technical solutions (Fitch and Cooper, 2005).

Transformity effectiveness proposed in this work is an environmental qualitative criterion to be used in conceptual design phase of the design process. The proposed approach is based on eco-evaluating energy, material and information transformations described by the technical process and internal technical system's transformation process. There are a lot of controversial issues tied to the concepts of emergy, 'available energy' and transformity (Cleveland, 2014). They are introduced for the purposes of quantitative energy accounting and audits of ecosystems bounded by geographical, time and other system boundaries. Transformity values are calculated by Odum (1988, 1996) through complicated procedures. It has not been able to repeat those calculations and in that way validate transformity factors.

Grandjean et al. (2011) performed energy consumption end-use analysis of conventional washing machine. Electrical power demands peaks noticeably during water heating in regular washing cycle. Comparison can be made with energy conversion efficiency factors specified by Ashby (2013). Electric to thermal energy efficiency (indirect energy conversions) is defined to be 100% (latent heat included). Qualitatively assessed, this energy conversion efficiency is excellent. Transformity effectiveness of the same theoretical conversion (without intermediate conversion to electromagnetic energy) equals 5%, qualitatively assessed - environmentally unfavorable energy conversion. Gallego-

Juárez et al. (2010) compared their ultrasound washing prototype to the conventional washing machine. Some general conclusions about energy, water, and detergent consumption can be are made, but more elaborated environmental performance analysis is needed. The same is with Xeros's polymer beads cleaning concept (2015).
In order to resolve the problem of performing qualitative eco-evaluation according to criteria proposed, a dimensional analysis is required. Coatanéa (2005) and Medyna (2013) demonstrated the use of dimensional analysis for early design eco-evaluation purposes. Quantification of operands and effects would enable that a qualitative grade is assigned to partial operations in the technical process and to establish an aggregated grade to effects supplied by the technical system.

5 CONCLUSION

Products are viewed as technical systems in this research, e.g. suppliers of effects to the technical process (Hubka and Eder, 1996). Proposed eco-evaluation in the conceptual design phase is performed by qualitatively assessing energy transformation qualities of effects supplied by the technical system, energy, material and information transformations defined in the technical process and eco-evaluating the type of waste outputs from the technical process. *Transformity effectiveness* and *waste eco-quality* are proposed as qualitative environmental criteria. *Transformity effectiveness* eco-criterion is based on the concept of solar energy conversion factor that is used in the analysis of ecosystems and energy conversion systems. Assumption that energy conversion quality (according to the adopted concept of energy form quality) is an indicator of environmental friendliness is based on the maximum power hypothesis (Cai et al., 2004) and the work of T. Ohta (1994) and H. T. Odum (1988, 1996).
Disadvantage of the proposed eco-evaluation approach is that it does not include life cycle aspects of concepts included, but only useful (operational) life aspects which can be influenced by the selection of the technical solution and technological principle of the product. Procedures for aggregation of values according to multiple environmental friendliness criteria have not been defined up to this point of the research. Also, latent side effects from the technical system and disturbances from the technical process have not been evaluated.
Most products (technical systems) that are developed and considered in engineering design field are electro-mechanical, so calculation of energy conversion quality may lead to obvious conclusions about environmental friendliness of energy conversions (electrical to mechanical energy and effects).
Eco-evaluation approach and criteria presented in this work will be improved further. A dimensional analysis will be performed to allow for qualitative comparison and eco-evaluation of conceptual design of the technical system and technical process. Effectiveness and efficiency of the improved approach will then be compared to qualitative and semi-quantitative ecodesign methods purposed for eco-evaluation in conceptual design phase.

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