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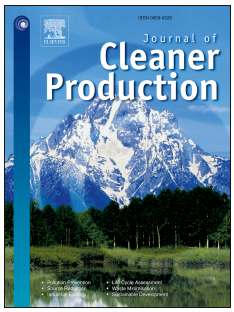

A survey of perceived prevalence of selected environmental topics in product development, and their relationships with employee's ecological concern

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Abstract

Activities to advance circular economy are accelerating, and ecodesign has been mentioned as a necessary ingredient for their success. These activities might be further accelerated with more shared understanding of the related terminology. Many of these suggested activities take place in companies' product development where employees should implement them, including that of ecodesign. Employees' interpretation of enhancing practices are assumed critical in supporting the implementation. A survey using a judgmental nonprobability sampling is used to assess the perceived level of selected environmental topics in the product development contexts, and how these are associated with perceived ecodesign practices in product development. One focus is on how the perceived durability considerations might be linked with these practices. Furthermore, the paper contributes to the discussion on the soft-side of ecodesign by examining how one human factor - ecological concern - might be associated with these perceived activities.

Highlights

- Empirical study deepens insights within the soft-side of ecodesign
- Durability considerations do not correlate with lifecycle thinking
- Ecological concern correlates with perceived level of few ecodesign practice
- Ecological concern and durability correlate with each other

Keywords

Ecodesign, durability, ecological concern, circular economy, product development

1. Introduction

In recent years circular economy has emerged as an umbrella concept to debate potential options for more sustainable futures for societies (Blomsma and Brennan, 2017; European Commission, 2018a). In the circular economy debates, the central idea is to keep both products and materials in the circle for as long as possible in order to retain their value added. Although the concept may first sound compelling, concept's fully realization has been questioned among others due to concept's association with cradle-to-cradle concept and perception of unlimited growth if it were fully realized (Bjørn and Hauschild, 2013; Hauschild, 2015). Concept has also been challenged for its measurement hurdles (European Commission, 2018a, 2018b; Haas et al., 2015), and by indeed its realization necessitating fundamental changes for the underlying logic of conducting business (European Environment Agency, 2017; Stahel, 2016).

Notwithstanding, various concerted efforts are under way. In European Union (EU) level, a recent circular economy roadmap is closely linked with job creation, and

innovation after initial focus on concept's environmental aspects only (European Commission, 2018a, 2017). This coincides with Stahel (2016) who pointed out the need for more manpower as a result of more circular use of resources in 1970's. Similarly, Sitra, a Finnish government think tank, has helped to establish a road map endorsed by Finnish parliament towards a circular economy not only spearheading in environment, but also in innovation and job creation (SITRA, 2016).

In these macro-level discussions, ecodesign has been raised as one way to enhance path toward circular economy, and more binding measures seem to be emerging in the European level (European Commission, 2018c). Indeed, it would be necessary to engage companies in the meso-level to make their value chains circular; including that of applying ecodesign. The product development in this paper is understood broadly as both the managerial and operational practices and processes that are needed to bring an idea into a form ready for sale (Ulrich and Eppinger, 2012). And with eco-design it is meant that environmental considerations are explicitly taken into account within these practices and processes considering the lifecycle of the product (Hauschild et al., 2005; Pigosso et al., 2013; Rousseaux et al., 2017).

Considering the above, ecodesign seems to fit with the circular economy ambitions; yet bringing these ambitions into practices and processes is not easy. Among others, Stahel (2016) reminds that indeed the aforementioned two circularities - products and materials - yield fundamentally different business models; and hence, they would lead to different implementation approaches towards the circular economy (Fig.1.). A different impetus would be provided to the product development if it were explicitly chosen to seek value in material instead of product circularity (European Environment Agency, 2017, p.23-24). Thus, the underlying reasons to potentially pursue ambitions towards circular economy should be carefully assessed to find a shared understanding also in the context of product development (cf. The British Standards Institution, 2017).

<<<INSERT FIGURE 1 HERE>>>

Furthermore, research shows that there remains room for improvement in implementing ecodesign in practice despite more than two decades of abundant, and solution-driven research (Baumann et al., 2002; Bey et al., 2013; Deutz et al., 2013; Johansson, 2002; Rousseaux et al., 2017; Short et al., 2012; Sihvonen and Partanen, 2016). However, discussion differs about what should be implemented and to what extent it should be implemented in order to classify as adequately implemented, although the role of early product development phases are considered pivotal (Boks and Stevels, 2003; Dekoninck et al., 2016; Lindahl, 2005; McAloone et al., 1998; The British Standards Institution, 2017). For example, one French study (ADEME, 2010; Rousseaux et al., 2017) reports that while one in five companies applied structured ecodesign practices for all their products, an additional 13 percent were in progress of doing so. But, a further 22 percent of companies did not consider it relevant and further 16 percent did not feel being concerned as they did not develop product themselves. Another study from all European countries reports that while on average 49 percent of larger companies claim to offer green products or services, only 24 percent from the Small and Medium sized enterprises (SME) are reporting the same. In addition, 63 percent of SMEs are not even planning to do so in the next two years (TNS political & social, 2018). In the context of this research: approximately half the

Finnish SMEs (53%) are not planning to offer green products or services during the next two years, while almost forty percent (38 %) are already offering them (ibid.).

Thus, despite progress being made, more is needed to advance ecodesign further within companies' product development. One approach could be to better understand the role of human factors in the micro-level (Boks, 2006; Brones and Monteiro de Carvalho, 2015; Dekoninck et al., 2016; Stevels, 2016, p.45). These human factors within soft-side of ecodesign have been raised as an intriguing, yet an emerging topic (Boks, 2006; Brones and Monteiro de Carvalho, 2015; Dekoninck et al., 2016; Stevels, 2016, p.76). So far, research into human factors have approached them from the company point of the view, and less from the individual level (Brones et al., 2017). The attempt in this paper is to fill this void by focusing on one human factor: ecological concern of employees working with product development. Ecological concern, or New Ecological Paradigm (NEP)(Dunlap et al., 2000), has been extensively used in the field of environmental sociology to examine the ways in which it may be linked with values, attitudes or behaviors (see reviews Dunlap et al. (2000), Hawcroft and Milfont (2010)). In recent years, research into examination of NEP's potentiality to have an impact also within organizations have gained more interest (Jansson et al., 2017; Lau et al., 2016). However, to our knowledge, no published studies on NEP exist among people working with product development, apart from Sihvonen and Partanen (2016).

The research objective in this paper is to examine employees working with product development in order to determine to what extent they perceive that environmental considerations are embedded in their respective product development contexts. Secondly, it is examined to what extent one human factor, ecological concern, may be related to these perceptions.

This research contributes to the knowledge by studying quantitatively the prevalence of selected environmental topics in the product development. For instance, the discussion on durability is expanded by these results. This research details further one human factor within soft-side of ecodesign and examines the ways this may be associated with the perceived extent of ecodesign practices, and these environmental topics. To do so, an established quantitative measurement from environmental sociology domain, with plentiful published results among civil society, students and citizens, is tested in the product development context (Dunlap et al., 2000; Hawcroft and Milfont, 2010). The study extends the results from the overall level of environmental considerations in product development practices reported earlier in Sihvonen and Partanen (2016) by analyzing further the measure to assess ecological concern, and by reporting the results from the perceived prevalence of selected environmental topics.

The remainder of this paper is structured as follows. Background chapter discusses examined topics using classic *causas* to frame discussion. This is followed by chapter on research methodology continuing then to report results from the survey. Paper ends with first discussing results reflecting literature, limitations, and then providing concluding remarks including contribution to the knowledge, and ideas for further research.

2. Background

Various approaches are called for to advance discussion on ecodesign (Boks and McAloone, 2009). Discussion in this paper is organized around *classic causas* to contextualize the emergence of Voice of the Environment for the Circular Economy (adapted from (Hart and Dowell, 2011). *Classic causas* by Aristotle allow approaching a given topic from four perspectives: *causa finalis, causa formalis, causa materialis, causa efficiencis* (Saarinen, 1997, p.54-56). Proxies for the last two are examined in this paper. Examples of related research is visualized accordingly in Figure 2.

<<< INSERT FIGURE 2 HERE >>

In the context of this paper, *causa finalis* could be company's sustainability strategy with an explicated overall approach towards circular economy discussed in the introduction. Then, *causa formalis* could be a choice from various EoL, or ReX (Sihvonen and Ritola, 2015), strategies available for a forthcoming product in order to reach the chosen *causa finalis*. *Causa materialis* could then refer to what is done to achieve *causa formalis* whereas *causa efficiensis* would be those actors needed to effectuate such doings. This chapter discusses these two starting with *causa materials* and concluding with potential determinants influencing taking action at micro- and meso-levels, as examples of *causa efficiencis*.

However, before choosing *causa materialis*, it is argued that it would be useful to spend enough of time to discuss and debate about the choice for the *causa formalis* in the context of the company's product development: prioritizing more material circularity over product circularity, vice versa, or something in between (Fig.1.). This might partly avoid dilemmas in later phases of product development (Prendeville et al. (2017). The need for such a discussion in the early phases of product development stems from the understanding that such a choice may potentially influence among others the business logic including the value chain structures (The British Standards Institution, 2017). Put it differently, according to Markides cited in (Niinimäki, 2011, p.272), such a choice may change fundamentally a logic who is the customer, what company is selling, and indeed, who are partners with whom this is achieved. For example, 26 percent of Finnish SMEs are having challenges to choose between resource efficiency actions and that for example, reusing materials or waste within companies is practiced less often than on average in EU (31% vs. 42%) (TNS political & social, 2018).

2.1. Selected environmental topics as *causa materialis*

One iterative step needed to implement any of the chosen *causa formalis* is to consider environmental topics, and their related impacts relevant to the company context throughout the lifecycle of company's products. Broadly speaking lifecycle could refer to only three phases: pre-use, during use, and post-use (Luttropp and Lagerstedt, 2006). However, this simplification undermines the length of global value networks, both up- and downstream, whereas it emphasizes equal importance of considering each phase. Namely, this may not always be the case in companies: For instance, interviewed SMEs in one study did not consider post-use to be their responsibility (Van Hemel and Cramer, 2002). On the other hand, Lansink (2014)

argues that specially the prevention during the pre-use might be less of interest for the companies.

Table 1 illustrates examples of overall environmental topics, that would differ in details, to consider in product development. Boks and Stevels (2007) suggest customization in this stage due to industry, and company specific characteristics. Researchers argue that basically three environmental impact areas cover most of the environmental issues within electronics industry (ibid): potential toxicity of materials used, understanding the resource depletion, and amount of emissions generated. Also, industry-generic approaches are proposed although similarly acknowledging that these should be customized later. For instance, Telenko et al. (2008; 2016) argue in favor of positive terminology and propose to compile environmentally related topics by categorizing them under six strategies from developer's perspective.

<<< INSERT TABLE 1 HERE >>>

Table 1. Selected examples of environmental topics supporting ecodesign implementation.

The Ten Golden Rules (Luttropp and Lagerstedt, 2006)	Six design for environment strategies grouping 76 guidelines (Telenko et al., 2016)	Six operational strategies grouping 35 guidelines (Pigosso et al. 2013)
"1. Do not use toxic substances and utilize closed loops for necessary but toxic ones--- *2. Minimize energy and resource consumption in the production phase and transport through improved housekeeping---* *3. Use structural features and high-quality materials to minimize weight—* *4.Minimize energy and resource consumption in the usage phase—* *5.Promote repair and upgrading, ---* *6.Promote long life---* *7. Invest in better materials, surface treatments or structural arrangements ---* *8.Prearrange upgrading, repair and recycling through access ability, labelling---* *9.Promote upgrading, repair and recycling by using few simple recycled, not blended materials and no alloys--* *10.Use as few joining elements a possible ---"*	*"A. Maximize availability of resources* *B. Maximize healthy inputs and outputs* *C. Minimize use of resources in production and transportation* *D. Minimize consumption of resources during operation* *E. Maximize technical and esthetic life of the product and components* *F. Facilitate upgrading and reuse of components"*	*"1. Minimize energy consumption* *2. Minimize material consumption* *3. Extend material life span* *4. Optimize product life time* *5. Select low impact resources and processes* *6. Facilitate disassembly."*

There exists ample amount of ecodesign guidelines, methods and tools to examine these environmental topics (Baumann et al., 2002; Bovea and Pérez-Belis, 2012; Luttropp and Lagerstedt, 2006; Peeters and Dewulf, 2012; Pigosso et al., 2013; Telenko et al., 2008). For example, Rousseaux et al. (2017) find almost 630 tools of which majority support diagnosing which environmental topics to consider and ways to act upon found information, whereas much fewer tools are focused on managerial and communication aspects. Also, Lindahl and Ekerman (2013) suggest a practical selection criteria for attributes in order to better choose a tool. Foremost, Lindahl (2005) argues that tools should be easy to use and understand, and that they should not take much time to learn. It is reasoned similarly that even understanding environmental topics should be enhanced in early product development phases in which little might be known about the product's forthcoming characteristics, and

common language is sought for (Boks, 2006; Stevels, 2016). To provide an example, durability, as one potential environmental topic, is discussed next among others due to its existence within circular economy (Dalhammar, 2016; European Commission, 2017, p.5) and ecodesign debates.

Term durability originates from Latin through *durabilis* meaning 'to last', and *durus* 'hard'(Oxford living Dictionaries, 2017). Within ecodesign it may refer, for instance, to various activities that make products last longer in use from first to last beholder of a product (Bakker et al., 2014). One approach to categorize these activities could be to assess product development activities by the company creating a product, and hence influencing forthcoming product's characteristics. Another approach might be to examine what does the user do, or not, to enhance product's longevity in use (Brook Lyndhurst Ltd, 2011, p.24). Former approach is applied in this paper with a focus on the activities within product development.

In the product development, the way durability is understood influences what key issues are identified to be important and how they are prioritized (Ardente et al., 2012, p.17). For instance, ensuring appropriate durability may be understood as activities aiming to ensure longevity of product's material properties or its intended functions (Ardente and Mathieux, 2014). In the first circular economy framework for organizations, durability is defined as "*maximum potential lifetime of a product, component or material to perform a required function under intended conditions of use and maintenance for a long period of time before it becomes obsolete because it can no longer be repaired and/or upgraded*."(The British Standards Institution, 2017, p.11)

Durability could also be understood as emotional durability that seeks to enhance the person's relationship with a product through understanding and consequently ensuring the dimensions of attachment and satisfaction in relationships with a product to last longer (Niinimäki, 2011), such as feeling good within emotional functionality dimension (Stevels, 2016). Example of such an attempt to increase emotional attachment would be, for instance, the wooden framed computer that would increase the tactile pleasure derived from touching the product (Fitzpatrick et al., 2014). In the updated categorization for ecodesign strategies, Telenko et al. (2016) have also taken these two ways to understand durability into account: researchers have changed wording from "*ensure appropriate durability of products and components* " into "*maximize technical and aesthetic life of the product and components*" (Table 1). Researchers further add two principles under this strategy to ensure equal length of both technical and aesthetic durability, and also to consider ways to "*increase value with age*". So, perhaps "brand-old" product, or a "brand-renewed" as Hood (2016) puts it, could be envisioned as a compelling outcome from the product development project instead of "brand-new" in the future?

But, as mentioned earlier, contradictions may arise depending whether circularity of materials or products are chosen. Choosing more durable materials for extending longevity during product's use might contradict the possibilities to recover materials later (Prendeville et al., 2017). Or, ensuring compatible material mixtures at post-use phase might pose challenges to the longevity during the use phase. As an example, Parajuly et al. (2016) demonstrate how recovery activities are hindered by un-aligned wire positions and incompatible materials in an emergent product category of robotic

vacuum cleaners. This result highlights the on-going need to continue discussing the issues many of which were introduced already in the 1990's (Boks and McAloone, 2009; Boks and Stevels, 2003; Hauschild et al., 2005; Vanegas et al., 2017).

It is insightful to consult regulatory frameworks for currently agreed shared understanding related to overall understanding of durability dimensions. While lifecycle is used in the three aforementioned framework directives, durability or durable are words sparingly used, if at all. In the Waste Directive, durability is however clearly indicated to denote "technically durable", or the most prioritized alternative target among alternatives for re-usable or recyclable products. Then, instead of durability, "extension of life time" is used in the EUP Directive. Interestingly, in argumentation section for the WEEE Directive term "EEE with a long lifecycle" is used. But, as the directive indicates lifecycle to mean several stages, it is not necessary clear which part of the lifecycle would be expected to be long.

Moreover, Bundgaard et al. (2017) point out that durability, as part of the resource efficiency efforts, is not necessarily seen desirable by the industry. Researchers argue that it should be incorporated within regulatory spaces as otherwise industry would not integrate durability aspects into self-regulatory mechanisms. Authors arguments are based on two case studies analyzing regulatory development on imaging equipment and vacuum cleaners in European Union. This seems to contradict somewhat the findings on generic positive attitude toward durability by industry based on qualitative interviews in another study (Dalhammar, 2016). Another study finds that only 15 percent of SMEs in Finland plans to "*design products that are easier to maintain, repair or reuse*" in the next two years, whereas 23 percent are currently doing so (TNS political & social, 2018). On the other hand, yet another study finds that 30-40 percent of larger companies globally are engaged with extending the lifespan of their products (Ghosh et al., 2017).

Two environmentally loaded topics - lifecycle and durability - are two topics assumed to provide profound leverage for strategies geared toward circular economy. Also, these two topics are usually discussed together, or even considered almost as intertwined as mentioned by one of our reviewer. For instance, conceptually, Pigosso et al. (2013) places activities to implement lifecycle thinking as an example of ecodesign management practices, while prolonging lifespan of material or products are categorized as examples of operational practices. Similarly, durability aspects appear to be an aspect embedded in the ecodesign guidelines targeted for people working in such processes (Table 1). On other hand, Tecchio et al. (2017) place "extend the lifetime" among the overarching policy goals for material efficiency, while durability is placed as a topic within the material efficiency.

This section sought to explicate that discussion continues on how to categorize different environmental topics, such as durability, and non-exhaustive lists in Table 1 is just one of many to this end. Next, examples are discussed on selected actors within product development that are needed to effectuate these *causa materialis*.

2.3. Selected micro- and meso-level perspectives as *causa efficiencis*

Micro- and meso-levels are applied to examine *causa efficiencis*, which are needed to implement the aforementioned *causa materialis*. This is based on understanding that

while individuals in micro-level implement the environmentally benign actions together with other members in the product development team and beyond, these actions may be constrained by the organizational context in the meso-level. This emphasizes the need to understand the ways individuals, teams, organization levels interact with each other to better effectuate change toward sustainability(Lozano, 2014; Ramus and Killmer, 2007).

Organizational contexts that support environmentally benign processes and practices in the meso-level may also be examined from various perspectives, such as organizational culture or change management (Ali et al., 2016; Brones et al., 2017; Verhulst and Boks, 2012, 2010). Building upon these, and emphasizing the process perspective (Cooper and Edgett, 2012; Deutz et al., 2013; Short et al., 2012), more explicit processes for environmental considerations are assumed to enhance their uptake in product development. Ideally, implementation of environmental considerations would be perceived at least 'need to have' instead of 'nice to have' within these processes and practices (Magnusson and Johansson 2006).

Individuals act as members in the product development teams constrained by the organizational contexts and their own mental models. Building blocks for mental models may include among others personal values, beliefs and attitudes (cf. Senge, 2006, p.163). While values could be seen as any topic that individual considers important, beliefs are about the strength in agreeing that a relationship between specific topics is true. And then attitudes could be seen as favorable or non-favorable approaches, for instance toward these beliefs.

As these mental models in micro-level are assumed to govern the perceived reality, they are also expected to govern the actual behavior (Senge, 2006, p.163). For example, mental models are argued to provide rules for decisions, such as potentially simply comprehending the assumed time needed in a specific product development stage differently from others in the very same product development project (Ford and Sterman, 1998; Senge, 2006).

Some micro-level perspectives are discussed also within ecodesign, although somewhat less than meso-level ones (Sihvonen and Partanen, 2016). For instance, the theory of applied ecodesign (Stevels, 2016) is broadly built on the interplay between actual practices to find and implement environmentally sound solutions, and the role that individuals' attitudes play in their implementation along internal value chains within organizations. In a similar vein, Handfield et al. (2001) and Boks (2006) note the differences between opponents and proponents while Short et al. (2012) reason that existence of individual's risk-avoidance hinders the uptake of sustainable practices in product development.

Sometimes micro-level issues are revealed while studying issues from a meso-level perspective. For instance, in one recent article researchers reframe their suggested theoretical framework on ecodesign by adding motivational factors influencing the employee's interest to engage with ecodesign (Dekoninck et al., 2016). Article's theoretical premises are mainly taken from the meso-level perspectives, but researchers' qualitative interviews highlighted a need to add this micro-level dimension into the suggested theoretical framework. This supports the soft-side of ecodesign perspective in which it is argued that "*the role of communication,*

language, personal views and objectives should be over- rather than understated" (Boks, 2006).

Lenox and Ehrenfeld (1997) posit that organizations' environmental design capabilities reside in their processes to communicate, create knowledge structures, and to interpret environmental considerations as necessary ingredients of their product development processes bringing ideas to market readiness (Lenox and Ehrenfeld, 1997; Ulrich and Eppinger, 2012). In other words, researchers suggest a definition for environmental design capabilities in meso-level. But it is individuals that are assumed to be the vital micro-level constituents in accumulating such ecodesign capabilities in meso-level. Hence, these same capability dimensions could also be used to examine micro-level perspective acknowledging the aforementioned views related to human factors. As an example, interpretative structures proposed by Lenox and Ehrenfeld could then be approached with individual's mental models about a topic or behavior including the language used.

One such relevant interpretation structure in the context of ecodesign could be beliefs that people hold on the various relationship dimensions between humans and natural environment. New Ecological Paradigm (NEP) is one measure proposed to gauge such generic ecological beliefs (Dunlap et al., 2000). This measure, as a proxy for ecological worldview according to Dunlap et al. (ibid.), seeks touching the core of individual's beliefs to these various relationships. Agreement to items, such as potentiality of limits of growth, potentiality of eco-crisis, potential fragility of nature's balance, and the potential dominant interplays of humans over nature, are expected to reveal these generic beliefs about the relationships between humans and natural environment (ibid.). For example, one item asks about considering the earth as a spaceship apparently stemming from the early researchers on CE concept such as Boulding (1966). These beliefs are expected to evolve slowly through continuous interactions with constrained external environment, and furthermore; albeit of their generic nature these beliefs may be further related to more specific environmental topics (Stern, 2000; Stern et al., 1995).

NEP's potentiality to influence actual awareness of environmental considerations, or related behaviors, within organizations might provide interesting insights into the soft-side of ecodesign domain. However, the link between NEP and actual behavior has provided varying results among employees in private organizations (Kindly see supplementary material online). For instance, Temminck et al. (2015) note a link between increased ecological concern, and employees' engagement in voluntary pro-environmental behaviors. To the best of our knowledge, no results have been published on the potential relationship of NEP in the context of product development apart from Sihvonen and Partanen (2016) in which it is reported that NEP seems to be associated mainly with generic management processes for environmental considerations in product development. Yet, a hint toward this perspective is provided for example in Short et al. (2012): This research indicates that approximately third largest reason to engage with Design for Sustainability is "own belief", although the content of this belief is not further elaborated in the survey itself but through interviews that indicate a belief toward sustainability issues. On the other hand, for instance, Lau et al (2016) find that a NEP factor denoting a "humans over nature" emerged while examining the structure of NEP among project managers within construction industry in Malaysia. This result would suggest a potential path to

examine the proponents and non-proponents within organizations (Boks, 2006; Handfield et al., 2001). We use term ecological concern to denote these generic beliefs measured with NEP.

So, we argue in this paper that understanding these micro-level perceptions might positively explicate underlying thinking premises enhancing for instance, circular economy related discussions during the product development. We contend that mental models govern the language used to describe for instance intended ReX strategies, and suggest that by understanding these mental models more explicitly would allow their expansion (Senge, 2006, p.166). As a recent example, a suggestion for "circular mindset" seemingly seeks to gauge this same need to explicate, although this suggestion seems to be targeted more to the meso-level activities apart from the name (World Business Council for Sustainable Development, 2017).

We embark next to explore empirically the potential bivariate relationships with the ecological concern, as one aspect contributing to the mental models in micro-level, and the perceived ecodesign practices in companies.

3. Research methodology

The overall research methodology follows iteratively a path suggested by Malhotra (2004). The path consists of formulating the research problem, and an approach to address research problem with related research questions; through literature review choosing underlying theories; deciding on research design, collecting data; preparing data for analysis, and finalizing by presenting the results. For the descriptive research design chosen in this research, quantitative research method in the form of survey is chosen mainly for three reasons: 1) to complement case studies and action research in the field (Johansson and Sundin, 2014) 2) to test NEP in the product development context; and 3) to examine the extent of ecodesign quantitatively similarly to (Deutz et al., 2013; Short et al., 2012).

3.1. Sample

Sample is derived using a justified nonprobability sampling representing respondents from organizations interested in environmental matters in Finland. Respondents from various industries, although biased toward larger companies, and metal and mining industries compared to sampling frame, answered anonymously to a web survey in 2014. Unit of analysis is individual. Final sample in this paper consists of 45 respondents, of which 60 percent have worked in product development weekly or more often during the previous 12 months. 58 percent of respondents have titles including either manager or engineer; one third titles with Vice-President, Head or Director, and 9 percent something else. Further sample and survey details are reported in Sihvonen and Partanen (2016).

3.2. Variables

Variables for *causa materialis* were derived from the literature (see Table 1, Appendix A). Mostly the following sources were consulted in selecting the potential environmental topics: The Ten Golden Rules (Luttropp and Lagerstedt, 2006), EUP Directive (European Union, 2009), and environmental principles and guidelines (Telenko et al., 2008).

Few selected product development practices were assessed as proxies for *causa efficiencis* dimension at meso-level, and how are they associated with *causa materialis*. These practices contain respondent's perception whether product development management processes include managing environmental considerations formally, as inspired by Short et al. (2012), and how frequently environmental considerations are applied in potential product development phases (Deutz et al., 2013). The role of environmental considerations as a requirement, or being at par with quality (Boks, 2006; Handfield et al., 2001) was assessed with nominal response alternatives; and categorized into two. Furthermore, two ecodesign capabilities were explored: perceived level of training for the knowledge dimension, and easiness to find information within company on environmental information for the dimension of communication.

NEP scale was used to assess interpretative structure within the ecodesign capabilities, as a proxy for *causa efficiencis* in the micro-level. NEP scale consists of 15 items that are theoretically categorized into five dimensions each containing three items that seek to capture respondent's ecological belief in terms of potentiality of eco-crisis, limits of growth, nature's fragility, anti-exemptionalism, and antianthropocentrism (Dunlap et al., 2000).

Scales used were mainly Likert-scales from one to five or seven, with an additional "not applicable" option for the selected items. Reversed questions for the selected environmental topics were retained 'as is' in subsequent analysis, while others were reversed. Kindly see Appendix A for the items examined in this paper that are not published in Sihvonen and Partanen (2016).

3.3. Statistics

SPSS version 24 was used to analyze the data. Analysis used included Spearman correlation (r) with two-tailed probabilities, as well as Mann-Whitney test (U-test) for testing the two independent samples for their potential distributional differences. Also, partial correlation is used. Statistical significance level, probability value (*p-value*), of 0.05 was applied.

In addition, factor analysis was used to examine the ecological concern. Although data is non-metric, this method has been used to study ecological concern for almost four decades (Dunlap et al., 2000; Hawcroft and Milfont, 2010). In this sample, the summated scale for 15 items reaches Cronbach Alpha 0.700 (n=45) passing just the minimum threshold for internal reliability (Hair et al., 2010, p.92), having standard deviation of 0.48, and mean 3.67.

However, acknowledging the theoretical discussion on the NEP scale's dimensionality (Amburgey and Thoman, 2012; Dunlap et al., 2000; Hawcroft and Milfont, 2010), we continued to exclude items from the original NEP scale until the statistical adequacy was reached, broadly based on Hair et al. (2010, p.103-105) and suggestion by Dunlap et al. (2000). Before conducting the factor analysis, three items were removed one at the time to reach sufficient intercorrelations over 0.500 using a measure of sampling adequacy (MSA). For the twelve remaining items, acceptable test result was reached for Kaiser-Melkin-Olkin with 0.616 categorized as mediocre according to Hair et al. (2010). Multicollinearity was checked with determinant that

reached a poor result at 0.054. Ratio of the number of observation per variables was 3.75, a result slightly below the suggested five. However, these may be accepted when conceptual structure is theoretically driven (Hair et al., 2010). Recently, such an approach has detected a group titled “denial” through a household survey conducted in the UK (Rhead et al., 2015).

We continued to examine factor analysis results with these remaining 12 items to derive the final construct for ecological concern applied in this paper. Unrotated factor solution yielded four factors that explained 60.280 percent of total variance (Appendix B). First unrotated factor constituted 26.467 percent of the variance with seven items yielding loadings above 0.500. These seven items from the first factor were chosen for summated scale (Hair et al., 2010, p.124-127) to present ecological concern with an acceptable level 0.719 for Cronbach Alpha. In addition to reporting this, one item “Earth is like a Spaceship with very limited room and resources” is separately reported due to its linkage with the circular economy discussions.

4. Results

First, results for selected dimensions as proxies for *causa materials* are reported followed by examination of proxies for *causa efficiencis*. Chapter ends with describing results for their bivariate relationships. A closer attention is given to relationship with durability and the other items examined.

4.1. Perceived prevalence of selected environmental topics

Lifecycle perspective seems to have found its place in the product development judged by the responses in the sample. Majority of respondents (89%, answers from 4 to 7 in 7-point ordinal scale, n=40/45, Fig. 3) reports that lifecycle thinking has been applied in a typical product development project during the previous 12 months, and by 22 percent of respondents to a large extent. On the other hand, approximately one in ten report the contrary, namely that lifecycle has not been considered at all or almost not at all in their product development projects during the previous 12 months.

<<<PLEASE, INSERT FIGURE 3 HERE >>>

We did not explore lifecycle item further but instead asked with a closed list of selected environmental topics that could be considered in a typical product development project. Answers provide somewhat mixed results among the respondents apart from the top three following environmental considerations (Fig. 4). Clear majority of respondents perceive (Agree strongly or mildly) that maximizing reliability (87%), minimizing hazardous substances (87%) have been considered in their typical product development projects. Third most often perceived environmental consideration is to minimize material usage with 71 percent of respondents reporting so.

Mixed results emerge for the level of respondents being either unsure or taking the view that selected environmental topic is not applicable for their typical product development project (Fig. 4). For instance, almost half the respondents perceive two items either not applicable or are unsure whether that topic has been considered in their typical product development projects. These items are considering increased recovery of plastics, and ensuring material compatibility for recovery. On the other

hand, it should be noted that the remaining respondents to these two items are more agreeing that these items have been considered, than not. Also, the perception for considerations of durability receives responses in all the six response alternatives.

<<< PLEASE, INSERT FIGURE 4 HERE >>>

Selected environmental topics correlate with each other to a varying degree, and few negatively. Highest correlations are detected with perceptions of increased considerations for recycled and renewable materials (r 0.788), and labeling with ease of material separation (r 0.541). Considering durability in a typical product development project is also positively correlated with perception of considerations for recycled (r 0.326) or renewable (r 0.400) materials. Furthermore, perceptions of considerations for durability is positively correlated with increased reporting for considering stand-by energy (r 0.333) and negatively correlated with considering reliability (r -0.391). The latter also correlates negatively with considering recycled materials (r -0.379), but then again it correlates positively with ease of disassembly (r 0.327).

Potential correlations with increased extent of lifecycle thinking and these selected environmental topics were examined next. Reporting of increased considerations for lifecycle to a larger extent in the previous 12 months correlates with reporting the perception of increased use of recycled materials (r 0.336) or minimizing the use of materials (r 0.376). Furthermore, weaker correlations (for all these items r 0.294, p-value 0.050) are detected with increased extent of lifecycle thinking and minimizing hazardous substances, or increasing recovery of metals or plastics. Among the rest of the uncorrelated selected environmental topics in the sample: the increased perceived consideration for durability does not correlate significantly with increased extent of lifecycle thinking (p-value 0.451).

4.2. Relationships with perceived prevalence of selected environmental topics and ecodesign practices at meso-level

Next, the aforementioned *causa materialis* are examined for their bivariate relationships with *causa efficiencis* at meso-level.

Those respondents reporting increased extent of lifecycle thinking in their product development projects in the previous 12 months are also more likely to notice that their organizations have more formal management processes for environmental considerations in product development (U-test, p-value 0.006), and that environmental considerations are perceived more as a requirement or mandatory checklist (U-test, p-value 0.012). Respondents reporting increased extent of lifecycle thinking correlate with those reporting more frequent environmental considerations in servicing phase (r 0.328), but not with those reporting more frequent inclusion of environmental considerations in other product development phases.

Perceived practices to include environmental considerations in product development are associated with few selected environmental topics. Perceiving that product development management processes for environmental considerations are formal is positively associated with perceived considerations for minimizing hazardous substances (U-test p-value 0.043) and increasing recovery of metals (U-test p-value

0.004). Perceiving that environmental considerations are a mandatory checklist or a requirement is positively significantly associated with increased reporting of recovery of metals (U-test p-value 0.015), and plastics (U-test p-value 0.008). But, considering durability in a typical product development project is not associated with perceiving environmental considerations as a requirement or a mandatory checklist; nor is it associated with perceived formal management processes for environmental considerations in product development.

The following is detected when exploring the relationship with selected environmental topics and frequency to include environmental considerations at early product development phases. It is noted that perceived more frequent inclusion of environmental considerations at conceptual phase is positively correlated with perception of increased considerations for ease of disassembly (r 0.378), ease of separating materials (r 0.388) and minimizing the material usage (r 0.330). Perception of more frequent inclusion of environmental considerations as functional requirement correlates positively with ensuring material compatibility (r 0.415), reliability (r 0.362), and recovery of plastics (r 0.331). Interestingly, while perception of increased considerations for durability correlates positively with perceived more frequent inclusion of environmental considerations at the task clarification and planning phase (r 0.343), perceived increased consideration of reusability of components correlates negatively with this same phase (r -0.342).

Bivariate relationships are also assessed with the level of considering environmental topics being at par with quality. Perception of increased extent of lifecycle thinking correlates with perceived considerations of putting environmental topics at par with quality criteria in product development (r 0.415). Indeed, the latter item correlates positively, and statistically significantly (all correlations above 0.310), with eight out of 15 other potential environmental topics studied. Highest correlations are detected with minimizing material usage (r 0.508) and increasing the recovery of plastics (r 0.502). Then, considering increased use of recycled or renewable materials, ease of material separation or their compatibility, minimizing hazardous substances, and recovery of metals correlate with putting the environmental considerations at par with quality. But, as mentioned, there are seven other examined items that do not correlate significantly with considering environmental topics being at par with quality; and among them is the consideration for durability in a typical product development project.

Another way to assess ecodesign practices in meso-level is to look at perceived level of received trainings or easiness to find environmental information within own company, and how these are associated with prevalence of the perceived selected environmental topics. From the selected environmental topics, only perceived increased level of recovery of metals in typical product development projects correlates with perception of having received enough of environmental training (r 0.434), while easiness to find information does not correlate significantly with these selected environmental topics. Hence, also increased perceived considerations for durability do not correlate significantly with the perceived easiness to find information on environmental considerations (p-value 0.178), nor with the perception of having received enough of environmental training (p-value 0.691).

4.3. Relationships between selected environmental topics, ecodesign practices and ecological concern at micro-level

As another dimension of *causa efficiencis*, this section reports results on examined micro-level item - ecological concern - including its potential association with meso-level environmentally benign product development practices and perceived prevalence of selected environmental topics.

Ecological concern measured with seven items reveals the following. The level of ecological concern is high among respondents with a mean 3.854 out of five and standard deviation 0.679. The scale does not differentiate by respondents' age groups (U-test p-value 0.526), nor does it differentiate by their functions (U-test p-value 0.828). Respondents agreed strongly with two items: "Humans are severely abusing the environment" (44%), and that "Plants and animals have as much right as humans to exist" (36%). "The earth is like a spaceship with very limited room and resources", was agreed strongly by 29 percent of respondents. The item on "When humans interfere with nature it often produces disastrous consequences" received the least number of respondents to agree with it strongly: 20 percent of respondents thinks so.

Turning next to potential direct associations with the other *causa efficiencis* dimensions at meso-level. Ecological concern is little associated with perceived practices to include environmental considerations at meso-level, apart from the following two aspects: increased ecological concern is positively associated with respondents reporting that his or her company formally manages the environmental considerations within product development processes (U-test p-value 0.026). In other words, no statistically significant correlations are detected with ecological concern and the perceived frequency to include environmental considerations in product development phases separately assessed. Perception that the environmental considerations are at par with quality correlates positively with increased ecological concern, but this is only marginally significant (r 0.255, p-value 0.091). However, with the item on spaceship this is not significant (p-value 0.217). And, although those with increased ecological concern are more likely to report that environmental considerations are a requirement or a mandatory checklist, this association is not statistically significant (U-test, p-value 0.130) similarly to the item on spaceship. Secondly, ecological concern correlates positively with perception that it is easy to find information on environmental topics (r 0.464), but then again, not with perception of having received enough of environmental training. However, with the item on spaceship, the latter correlates marginally significantly (r 0.271, p-value 0.071), while the former item correlates significantly similarly to the ecological concern.

Finally, the following types of relationships are detected with the ecological concern and the selected environmental topics. First, no significant correlation is found with perception of increased extent of lifecycle thinking and the ecological concern (p-value 0.711). On the other hand, direct significant correlations are detected with increased perceived considerations for recycled or renewable materials (r 0.396 and r 0.405, respectively), enhancing material separation (r 0.348), and recovery of metals or plastics (r 0.410 and r 0.327, respectively). Also, durability correlates positively with ecological concern (r 0.313). Other selected environmental topics do not correlate significantly with the ecological concern in this sample.

When looking at the item on spaceship separately, the following direct associations are found. Item correlates significantly with durability (r 0.333) and recycled materials (r 0.351), and marginally significantly with the recovery of metals. Then, instead of material separation for recovery, the material compatibility (r 0.343) for recovery correlates with this item, but the recovery of plastics and renewable materials do not – and neither the link between consideration for lifecycle.

As the correlations for durability with recycled materials and renewables were detected earlier, the potential partial influence of the ecological concern was tested. Indeed, while correlations with perceived increased considerations for durability and renewables remained significant, the relationship with perception of increased considerations for the recycled materials and durability was attenuated when controlling for the ecological concern (p-value 0.016 down to 0.122). Also, the item on spaceship behaves the same way (p-value 0.016 down to 0.100).

5. Discussion

By framing the discussion around classic *causas* this paper approaches aspects in implementing ecodesign within companies from two dimensions crossing disciplines. Specifically, the approach taken is to look at these aspects from employees' perspectives regarding their work in assumingly environmentally proactive companies. This section discusses results reflecting these findings with the literature.

The core of ecodesign thinking stems from acknowledging the lifecycle aspect of products' environmental impacts (Hauschild et al., 2005). This type of lifecycle thinking seems well established in this sample. Also, our results confirm that perception of increased extent of lifecycle thinking and selected environmentally benign product development practices seem to be closely intertwined. Hence, these examined employees seem be an example of respondents representing more mature companies practicing ecodesign in this aspect (Pigosso et al., 2013), although the extent of implementation may be questioned (Sihvonen and Partanen, 2016). This is aligned with the sample drawn using nonprobability judgmental sampling technique among respondents expected to represent more environmentally oriented companies in Finland. However, the way perceived extent of lifecycle thinking is related to actual selected environmental topics provides a more nuanced picture. Namely, these results suggest that perception of increased extent of lifecycle thinking is mainly linked with perceived prevalence of selected environmental topics around materials either in Pre- or Post-use phase.

These results further indicate that three selected environmental topics are widely applied in the product development projects irrespective of respondents' industries. Specifically, while Boks and Stevels (2007) point the three environmental impact areas of toxicity, resource depletion, and emissions, our results similarly suggest strong agreement with prevalence of perceived considerations for minimizing material use and hazardous substances, but also for reliability. Saving materials was practiced by 54 percent of SMEs in Finland presenting one of most prominent practices in this EU-wide study(TNS political & social, 2018), whereas in our sample with respondents from larger companies minimizing materials reached 71 percent. Then, although results cannot either directly be compared due to different research

constructs, our results both differentiate and are aligned with an empirical research by Deutz et al. (2013). This research suggests different level of considerations regarding hazardous substances compared to our results: approximately half the companies consider hazardous substances in the sample from companies in the United Kingdom, although increasingly so if involved with end-of-life issues (ibid.). In our sample, 87 percent of respondents perceive that minimizing hazardous substances have been considered in typical product development projects. In contrast, results are aligned with each other related to perceived level of reliability considerations.

Rest of the assessed environmental topics as proxies for *causa materialis* yield a picture in which many respondents are either unsure or consider assessed environmental topic not applicable in their product development projects. This result is well aligned with researchers (Luttropp and Lagerstedt, 2006; Pigosso et al., 2013; Telenko et al., 2016) calling for industry, and company specific environmental topic alignment. Yet, it would be intriguing to examine these same broad items in one company setting in search of determining applied strategies for *causa formalis*. For instance, this examination might allow to assess how perceptions are linked with triangulated information from other sources, such as internal product development project documents, sustainability reports, or respondents from same product development context. In such a situation, an illustration such as Fig.5., might explicate visually potential perceived knowledge gaps among the members of a given product development team. In other words, the illustration might provide an increased shared understanding of *causa formalis* for a given product development project: namely, to compare what strategies are applied in the given project, and how coherent this is with what is actually considered in the projects as *causa materialis*.

<<< PLEASE, INSERT FIGURE 5 HERE>>>

One of our research objective was to explore how durability is perceived among respondents working with product development. Overall, perceived prevalence of durability considerations in typical product development projects is somewhat low in this sample. Less than one in three perceive that it has been considered in typical product development projects. This result appears to differentiate from the aforementioned study by Dietz et al. (2013), in which clear majority, or 91 percent of respondents, consider durability as a product characteristic; yet, this large proportion may be explained by the sample criteria focusing on companies that manufacture durable goods. Also, our results seem to deviate from an interview study in which the positive attitudes toward durability are reported (Dalhammar, 2016). In contrast, our results seem to resonate with a case study by Bundgaard et al. (2017). In this study, it is reported that companies are reluctant to advance durability aspects within the development of regulatory frameworks in Europe. Yet, these comparisons may only be regarded as indicative due to different research constructs. As one of our reviewers pointed out, perceptions do also change over time. For example, Telenko's ecodesign guidelines provides an interesting example of this. Namely, one of the updated ecodesign principle regarding "appropriate durability" is now updated into "technical and aesthetic life"(Telenko et al., 2016, 2008).

To our surprise, these results further suggest that perceived durability considerations are not significantly linked with perceived increased extent of lifecycle thinking nor with practices to include environmental considerations in product development. In a

similar vein, Prendeville et al. (2017) report on the case-study findings that decisions on durability aspects are strategic and hierarchical ecodesign dilemmas rather than tactical or operational ones. In our data, this was also indicated by the following result: reporting of more frequent inclusion of environmental considerations in task clarification and planning phase seems to be the one practice that correlates with increased perception of durability considerations in typical product development projects. This would seem to warrant a need to further examine durability considerations in product development practices. Namely, could it indeed be so that choices toward durability aspects are perhaps made earlier, and hence rendering them more strategic instead of being considered as an operational aspect?

So, with what selected environmental topics considerations for durability is linked, if any? Based on these results, correlations are found with increased reporting of considerations for recycled and renewable materials, and for stand-by energy during use. Furthermore, perceived considerations for durability are inversely linked with reliability among the respondents working in product development concurring with the case study results reported by Prendeville et al. (2017). Also, reliability correlates negatively with recycled materials suggesting that at least in this sample: perception of increased considerations for reliable products does not seem to be achieved with products containing increased amount of recycled materials nor does it relate with durability, or vice versa.

Based on this survey, it seems that selected potential environmental topics are associated with different product development phases in which environmental considerations are more frequently included. With this result, we agree with the suggestion by Boks (2006): namely, if interest is in better understanding the implementation challenges in practice, then examining product development phases separately would provide useful insights. For instance, if it is allowed to consider environmental aspects more frequently in the conceptual phase, this can be positively linked with environmentally oriented topics such as considering ease of disassembly, separation of materials or quantities of materials.

One research objective set for this paper was to deepen understanding on how ecological concern, as a proxy for the *causa efficiencis* in micro-level, might be associated with perceived ecodesign implementation in product development contexts. The ecological concern was measured with a scale consisting of seven items derived from the 15 NEP items (Dunlap et al., 2000). Interestingly, the derived scale contained five items from the original NEP scale created in 1970's; furthermore, these seven items are oriented more toward the pro-ecological dimensions of construct measuring ecological worldview, as opposed to dimensions on human's role with natural environment also available in this measure (Lau et al., 2016). This suggests that the path followed to derive these seven items may be deemed sufficient to explore ecological concern.

We explored with the ecological concern the point raised on the need to study deeper on the motivational factors at micro-level (Dekoninck et al., 2016). First, initial data revealed intriguing further research path to increase the understanding of potential human factors between proponents and non-proponents of ecodesign (Boks, 2006; Dekoninck et al., 2016). Namely, similarly to a recent article revealing group of 'denials' from the household data (Rhead et al., 2015), our unrotated factor solution

suggest potentially similar types of factors in the context of product development (Appendix B). But, as mentioned, those items denoting toward more human-dominant position toward natural environment were excluded from the final scale due to the working procedure for statistical adequacy. Nonetheless, it would be interesting to investigate this further in similar context representing people from product development projects.

It should be noted that in this sample ecological concern seems not to be associated directly with assessed ecodesign practices except for the following two aspects (Fig 6). It seems to correlate with the awareness of those aspects that are related to easiness to find environmental information and general perception of formal processes to manage environmental considerations within product development. Interestingly, the former issue has also been found to hinder implementing ecodesign; for instance, Bey et al. (2013) report that finding information on environmental impact within the company is seen among the top barriers to implement ecodesign. This seems plausible if it is assumed that individuals may take note on issues the more one values them while also acknowledging the organizational constraints (Stern et al., 1995). In addition, an increased ecological concern might activate employees to provide suggestions at least for voluntary pro-environmental behaviors (Temminck et al., 2015).

In contrast, the awareness of few topical items correlates with ecological concern. Bivariate associations are found with awareness of potential environmental considerations that may be broadly regarded as items relating to acknowledging resource scarcity (cf. Boks and Stevels, 2007). For example, reporting increased considerations for recovery of plastics correlate with ecological concern in this sample: this may be seen interesting considering the recent focus on plastics within EU (European Commission, 2018c). Also, perception of increased considerations for durability and increased ecological concern correlate with each other. This suggests that perhaps internal discussions around renewables, recycled, or recoverable materials, and even product's durability considerations might sometimes also be connoted with value laden aspects, such as the ecological concern explored in this paper. In this sample, for instance, while correlation between perception of increased durability considerations and recycled materials is detected, this relationship is attenuated when influence of ecological concern is removed.

<<<< INSERT FIGURE 6 HERE >>>>

These results put forward among others an interesting question related to advancing durability aspects for the organizations' forthcoming products, although further research would be needed to examine these preliminary linkages in other samples. Namely, what if these internal debates around environmental topics, such as considerations for durability, should be approached also by better understanding extent of individuals' ecological concerns that might mediate individual's responses to ecodesign practices, such as being aware of durability considerations in the first place. This might provide impetus for different types of argument base for proponents of ecodesign within internal value chains (Pascual et al., 2003; Stevels, 2015). Would it then be possible, that even other constraints detected in the product development context are mediated by the respondent's ecological concern? Based on these results, ecological measure coined by Dunlap et al. (2000) might provide useful information

to explore such mediating effects. As we are not aware of other published study applying NEP among people working with product development, more research is needed. Yet, these results suggest new and fresh practical insights to advance discussion, in line with similar points raised by Stevels (2016, p.71) and Dekoninck et al. (2016), on the issues of human factors within soft-side of ecodesign.

5.3. Limitations

Using surveys as a research method is prone to biases stemming for instance from the way sample is derived and the way items are asked. It is unlikely to be able to remove all the hurdles from self-reported surveys. In addition to issues discussed in Sihvonen and Partanen (2016) including the generalizability due to companies representing assumingly more environmentally proactive companies, small sample size and using items mainly from literature in order to seek content validity, the following limitations may occur in interpreting these results.

At the time of developing and conducting the survey in 2014, it was realized that no agreed understanding of EoL seemed to exist in the literature; this may have hindered the choice of most agreed specific environmental topics for the survey. Hence, potentially significant omissions may have occurred. However, we argue that these selected environmental topics do cover the majority of generic environmental considerations discussed in the literature. Our view is that by using a category "non-applicable" as one response alternative allowed respondents further to either reject the item or support it by providing the extent the examined item had been considered.

Discussion is on-going on the construct to measure ecological concern with the original 15 items, and hence potentially influencing the measure of ecological concern in the future (Amburgey and Thoman, 2012; Dunlap et al., 2000; Hawcroft and Milfont, 2010). However, it is argued that nomological validity was enhanced in the current paper by conducting factor analysis to reduce number of items; in our sample, down to seven. Five out of these seven items were already in the first version of the NEP scale back in 1978 supporting the nomological validity. Furthermore, as noted by Lau et al. (2016), these seven items may be understood as pro-ecological concern of the NEP scale, while those items dropped out were more about the role of humans in controlling the nature. This was further visible in direct correlation between awareness of resource-use related items and the derived scale for ecological concern. Also, as this sample represents individuals working in product development projects, the sample may be assumed as consisting of solution-driven individuals. Hence, while rejecting some of the variables, specifically the more human-dominant relationship ones in order to reach statistical adequacy, seems to suggest reflecting this capability beyond the general public.

6. Concluding remarks

The research reported in this paper set out to examine interpretations of ecodesign practices in organizational setting, as perceived by employees through their mental models. Organizations consist of individuals that take actions including among others more environmental conscious product development practices. Therefore, it is of vital importance to better understand how human factors are associated with such actions. This may, in its simplest terms, include highlighting selected issues that could clarify unshared understandings of terminology among these individuals acting in the

product development teams. In this regard, this paper explores term durability to point out the need for such discussions.

Despite various limitations in this research, this research provides interesting ideas for further research. For instance, it would be very intriguing to better understand how durability aspects enter the product development process in more detail, and how are they determined. It may have been understood as a strategic choice earlier, but these results further suggest they seem to enter product development processes perhaps even earlier than anticipated. Moreover, if durability aspects may even be mediated by individual's ecological concern, it might be insightful to research this further.

Furthermore, as the research in this paper mainly relies on self-reported ecodesign practices in various industries, it would be intriguing to study similarly in one company setting with similar items but triangulate them with other sources. These triangulated sources could include, for example product development project steering documents, and responses from other members within the same context. Also, it would be intriguing to examine further in a context of one or two product development projects whether interpretations of the practices and processes in meso-level are framed by the generic ecological concern, and how other human factors, such as emotions, might also play a role. In other words, how the level of individual's concern for natural environment might influence interpretations individual makes in the organizational context at meso-level.

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Appendix A. Questionnaire items

(Kindly see other examined items in Sihvonen and Partanen (2016))

- According to your understanding, to what extent has life-cycle perspective been considered in a typical product development project during the past 12 months? Life-cycle refers to the entire life of the product including for instance, raw materials extraction, design, manufacturing, use, and the end-of-life. (Bipolar with seven scales, from "Not at all" as one, and "To a large extent" as seven)
- According to your opinion, to what extent do you agree that the following are considered in typical product development project/s? (Likert-scale: strongly agree, mildly agree, unsure, mildly disagree, strongly disagree, not applicable)
    - Increasing use of recycled materials (European Union, 2009; Ulrich and Eppinger, 2012)
    - Minimizing use of materials (Boks and Stevels, 2007; European Union, 2009; Luttropp and Lagerstedt, 2006; Telenko et al., 2008; Ulrich and Eppinger, 2012)
    - Increasing use of renewable materials (Ulrich and Eppinger, 2012)
    - Maximizing reliability (Deutz et al., 2013)
    - (Reversed) Minimizing durability (Deutz et al., 2013; European Union, 2009; Luttropp and Lagerstedt, 2006; Mobile Phone Working Group, 2010; Ulrich and Eppinger, 2012)

- (Reversed) Maximizing number of components (Mobile Phone Working Group, 2010; Telenko et al., 2008)
- (Reversed) Minimizing reusability of components (European Union, 2009)
- (Reversed) Maximizing stand-by energy consumption
- Ease of disassembly sequence and/or time (European Union, 2009; International Telecommunication Union, 2012; Pahl et al., 2007; Telenko et al., 2008)
- Ease of separating materials (European Union, 2009; Mobile Phone Working Group, 2010; Pahl et al., 2007; Telenko et al., 2008)
- Labelling material/s for recycling (European Union, 2009; Mobile Phone Working Group, 2010; Telenko et al., 2008)
- Ensuring material compatibility for recovery (European Union, 2009; Pahl et al., 2007)
- Minimizing hazardous substances (Boks and Stevels, 2007; European Union, 2009; Luttropp and Lagerstedt, 2006; Mobile Phone Working Group, 2010; Pahl et al., 2007; Ulrich and Eppinger, 2012)
- Increasing recovery of metals (Mobile Phone Working Group, 2010)
- Increasing recovery of plastics (International Telecommunication Union, 2012, p.32; Mobile Phone Working Group, 2010)

Appendix B. Factor analysis loadings for the ecological concern.

	Component			
	1	2	3	4
NEP15_r_If things continue on their present course we will soon experience a major ecological catastrophe.	0.669	0.449	-0.116	-0.233
NEP1_r_We are approaching the limit of the number of people earth can support.	0.640	0.164	-0.010	-0.458
NEP3_r_When humans interfere with nature it often produces disastrous consequences.	0.593	-0.229	-0.112	-0.036
NEP5_r_Humans are severely abusing the environment.	0.592	0.239	0.236	0.374
NEP11_r_The earth is like a spaceship with very limited room and resources.	0.550	-0.519	-0.028	-0.338
NEP2_Humans have the right to modify the natural environment to suit their needs.	0.453	-0.529	0.074	-0.007
NEP8_The balance of nature is strong enough to cope with impacts of modern industrial nations.	0.474	0.487	-0.015	0.259
NEP9_r_Despite our special abilities humans are still subject to the laws of nature.	0.152	0.477	-0.394	-0.007
NEP7_r_ Plants and animals have as much right as humans to exist.	0.519	-0.311	-0.645	0.080
NEP10_The so-called "ecological crisis" facing humankind has been greatly exaggerated.	0.488	0.340	0.581	-0.159
NEP6_The earth has plenty of natural resources if we just learn how to develop them.	0.304	-0.405	0.547	0.143
NEP13_r_The balance of nature is very delicate and easily upset.	0.511	-0.136	-0.109	0.604
Extraction Method: Principal Component Analysis. NOTE. Item in bold is used in the subsequent analysis titled as ecological concern.				

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Fig.1.

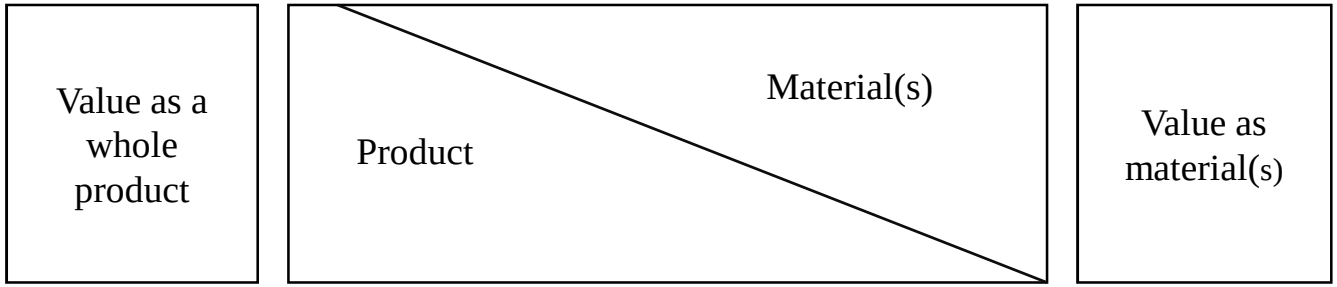

Fig.1. Value continuum ranging from product as a whole toward value as materials (illustration inspired by Tukker (2004)).

Fig.2.

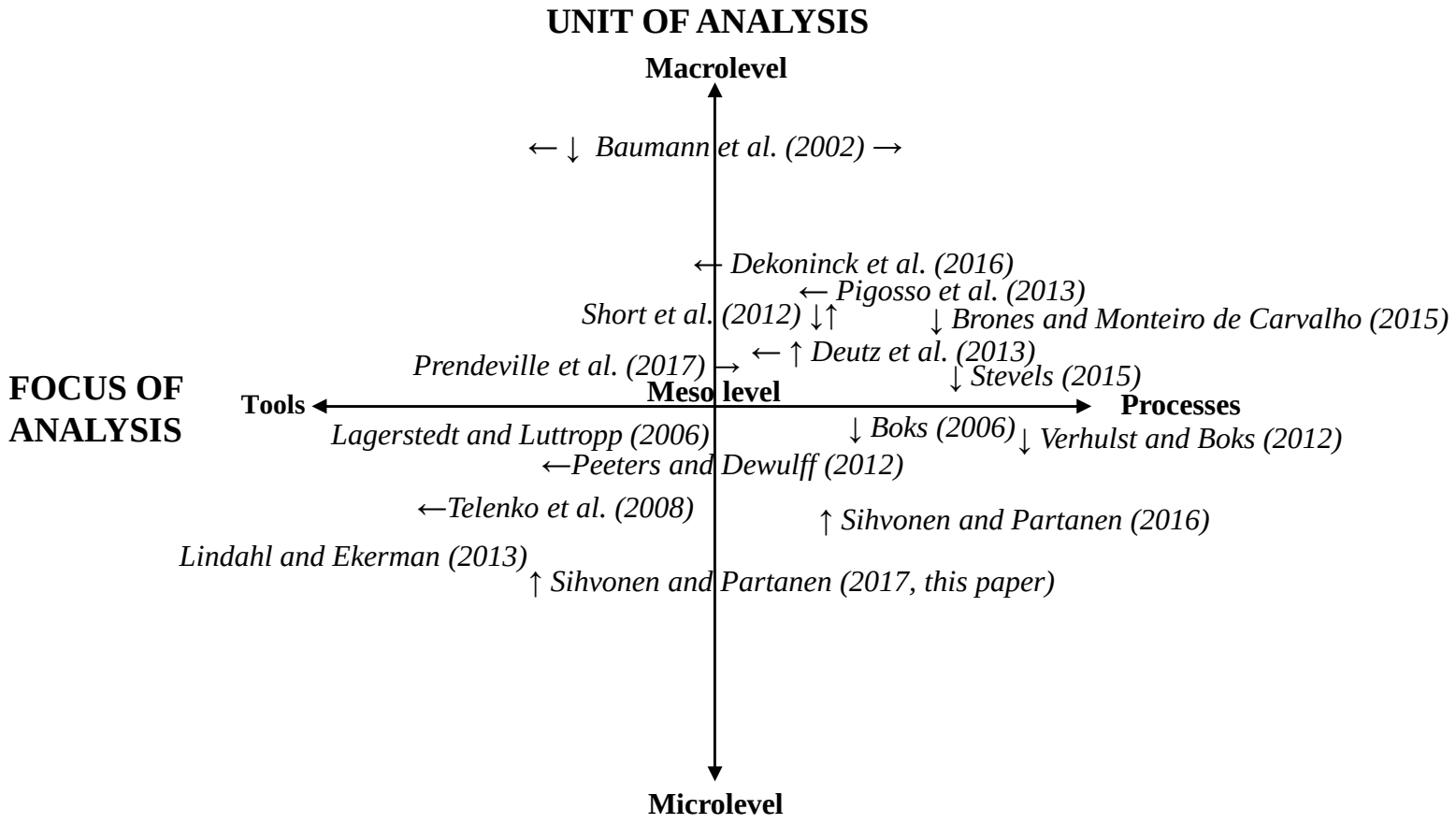

Fig.2. Suggested position of this paper among the selected conceptual, empirical, and theoretical researches within eco-design.

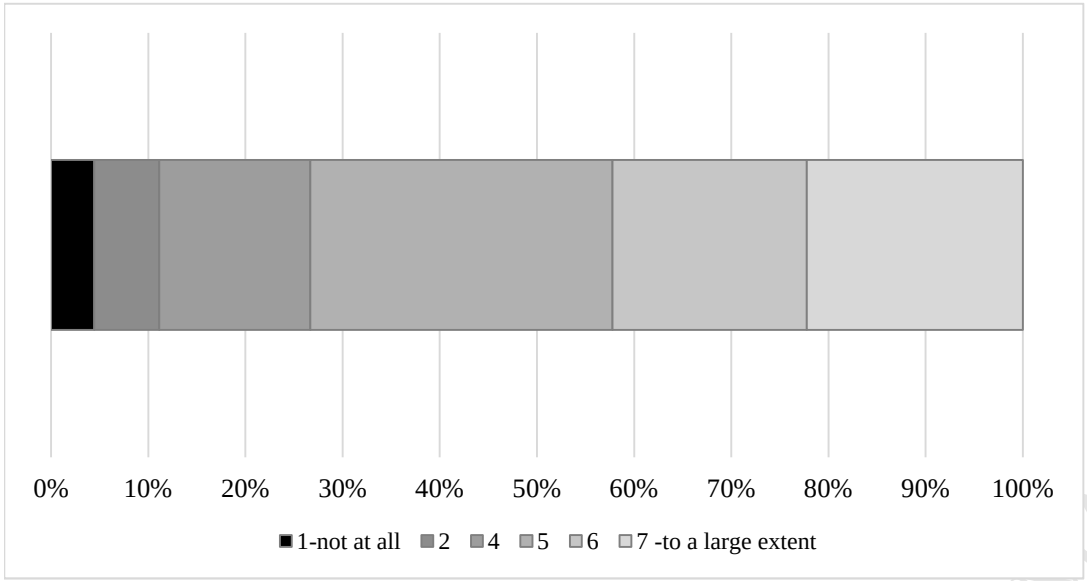

Fig. 3. Perceived extent of lifecycle thinking (n=45).

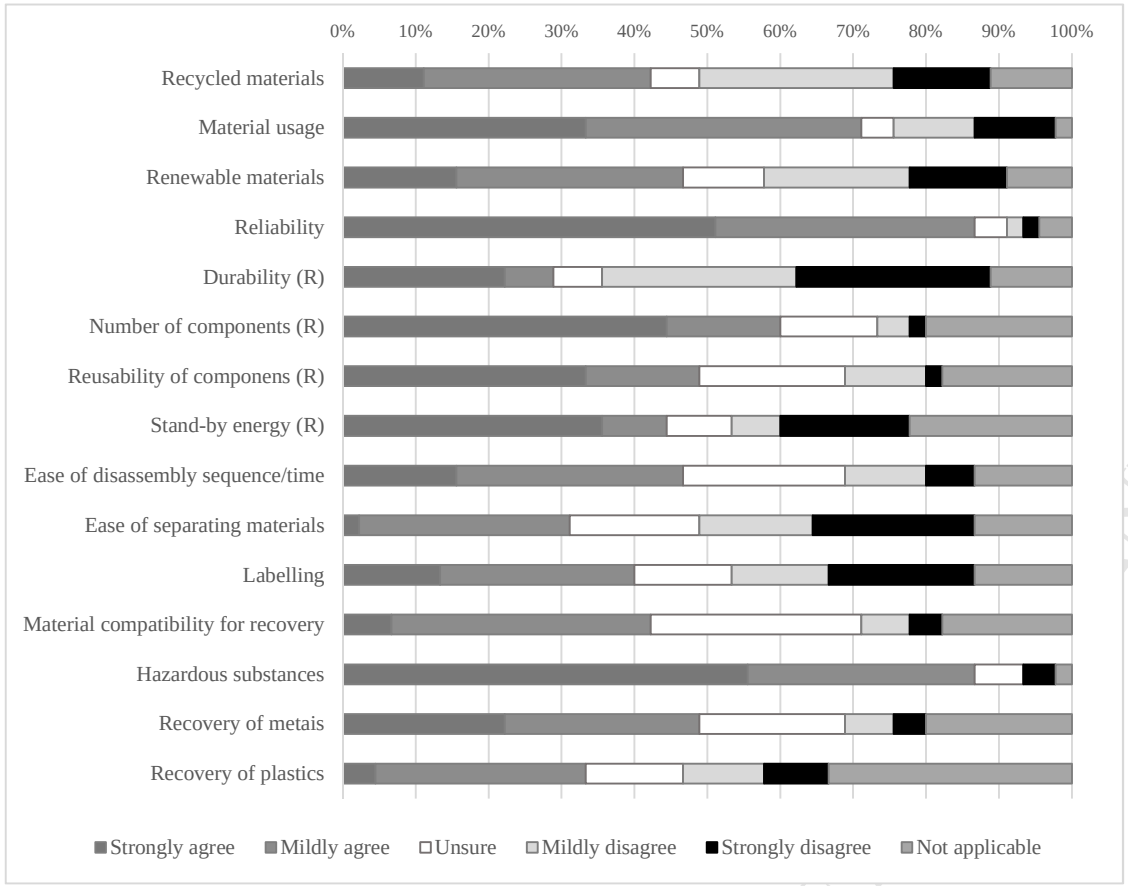

Fig. 4. Selected potential environmental topics considered in typical product development projects (n=45, R for reversed question).

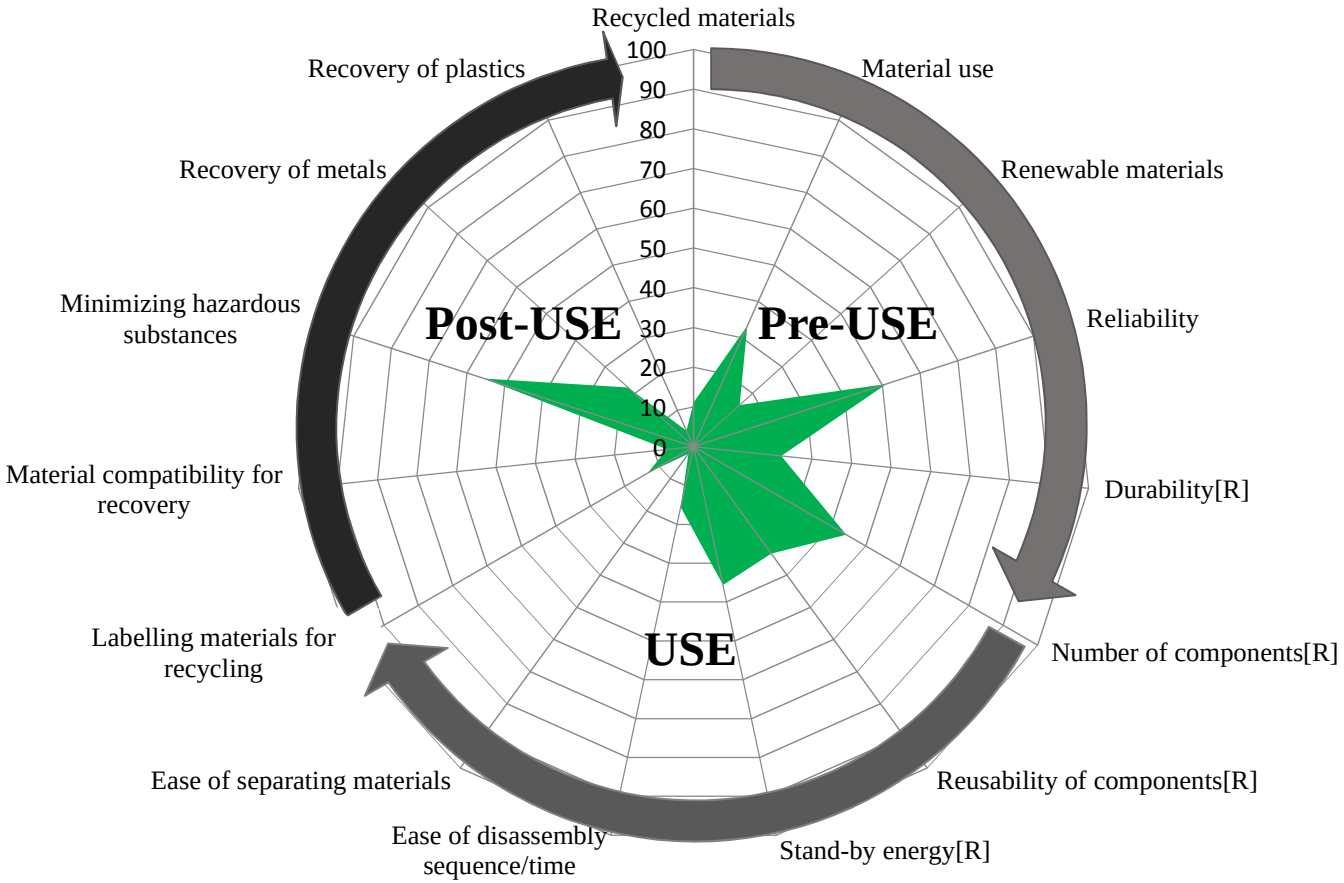

Fig. 5. Example of illustration for the prevalence of selected environmental topics in typical product development project (n=45, answered ‘strongly agree’ in Likert 5-scale, [R] reversed item).

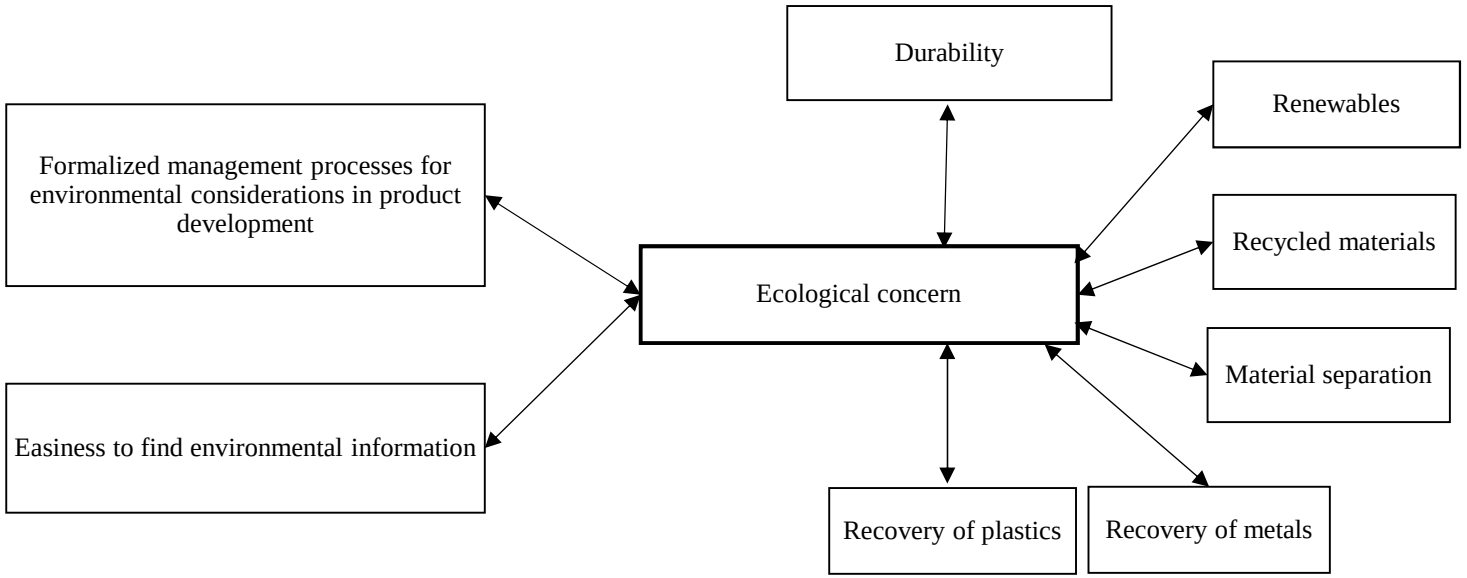

Fig. 6. Relationships of ecological concern with perceived selected eco-design practices, and awareness of selected environmental topics.