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UNANSWERED QUESTIONS IN CONCEPTUAL DESIGN TOWARDS CIRCULAR ECONOMY

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1. Introduction

Today, industry is encountering a challenge concerning resources due to, for instance, increasing prices of materials. This challenge has placed a lot of attention on our society regarding Circular Economy [European Commission 2014]. For instance, resource efficiency improvements could lead to increasing GDP growth, creating new jobs, reducing carbon footprint, reducing virgin resource consumption, material inputs needs by 17%-24% by 2030 [Meyer 2012] and [Ellen MacArthur Foundation 2013].
From the perspective of engineering design, the notion of a Circular Economy is a motivator to further develop its knowledge but is not entirely new. For instance, the notion of Inverse Manufacturing, coined in the 1990s by [Yoshikawa et al. 1999, in Japanese], has substantially affected engineering design research and has several issues in common with the Circular Economy. Environmentally conscious design of products [Vallet et al. 2013] can also be regarded as a broader and connected concept that has been continually developed in the engineering design research community since the 1990s (e.g. Alting and Legarth [1995]). However, thus far it is unclear what the Circular Economy, or more generally the challenge behind the Circular Economy, means to engineering design and if that differs from previously debated issues and concepts. More specifically, what does the engineering design research community know, and yet need to know, about implications of this emerging resource-related challenge to the community?
To help realize the Circular Economy, Product/Service System (PSS) has been heralded as one of the most effective instruments [Tukker 2015]. Thus, a substantial part of PSS design research has been performed in this context, (e.g. by Sakao and Shimomura [2007]). Although PSS design research has produced valuable insights, industry still seems to be facing challenges in implementing PSS design. The reasons may be debatable, however, much about PSS design is still unknown due to its complexity. It is even unclear what the community does and does not know about PSS design in order to further support industry.
Motivated by this void, this research aims to further develop knowledge about conceptual design towards Circular Economy, in order to manage and reduce related environmental impacts. Conceptual design is studied by e.g. [Andreasen et al. 2015], who describe conceptualization strategy as to ensure that "the selected concept has a strong rationale, builds on the best available knowledge, and leads to successful business and need satisfaction". As an initial step, this paper aims to describe known from existing literature and potential gaps within this subject and in current research of conceptual design towards Circular Economy. The adopted research method is literature review and, as a result of that, unanswered questions are presented as hypotheses. The intention is to test the hypotheses as the authors' immediate future work.

The remainder of the paper is structured as follows. In Section 2, the method for the literature analysis is specified. Section 3 consists of the results of the literature review, where existing literature and some of what is known in the topic are presented, divided into three major areas of the paper: design towards Circular Economy, collaboration between product designers and service designers, and the involvement of customers. Section 4, the discussion, is divided into the same three areas, and here what seems to be the gaps of existing literature is presented and results in three hypotheses.

2. Method

The method adopted for this paper is literature review. The literature review research what is known in the field of conceptual design towards Circular Economy, and the discussion of gaps within existing literature leading to hypotheses that lay the foundation for the authors' future work. Future research following this paper will include the method protocol analysis Ericsson and Simon [1993], as depicted by Figure 1, where the hypotheses will be tested. Protocol analysis has its roots in the "think aloud" method, which was introduced by Ericsson and Simon [1993] and further detailed by van Someren et al. [1994]. When protocol analysis is performed the designers are asked to literally think aloud and gets record for later analysis. Some existing research is based on generic models of designing and a coding methodology (e.g. [Gero and Neill 1998]). By using this approach in research it allows observation of temporal aspects of the design process and capturing of designers' behaviour.
What this paper addresses can be seen in Figure 1, encircled by the dotted line. It includes the literature review congregating what is known and also what seem to be the gaps of current literature. Further research will include deriving recommendations as specifications for design methods and interview study with industry where feasible specifications for design methods will be presented.

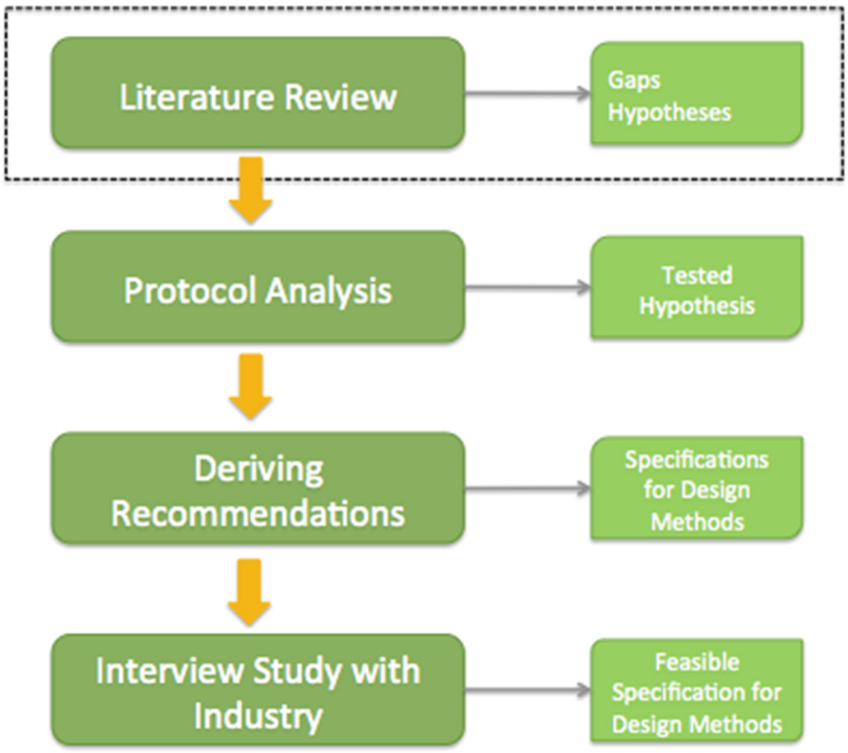

Figure 1. Method adopted in the paper (dotted line) and future work

3. Results of the literature review

3.1 Design towards Circular Economy

Current industries are facing a societal need to realize the Circular Economy [Ellen MacArthur Foundation 2013]. This is not entirely new, however, and some research in design based on initiatives related to the Circular Economy has already been carried out. For instance, the notion of Inverse Manufacturing was coined in the 1990s by Yoshikawa et al. [1999, in Japanese] and highlights the processes making more use of products in service or at end of use via e.g. maintenance, remanufacturing, or recycling. Inverse Manufacturing has several issues in common with the notion of Circular Economy and the initiative resulted in, for instance, a set of design methods for Inverse Manufacturing [Kimura and Umeda 2004, in Japanese]. Broadening the scope to research the environmentally conscious design of products, the research has produced concepts, models, and methods for supporting Ecodesign (environmentally conscious design) since the 1990s, (e.g. by Alting and Legarth [1995]). Some of them are useful for practice in industry to contribute to Circular Economy (see reviews e.g. by Ramani, Ramanujan et al. [2010] and Umeda et al. [2012]). A more specific concept, such as design for remanufacturing [Hatcher et al. 2011], is also provided. One of the most crucial insights from research in literature within Ecodesign in general is the recommendation to incorporate the environmental aspects into various phases of product design procedures used by a company as early as possible, in order to have a greater impact on design solutions. As for Ecodesign, the mindset of cradle-to-cradle emphasizes the importance of keeping the aspects of various phases in mind when designing and adds a large focus of designs of industrial systems to be commercially productive, socially beneficial, and ecologically intelligent [Rossi et al. 2006].

Among the important issues put forward for the Circular Economy is economic advantage for the involved companies by realizing circular flows of materials. A transition towards a Circular Economy is essential to be able to deliver the resource efficiency agenda established under the Europe 2020 Strategy [European Commission 2014] and it will impact on both economic growth and job creation, and can therefore lead to more than environmental advantages [Ellen MacArthur Foundation 2013]. The research made by Ellen MacArthur Foundation [2013], considering product sectors and clinics in Denmark, shows that a change towards a Circular Economy could lead to increasing GDP growth by 0.8-1.4%, creating 7,000-13,000 jobs, reducing the carbon footprint by 3-7%, and reducing virgin resource consumption by between 5 and 50%, all by the year 2035. In order to help companies with implementing a Circular Economy, Ma et al. [2015] developed a guiding method that resulted in increased total economic benefit and improvement by different degrees of recycling efficiencies of accompanying resources.

PSS is defined as "a system of products, services, supporting networks and infrastructure that is designed to be competitive, satisfy customer needs, and have a lower environmental impact than traditional business models" [Mont 2002]. A key factor when developing PSS is to design from an economic and environmental perspective [Mont 2008], including all life-cycle phases, that is manufacturing, use, maintenance and end-of-life treatment [Sundin et al. 2009]. Thus, PSS design research has been performed due to economic reasoning, several methods have been proposed, e.g. by Morelli [2003], Alonso-Rasgado et al. [2004], Aurich et al. [2006] and Sakao and Shimomura [2007], [Mont 2008]. Insights for design derived by these articles include among others the importance of analysing and addressing problems and values for customers instead of functions of physical products only, thereby increasing competitiveness of offerings.

3.2 Collaboration between product designers and service designers

Servitising and optimising products in a service system is, according to Aurich et al. [2006], to live up to the customer expectations and demands. A PSS designer is expected to consider a wide range of aspects and dimensions, with different points of view to meet customer expectations [Morelli 2003]. To efficiently carry out PSS design the product designers and service designers should be collaborating and working in parallel, meaning matching corresponding inputs and outputs, i.e. ingoing and outgoing information and resources, as discussed by Aurich et al. [2006] and Sakao and Shimomura [2007]. Vasantha et al. [2012] bring up the primary motivation in PSS modelling as co-creation of conceptual

models for design solutions that can be shared of different stakeholders. In the case study of a PSS design project by Morelli [2003], the author noted that during the test phase, improvement of the internal communication was needed. To solve the problem, Morelli [2003] highlighted the importance of less written text for the convenience of the customer and automating parts of the process. Aurich et al. [2006] bring up the aspect of time differences when designing products as physical object and services by stating that product core is developed at a specific point in time while the corresponding services are successively realized such as individual conferring to the customers and product users. This problem was tackled by e.g. proposing an integrated way of designing products and services (e.g. [Sakao and Shimomura 2007]).
Broadening the scope to design by multiple persons, a number of articles are available in the literature. For instance, in a study by [Goldschmidt 1995], comparisons of the process for a individual designer versus a group of designers was made. She questioned if the single mind is constrained by personal biases or limited expertise, or if the single mind is freer to explore. Feast [2012] brings up the importance of equal feeling of responsibility for the collaboration and also the downside that responsibility can create a feeling of obligation that can create boundary issues between the individual's interest and the group's interest. McDonnell [2009] argues that too much respect on the designer's role as an 'expert' could affect the stakeholders negatively when their role is reduced to a 'non-expert' within a collaborative conversation. Results from [Goldschmidt 1995] show that even though in equal groups there tend to be implicit or explicit roles along with disciplinary and behavioural lines, the participants in a team do not resemble different aspects of an individual designer, rather that an individual designer is a unitary system that is similar to the team. However, lack of respect or questioning of another participant's contribution when working in teams can cause participant to withdraw mentally from the collaboration [Feast 2012].

3.3 Involvement of customers

In an early design stage, critical decisions are made on the future product in the aspect of value [Ullman 1997]. However, suggestions for design solutions in that stage often lack consideration of the value of the information [Bertoni 2013]. This, in turn, makes the understanding of the customers' needs and perceived value scales important at an early stage [Bertoni 2013]. These are applicable to the designer's requirement for finding solutions in PSS, while keeping a wide range of aspects, dimensions, different needs and socio-cultural models from an early stage in the design phase in mind [Morelli 2003].
To carry out PSS or service design effectively, it is argued that the customer as the user is preferred to be involved [Vasantha et al. 2012] . This recommendation is applicable also to the case of product design [Magnusson 2003], but it is more relevant in PSS design because the service requires co-creation [Payne et al. 2008], between the provider and user. A PSS designer is expected to consider a wider set of expectations and needs from the stakeholders and the customers than a product designer, as described in Section 3.2. The ability to identify those needs at an early stage saves time and avoids rework in the later phases of the design process. Dynamics between a provider and a customer are essential in PSS; even so, the customer gets little opportunity to influence the design process [Morelli 2003]. Further, Kowalkowski and Kindström [2009] emphasize the importance of the relationship between the PSS provider and customer by presenting three dimensions: Product, Service and Relationship. This is in a broad sense in line with the concept of open innovation, which [West et al. 2006] confirm the mindset of relationships, since it brings up the relevance of input from various sources.
The change towards a closer relationship between the provider and customer in PSS, and the encouragement of stakeholders' participation, leads to increased customer loyalty [Manzini and Vezzoli 2003], [Evans et al. 2007], and [Williams 2007]. Durugbo [2013] shows that the fulfilment of marketable requirements lay in a trustworthy information system and sustainable relationships between suppliers, customers and the market. Christensen [2013] addresses the importance of a good relationship with the customer. At the same time he states that customers cannot be expected to help with innovations since the customers cannot know what they truly want. Due to that reason, the provider may be provided with misleading data [Christensen 2013].
Regarding the importance of addressing the relationship of the provider and customer in PSS design [Kowalkowski and Kindström 2009], in a different manner than in product design, Morelli [2003] looks

at the design process in different steps. The steps are shifting from different phases of solutions that redefine problems, which, in turn, generate solutions, implying the need of interaction between the provider and customer.
Vasantha et al. [2012] also note that the position of stakeholders must be improved to increase the opportunity for co-design and co-creation of value. This is due to the designers' capability to observe and interpret cultures, social needs and attitudes [Morelli 2003]. Morelli [2003] describes how the organisational and social aspects are related to the design aspects, which should be seen as a multidimensional activity in the design phases in PSS.

4. Discussion

4.1 Design towards Circular Economy

Even though research on the Circular Economy is not particularly new and has been performed under different notions, a common thought of science is that it creates both the economic and environmental benefits. Furthermore Ellen MacArthur Foundation [2013] has shown in their research that job creation also seems to be perceived as a major positive outcome of Circular Economy, which also brings a social aspect to the benefits. Circular Economy seems to emphasise provider value rather than customer value. Ecodesign and cradle-to-cradle consider environmental aspects and lifecycle thinking. PSS design research has been partly motivated by lack of addressing value and customer orientation of Ecodesign (e.g. [Sakao and Shimomura 2007]). However, acknowledging that Circular Economy and the flow of materials emphasizes benefits to providers and customers, the value may be considered differently than in traditional product design. A question rises to whom is design towards Circular Economy creating benefits? The thought of value considered differently leads to the first research hypothesis in our study:

> H1. In conceptual design towards Circular Economy, designers address more provider value than customer value.

4.2 Collaboration between product designers and service designers

The steps described by Morelli [2003] imply the need of interaction in the design process and that a internal communication is important for a quality outcome. [Aurich et al. 2006] point out the importance of working with integration and in parallel as designers. McDonnell [2009] brings up that different roles of expertise can stand in a way of good collaboration between designers and stakeholders and argue the importance of stakeholders feeling of being included and heard in the collaboration.
Collaborations should be a natural part of developing PSS is widely known and also that it should be done from an early stage of the process. However the identified literature does not seem to bring up what kind of information, and in which steps of the design, product designers and service designers should be sharing information specifically. The designers have to keep much in mind from both product and service designers' perspectives to deliver a high quality PSS. Customers are more naturally involved in services than in products [Vasantha et al. 2012] since it is a selling that extends over time and thereby maintaining contact between the customer and the provider.
A question rises if the service designers are more likely to address customer requirements than the provider requirements? Could there be that the customer is more considered by service designers in PSS design than the provider? These thoughts lead to the second hypothesis to be tested in future studies.

> H2. In PSS design, service designers address the customer more than the provider.

4.3 Involvement of customers

[Sakao and Shimomura 2007] stress the importance of customer value, which makes it essential to have a good relationship between the provider and customer to ensure the outcome to fulfil customer's demands and expectations, which is also implied by [Aurich et al. 2006]. Vasantha et al. [2012] bring up the opportunities of co-design and co-creation for increasing value. The common thought of open innovation is to bring ideas from both internal and external actors [West et al. 2006], which increase the opportunity of customer influence at an early stage which in turn both saves time and energy.

The participation of the customer can lead to higher customer loyalty [Manzini and Vezzoli 2003], [Evans et al. 2007] and [Williams 2007], and that is assumed to be correct if the customer feels included in the process or the design. As McDonnell [2009] argues that too much respect for the designer could influence badly of other participants contribution hence to the feeling of neglect. However, Christensen [2013] discusses the dilemma of customer involvement since the customers does not know what they want and it may lead to incorrect data for the provider. There still seems to lack common knowledge whether or not customers should be involved in design in general. This may be caused by lack of specifying the type and phase of the design in question.
Therefore, in order to advance the body of knowledge specifically in conceptual design towards Circular Economy, a more specific question is raised, leading to the third hypothesis to be tested in future research. The hypothesis is divided into two sub hypotheses. The second sub hypothesis is incorporated, since it seems to be a key for distinguishing different phases in design if the candidate solutions are available or not.

> H3a. In conceptual design towards Circular Economy, involving customers decreases lead-time for design.
>
> H3b. In conceptual design towards Circular Economy, involving customers before candidate solutions are created decreases lead-time for design than doing so after.

5. Conclusion and future research

As an initial step, this paper has shown what is known and unanswered in conceptual design towards Circular Economy. Studies have shown that Circular Economy has potential for a positive impact from both environmental and economic aspects and it emphasizes benefits to providers, but there is no thorough discussion of its impacts on engineering design. The major scientific value of this conference paper exists in the clearly pointed-out unanswered questions from current literature. It should be noted that a systematic literature review was not adopted in this paper and there is reservation on the completeness of the review. The unanswered questions are presented as three testable hypotheses. As the authors' immediate future work, the hypotheses will be tested using protocol analysis. Furthermore, design towards Circular Economy, which is used in the hypotheses, will be concretized to be transparent before the protocol analysis.

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