FROM INDUSTRIAL WASTE TO PRODUCT DESIGN

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ABSTRACT:

To use waste as a starting point for new product development would be a sustainable use of material resources that alleviates waste handling loads. So far, products that use waste as a starting point have not been able to significantly affect waste trends. This shows a need for methods that facilitate using waste materials for product development. With this in mind, the project "From Industrial Waste to Product Design" was initiated. Industrial design engineering students are encouraged to do their master theses on exploring product development with currently unused waste. This article suggests a methodology to help designers achieve this. Two approaches were undertaken: a product study to review the state of the art in designing with waste; and an analysis of traditional design processes. In the end, an expanded design process was proposed, since a description of a systematic process for this issue was lacking among researchers or practitioners.

1. BACKGROUND

Closed-loop production has been proposed as a way to enable sustainable use of material resources in society (El-Haggar 2007; Ludwig et al. 2003; Foundation 2012; McDonough & Braungart 2002). Most of today's discarded goods however, do not end up in development of new products but in landfills or incineration plants (Blumenthal 2011; Baker et al. 2004). There is a need to better connect product development with waste management and to encourage designers to find use for discarded material.

However, there have been some products developed with discarded materials, in a trend that today seems to be growing. They differ from traditional recycling by using formal and structural changes to put the whole object or

components back to work, instead of transforming and reusing the material of the object through chemical and physical processes (Barbero et al. 2012).

Designing with waste has also been called Up-cycling. This involves a retrospective process where designers try to match the existing form of a discarded product to a new function. However, up-cycling is characterized by being handmade, not cost-effective and unable to effectively re-process the waste stream it uses (Crabbe 2012). Furthermore, many up-cycled products use materials that have existing and well working recycling systems (e.g. PET, metals, paper, etc.), so one could debate their contribution to effective resource recovery.

To reduce waste and promote product development with waste seems to be a hot topic. Earlier this year, the Swedish national foundation for strategic environmental research, Mistra, called for research proposals on industrial waste. Mistra Closing the Loop research programme is aiming to attain higher resource efficiency and creating new markets for recycled, eco-friendly materials and products (Mistra 2012).

1. 2. "FROM INDUSTRIAL WASTE TO PRODUCT DESIGN" PROJECT

With the intention of facilitating collaboration between the recycling industry, product designers and manufacturers, the project "From Industrial Waste to Product Design" (IWtoPD) was submitted to the Mistra Closing the Loop initiative and was accepted for funding. The project is a collaboration between the (a) recycling industry Stena Recycling, (b) the engineering consultancy company Semcon, (c) researchers from Chalmers University of Technology and (d) students from the Master programme in Industrial Design Engineering at Chalmers.

The project layout is according to this five-step approach:
1. Stena Recycling presents discarded materials from their current waste-stream, which is impossible to recycle and to extract value from. They provide the material for testing and explain its current recycling market situation.

2. Professionals from the three organizations involved propose possible areas of application for these materials, regarding their characteristics and conditions.

3. The challenge of developing a product with the selected material is then offered to students from Industrial Design Engineering at Chalmers University as a master thesis topic.

4. The students who are registered for the proposed master degree within IWtoPD work with the product development for six months. Regular supervisions by professionals from Stena Recycling, Semcon, and specialized academic researchers support and monitor their progress.

5. In the end, professionals from Semcon help the students in visualizing their final proposed product development and design concepts to better generate market interest.

This project generates a triple helix collaboration between recycling industry, product development and academia in order to better tackle the problems that appear, when trying to reincorporate industrial waste to new manufacturing. The project IWtoPD requires diverse domain knowledge, as to list the understanding of recycled material markets, the requirements that enable successful production, material properties and their limitations, but above all, ingenuity to propose new and innovative product development and design concepts with what is given. It reformulates the design process, since there is an extra barrier to overcome far beyond the setting of all user requirements: a material that was aimed to be discarded has to be re-purposed into a component for a commercially viable product.

The project is now on its first semester of implementation, with a couple of students starting their master thesis.

2. AIM

Find, develop or propose a methodology that helps to better educate designers to use industrial waste as a starting point for their product

development while still aiming for fulfilling functional requirements at compatible costs.

3. METHOD

Two approaches were taken: a product study in order to review the state of the art in designing with waste; and an analysis of traditional design processes.

The **product study** gathered examples from three books dedicated to eco-designed products (Barbero et al. 2012; Fuad-Luke 2009; Fusion Publishing 2008), a couple of articles focused on the topic (Crabbe 2012; Ordoñez & Rahe 2012) and an intensive web search. This review targeted products that consist mainly of waste materials that had been either reused or recycled. It intended to find any description of the methodology used and to determine two aspects for each case:

1. If they were handmade or serialized.
2. If the material used had a previously working recycling system or not.

For this last aspect, it is important to clarify that the recycling systems that were considered to be well established were those for paper, wood fibers (regarded as pulp for paper), glass, metals and sorted PET. Mixed plastics, PVC, tires, rubber, fabrics, wood scraps, furniture and reclaimed wood were not considered to have a working recycling system.

The **analysis of traditional design processes** has been done in order to find tools that could later be considered when designing with industrial waste as a starting point. These findings have been discussed with the students who are currently working on the IWtoPD project to identify the main difficulties they have encountered so far as well as to gather their suggestions.

4. RESULTS AND DISCUSSION

4. 1. DESIGNING WITH WASTE: PRODUCT STUDY

The study provided 57 examples, which are evenly divided between recycled and reused materials. Three cases did not consist of a particular product

type, but rather a large variety of items that included both recycled and reused materials. Recycled products tended to be serialized (~80%) and to use materials that did not have a recycling system previously defined (~74%). Reused products tended to be handmade (~70%) and have a more even distribution between materials that had and did not have a previous recycling system (table 1).

Strategy Used	N° of cases	Hand Made / Serialized		Previous recycling system		Comments on Method
Recycle	27	HM	5	Yes	7	No
		S	21	No	20	No
Reuse	27	HM	18	Yes	12	No
		S	9	No	15	No
Both	3	S	3	Depends on each item		No

Table 1: Summary of the Product Study, sorted by strategy used.

In order to use this type of product development as an effective resource recovery system, it should develop products that can be serialized and that make use of materials that currently do not have any well-established recycling system. Additionally, they should be independent of the strategy they use (i.e. Reuse or Recycle). The study shows a larger amount of cases where the products are serialized (~60%), on the contrary to what could be expected (Crabbe, 2012, considers up-cycling as mainly handmade). In both types of production (i.e. Hand Made or Serialized) there are more examples of products that use materials that do not have a well established recycling system (table 2). In spite of this positive result, current design with waste has not yet improved a reduction in the waste trends. Despite of having a serialized production, the sales of products made from waste are probably significantly lower than the sales of comparable products made from virgin material. That also implies a probably higher rate of waste generation than the one of the material they reuse/recycle.

Hand Made / Serialized	N° of cases	Previous recycling system		Comments on Method
HM	23	Yes	9	No
		No	14	No
S	34	Yes	10	No
		No	24	No

Table 2: Summary of the Product Study, sorted by type of production.

In all the cases reviewed, there were no comments found on the used methodology, designing with waste. A reason for this could be the fact that designers rarely document or make public their designing process (Cross 2011). Another possible explanation is that the relatively new area of waste material design is in a state of "demonstrating that it *can* be done" rather than "demonstrating *how* it can be done". Table 3 shows the complete list of products that were reviewed in the study.

	Product	Designer	Material	Reuse or Recycle	Hand Made / Serialized	Industrial Waste / Post Consumer Waste	Material recycling system previously in place	Comments on Method	Webpage
1	Sushi furniture	Fernando and Humberto Campana	Textile scraps	Recycle	HM	PCW	No	No	http://campanas.com.br/home_en.html
2	Favela	Fernando and Humberto Campana	Wood scraps	Recycle	HM	IW	No	No	http://campanas.com.br/home_en.html
3	Ouro	Lea Bogdan	tires, leather	Recycle	HM	PCW	No	No	http://leadesignsid.com/artwork/
4	Tread	Karen Brierley and Anna Tutton	discarded car tires	Recycle	HM	PCW	No	No	http://www.re-tread.com/
5	Profil belts	Yeayea	Bike tires	Reuse	HM	PCW	No	No	http://yeayea.de/
6	Furniture	Showraum	Reclaimed wood, furniture	Reuse	HM	PCW	No	No	http://shop.showraum.de/
7	Reline tableware	Anna Bormann	white tableware	Reuse	HM	PCW	No	No	http://www.annabormann.de/
8	Creatures	Tobias Rockenfeld	Broken toys and HH appliances	Reuse	HM	PCW	No	No	http://www.droog.com/store/studio-work/creatures
9	Furniture	Amir Raveh	Reclaimed wood, furniture	Reuse	HM	PCW	No	No	http://www.nagarya.net/en-gallery-1/
10	Scrapile furniture	Carlos Salgado & Bart Bettencourt	Wood scraps	Reuse	HM	IW	No	No	http://www.scrapile.com/collections_main.html
11	New Heirlooms	CJ O'Neill	Used tableware	Reuse	HM	PCW	No	No	www.cjoneill.co.uk
12	Bags	Ornjbags	Construction fencing	Reuse	HM	IW	No	No	www.ornjbags.com
13	Bags	Retape	magnetic tape	Reuse	HM	PCW	No	No	www.retape.de
14	Wheels-on-Fire Collection	Jan Willem van Breugel	Bike inner tire	Reuse	HM	PCW	No	No	www.wheels-on-fire.nl
15	Glass tiles	Terri Baudenbush, Sandhill Industries	Glass	Recycle	HM	PCW	Yes	No	
16	Chandeliers	Carolina Fontoura Alzaga	bicycle parts	Reuse	HM	PCW	Yes	No	http://www.facaro.com/home
17	Milk Bottle light	Tejo Remy	milk glass bottles	Reuse	HM	PCW	Yes	No	http://www.remyveenhuizen.nl/
18	Dawn light	Tiffany Threadgould	aluminium blinds	Reuse	HM	PCW	Yes	No	http://www.replayground.com/
19	Plastic bottle lights	Sarah Turner	Plastic bottles	Reuse	HM	PCW	Yes	No	http://www.sarahturner.co.uk/index.html
20	Crush Lamp	Brendan Young	PET bottles	Reuse	HM	PCW	Yes	No	http://www.studiomold.co.uk/
21	tranSglass	Emma Woffenden and Tord Boontje	Glass bottles	Reuse	HM	PCW	Yes	No	www.artecnicainc.com
22	*	Taller Re-Crear	PET	Reuse	HM	PCW	Yes	No	
23	Northern Fleet chandelier	Deborah Thomas	broken glass	Reuse	HM	PCW	Yes	No	
24	Remarkable office material	Ed Douglas Miller	Plastic, tires, paper and card from MSW	Both	S	PCW	-	No	Remarkable.co.uk
25	*	Terracycle	packaging, others	Both	S	PCW	-	No	www.terracycle.com
26	Doormat	Teppich-art Team	hemp, paper, plastics, rubber	Recycle	S	PCW	-	No	
27	Revolve UK	-	circuit boards, juice cartons, plastics	Both	S	PCW	No	No	www.revolve-uk.com
28	Sway Stool	Daniel Michalik	100% industrial cork waste	Recycle	S	IW	No	No	http://www.branchhome.com/index.php
29	Um	Josh Jakus	Wool felt 85% industrial excess wool	Recycle	S	IW	No	No	http://www.actualsf.com/
30	Plastic furniture	Bär + Knell	Plastic packaging waste, HDPE, LDPE	Recycle	S	PCW	No	No	http://www.baer-knell.de/
31	Synchilla	Patagonia	PET, PE	Recycle	S	PCW	No	No	http://www.patagonia.com
32	Bags and accessories	Kelly Atkins, Carpet-Burns	faulty PE carpets	Recycle	S	IW	No	No	
33	Inplum	Genoveva Cifuentes	Plum core agglomerate	Recycle	S	IW	No	No	remadeinchile.cl
34	Felt Rocks	Todd MacAllen & Stephanie Forsythe	wool remanants from polishing disks for lenses	Recycle	S	IW	No	No	www.molodesign.com
35	MicroBore	Porius Pipe UK	tires, leather	Recycle	S	PCW	No	No	
36	LINPAC	Linpac Environmental UK	HDPE bottles	Recycle	S	PCW	No	No	
37	Preserve toothbrush	Recycline, USA	plastics	Recycle	S	PCW	No	No	
38	Inka presswood pallet	INKA Paletten DE	waste timber	Recycle	S	IW	No	No	
39	Sine seat	V K &C Partnership UK	plastic waste	Recycle	S	PCW	No	No	
40	Silencio 6 flooring	Hunton Fibers AS, Norway	softwood fiber	Recycle	S	IW	No	No	
41	Super Duralay flooring	Duralay UK	car tires	Recycle	S	PCW	No	No	
42	Dal-lastic flooring	Dalsouple Direct, UK	rubber	Recycle	S	PCW	No	No	
43	Belts	Cinelli Bootleg	Bike inner tire	Reuse	S	PCW	No	No	http://www.bootleg.it/scripts/accessori.php
44	Tennisball Bench	Tejo Remy & René Veenhuizen	Tennis balls rejected for sale	Reuse	S	IW	No	No	http://www.remyveenhuizen.nl/
45	Bags	Demano	Discarded PVC advertising	Reuse	S	PCW	No	No	www.demano.com
46	Paperbag	Jos van der Meulen	Discarded PVC advertising	Reuse	S	PCW	No	No	www.goods.nl
47	Giddyuo Rocking Chair	Tim Wigmore	discarded horse saddles	Reuse	S	PCW	No	No	www.timwigmore.co.nz
48	Polyplank	-	recovered thermoplastics with wood fiber	Recycle	S	PCW & IW	Yes	No	polyplank.se
49	Richlite	-	Composite cellulose fiber counter-tops	Recycle	S	IW	Yes	No	Richlite.com
50	Garden bench	Jurgen Bey, Droog	Plant waste	Recycle	S	IW	Yes	No	
51	Pet Pod	Vaccari Ltd, UK	papier maché	Recycle	S	PCW	Yes	No	
52	Viper	Hans Sandgren Jakobsen, DK	cardboard	Recycle	S	PCW	Yes	No	
53	Sundeala Board Screen	Celotex UK	newsprint	Recycle	S	PCW	Yes	No	
54	Wretman-stället	Torstensson	Silverware production discards	Reuse	S	IW	Yes	No	http://torstensson.se/product.aspx?r_id=53407
55	Cabbage Chair	Nendo	pleated paper, by product of pleated fabric industry	Reuse	S	IW	Yes	No	http://www.nendo.jp/en/works/detail.php
56	Boardbar	Stephan Boltz	Airplain trolleys	Reuse	S	PCW	Yes	No	www.bordbar.de
57	*	Creatables	Laminated industrial discard	Reuse	S	IW	Yes	No	www.creatables.se

Table 3: Complete list of products reviewed during the study.

4.2. TRADITIONAL DESIGN PROCESSES

Product design work is typically constituted by both *elaborative* and *reducing* activities (figure 1). The elaborative activities, such as idea generation, have the purpose of seeking for opportunities, while the reduction of activities is related to decision-making and refinement.

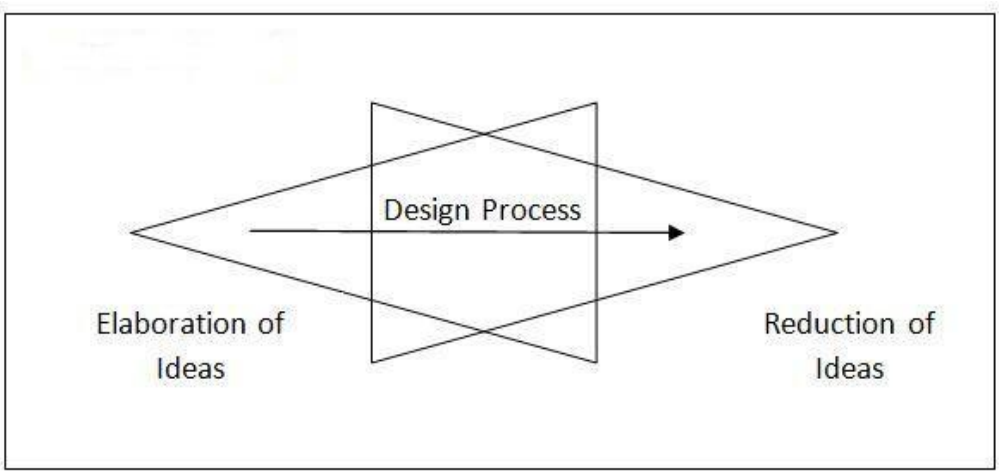

Figure 1: Creative work, such as Design, is constituted by elaboration and reduction (Laseau 1980).

The product design process as a whole is often described as a funnel, consisting of a series of activities alternating between elaboration and reduction (figure 2).

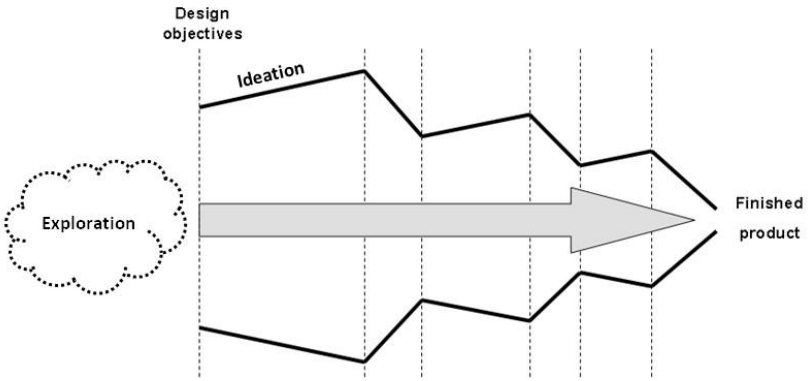

Figure 2: A generic design process, based on Pugh 1991. Today's description of design processes usually contains an exploratory phase before the ideation phase.

Early descriptions of the design process, such as the "New product development process" (Cooper, 1983), often list *idea generation* as the first activity of the process. Since then, there has been an increased focus on where ideas come from. More recent descriptions of the design process (e.g. Andreasen & Hein 1987; Kelley 2001; Ulrich & Eppinger 2004) generally include a phase before the ideation activity. This phase, often named "exploration", "understanding" or similar, is centered around understanding the product use and customer needs. When designing products from industrial waste however, a generic design process is not sufficient. It needs to be complemented with more specific up front-activities, as the design objectives are too vague in relation to the objectives of 'traditional' product design. Usually, the designers know if they are to design a pencil or a car, and often, they also have an idea about the product's users and their respective needs. That is not the case when designing with waste material. Here, the designers only have one starting-point: how to incorporate a defined material into a solution yet to be determined.

4.3 EXPANDED DESIGN PROCESS FOR WASTE MATERIAL DESIGN

In this paper, we propose an expanded design process, to be implemented by the students in the IWtoPD project. It focuses on the activities that need to take place before the traditional design process can set in, constituting an extra dimension or phase to the generic design process (figure 3).

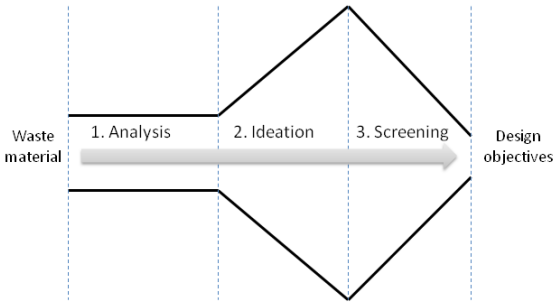

Figure 3: Design pre-process to be carried out before a traditional design process.

This new "pre-process" has its starting point in the waste material itself. This material has to be analyzed, after which ideas for what it could be used in should be generated. Finally these ideas should be screened and evaluated to finalize with design objectives so a traditional design process can be initiated. After this pre-process, one should have an idea of what product is to be designed. The phases of this pre-process can be further explained as:

1. Analysis: The idea of the analysis phase is to generate a basis for the ideation work to follow. Thus, this phase has basically the same function as a traditional exploration phase (figure 2), but the point of departure is quite different. Here, the single known factor is the waste material, so the analysis focuses on the material and its properties.

2. Ideation: The activities of the ideation phase are similar to traditional idea generation, but again the objectives are different. Based on what is known about the waste material, the aim of ideation is to come up with previously unknown ways of using it.

3. Screening: This phase is for deciding on which solution(s) to discard and which to keep. The activities of this phase are similar to traditional screening processes, although a different competence, such as material expertise, might be needed.

So far, most effort has been put into refining the analysis phase and the ideation phase of this pre-process. During this refinement, three particular challenges (see figure 4) have been identified:

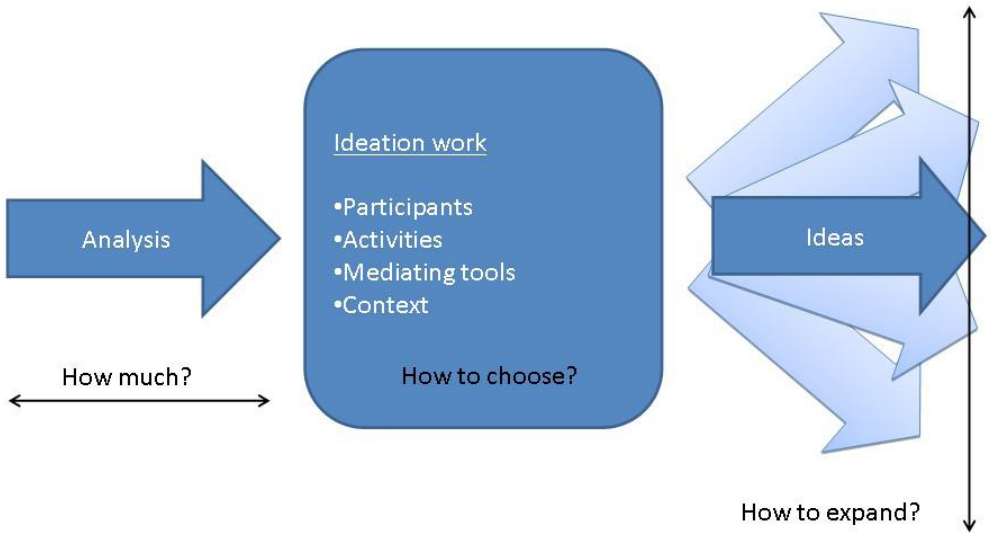

Figure 4: Challenges for creating a successful ideation.

1. How much analysis should be carried out before the ideation? The design work has a very specific input i.e. the waste material itself. A natural first step is to analyze its properties and how the material could be processed. Other activities could be to identify materials with similar properties or to study regulations. The question is: How detailed should such an analysis be? In the project, some initial experiments have been made with design students as 'ideators'. It was clear that simply putting the material on the table and asking them to "come up with ideas how it could be used" was not successful. The students found it difficult to generate ideas because they had so little substance to build their ideas from. On the other hand, it can also be possible to have an excessive analysis phase that delays the ideation process. To identify the materials properties in detail may not only reduce the space of possible ideas, but it may also be a very cumbersome analysis to carry out. Material data for waste material is often not represented in databases (since properties of the material may have been affected by use and wear), which means that practical experiments, such as tensile tests would be additionally needed to be able to describe the factual properties of the waste material studied.

During the IWtoPD project, one goal is therefore to identify an adequate depth of the analysis phase.

2. How should the components of the ideation session itself be chosen? A generative method is typically constituted by four factors: participants, activities, mediating tools and context (Engelbrektsson 2004). As part of the IWtoPD project, workshops are to be carried out. The main reason for this is that workshops are a method, suitable for gathering participants with different expertise. The participants are presumed to be a key factor in the ideation process, and there are two motives for gathering a multidisciplinary group. First, experts regarding both the material and design are presumed important. Secondly, as many disciplines as possible will be an advantage, since nobody knows what type of solutions are to be developed.

The choice of the right mediating tools (i.e. the stimulus) is another key factor for these ideation sessions. 'Putting the material on the table' could be such a tool, but it could be complemented with other ones. The role that the mediation tools have to play is to communicate the findings of the analysis phase to the participants (such as properties of the material), but even to help the participant in expanding their view of the possible idea-range. The activities of the ideation session (such as brainstorming) and the context where the session takes place, are presumed to work in the same way as in traditional product design processes.

3. How should the range of ideas be expanded? Coming up with an idea for how a waste material can be used is a huge challenge; otherwise someone else would probably have done it already. The participants of the ideation session are therefore in need of help and inspiration to come up with ideas. As already mentioned, selecting a multidisciplinary group of participants may gain help from their different backgrounds. Another support is to provide inspirational mediating tools to the ideation session. These tools could consist of real examples of how waste material is implemented in other new products. It could also describe other solutions with different approaches, for example to replace a material with our waste material in an existing product, if profitable. It is not necessary for a new product to be developed from scratch. The solution could also be that waste material is used to improve product quality.

CONCLUSIONS

The traditional design process approach is insufficient for teaching when design with waste material is in focus of student's design efforts. Therefore, the expanded design process, starting up with a pre-process has been proposed, specifically to address the new challenges when designing with waste material. It was developed since a description of a systematic process for this issue could not be identified among neither researchers nor practitioners. The developed process is however only to be considered a suggestion at this stage, to be applied by the student's in the IWtoPD project. Since this study within the Mistra Closing the Loop initiative will cover a period of three years and a number of different master thesis projects, all of them taking off from waste material, the process model will be be refined and further developed. Later on, an evaluated process and methodology for waste material design is expected that may be taught to design students everywhere, resulting in a multitude of new solutions building on waste material re-use.

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