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A MODEL FOR EVALUATING MASS CUSTOMIZATION TOOLKITS

Guido Hermans
Umea University, Umea Institute of Design, Umea, Sweden

Abstract: *Mass customization involves the consumer in the design process by enabling them to customize a design through the use of a toolkit. In this paper, a model is introduced that can be used to evaluate mass customization toolkits. The model is based on target outcome and guidance and analyzes the toolkits by looking at product attributes, mechanisms, freedom in the solution space and guidance in terms of the starting point and provided instructions. The three main findings presented in this paper concern the emphasis of current toolkits on customizing hard product attributes, a focus on 'lower-level' product attributes, and the uniqueness of the outcomes that current toolkits produce.*

Key Words: ***Mass Customization, Toolkits, Product Design, Freedom, Model***

1. INTRODUCTION

A well-known mass customization toolkit is NikeID [1] which offers consumers the possibility to customize their own pair of shoes. When you enter the website you can select from a range of different shoe types for running, soccer and other sports, and for each shoe type there are a few materials in many colors to choose from. The number of possible designs this toolkit could produce is vastly. However, every shoe that comes out of this toolkit will still be recognized as a Nike shoe. A toolkit allows the user to customize some parts of a product within set boundaries. The creative task is constrained for two main reasons, maintaining the brand identity of the shoe and making it easy for non-designers to engage in customization. In traditional product design the designer completely defines a product, he might design variants but he has complete control over every aspect of the design. In mass customization on the other hand, a certain amount of control is given to the consumer. The user can be creative within the boundaries of the toolkit.

The aim of this paper is to propose a set of concepts to which will be referred as a model for evaluating mass customization toolkits focusing on the freedom an user has in the solution space. In order to develop toolkits for mass customization, it is important to understand the creative freedom a solution space offers to the user. This paper's purpose is to develop a deeper understanding of toolkits that enable consumer involvement in the design process by performing a qualitative analysis of toolkits to capture the richness of each particular and to evaluate and refine the proposed model.

The paper is structured as follows: in the background section mass customization and existing relevant studies are discussed. An previous empirical study is introduced as a case study. In the next section a model is introduced for evaluating toolkits, this is followed by the analysis of 12 toolkits. The paper ends with a discussion where the findings are presented and a conclusion that covers the implications for industrial designers and other professionals involved in developing customizable products and their toolkits.

2. BACKGROUND

Mass customization is a strategy concerned with offering products that meet individual's needs and desires. These offerings are produced with near-mass production efficiency [2]. One way of obtaining one's needs and wishes is done through direct consumer involvement, also referred to as collaborative customization [3] which is the interest of this paper. The transfer of sticky information [4] is typically done through a toolkit or configurator, a piece of software that lets the user customize a product, for instance a pair of shoes, a vase or jewelry. A toolkit encompasses a *solution space* [5] where the designer has determined what the consumer is able to customize. A solution space is constrained, whereas a *design space* is seen as an infinite one. Von Hippel defines a toolkit by five characteristics [4]: trial-and-error learning, appropriate solution space, user friendly, libraries of modules and producible by intended manufacturer.

In literature, three types of customization are defined based on the three functions of a product which are utilitarian, kinesthetic or visual [6]. Berger & Piller offer a similar definition of the types of customization into functionality, fit (ergonomic) and style (aesthetic) [5]. Product attributes are used to establish one or more types of customization. For example, by changing the shape of the juice squeezer, the aesthetics changed, but also the ergonomics could have changed. Therefore, product attributes can establish more than one type of customization.

Customizing a design in a mass customization toolkit is a creative task. A creative task is defined as any activity in which ones produces an outcome [7]. In the case of mass customization, the outcome is a digital

design for producing a physical product. Dahl & Moreau categorize creative tasks by target outcome and guidance, where target outcome is fixed, a toolkit is specific to a product type and a production method [4], and a certain amount of guidance is provided by the interface. In order to offer a customizable product, one needs to possess three capabilities, which are solution space development, robust process design and choice navigation [8]. In other literature it is defined as elicitation, process flexibility and logistics [9]. The aspect of process flexibility is important in order to be able to produce one-offs, something that is difficult with high volume line production.

The Customization 500 [8], a benchmark study, analyzes 500 mass customization companies. The offerings are evaluated on visual realism, usability, creativity, enjoyment, uniqueness and number of given choice options and are based on expert ratings. A qualitative analysis has been comparing five toolkits that use rapid manufacturing as a production technology [10]. The main recommendation from this analysis was to further investigate the solution space and the freedom users have in it. Furthermore, there are two online databases which give an overview of available mass customization toolkits, the Configurator Database [11] and Milk or Sugar [12]. The literature gives a broad overview of the available mass customization toolkits. However, a deeper understanding of the user in relation to the solution space is lacking. How free can a user be in the space of a mass customization toolkit and what constitutes this freedom? In order to answer this question, current toolkits and their solution space are analyzed, but before the model is introduced, I will explain the concept of mass customizing a design with a case study.

3. CUSTOMIZATION OF SHAPE: THE JUICE SQUEEZER CASE

In our previous experiment we explored parametric customization of a consumer product by non-designers [13]. The aim of this experiment was to get a better understanding of the role of the consumer in customizing a product.

3.1 The study

An experiment was conducted that invited participants to customize, use and evaluate a juice squeezer. The experiment consisted of four steps: the development of the solution space, the customization of the object by the participants, the production of the object by additive manufacturing and the use and evaluation of the object by the participants. A parametric approach has been used in order to enable the shape of the object to be customized. A simple toolkit has been developed consisting of a 3D CAD model with eight parametric sliders (Figure 1, part A) that controlled different parts of the shape. By changing the values of the sliders, the 3D model on the screen changed in shape in real-time. The participants could experiment and change the shape until they were satisfied with the result. Hereafter, the designs have been 3D printed in ABS plastic. The final stage of the experiment consisted of the use and evaluation of the prototype. The results of this study are both the prototypes (Figure 1, part B) as well as the evaluations of the participants.

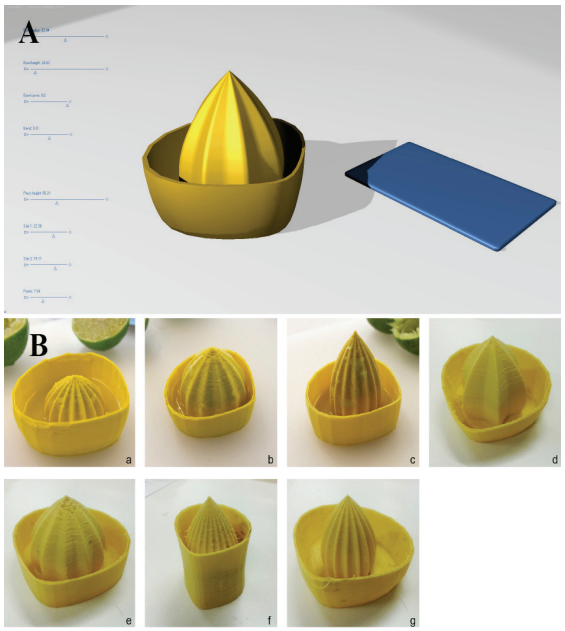

Figure 1: *Part A: Screen shot of the interface with sliders (left), the design (middle) and reference object; Part B: 3D printed prototypes (a-g) of the customized designs*

3.2 Findings

Five findings have been pointed out that I will discuss here shortly. There was a lack of variation (1) in the customized designs produced in this study. The participants were given a solution space in which they were able to design their own object. The notion of a solution space is well understood among designers and other professionals, but do consumers also understand this? Secondly, participants noticed a responsibility shift from designer towards consumer. Furthermore, the issues of understanding a 3D virtual model, prioritizing what can be customized and control over what can be customized have been pointed out.

3.3 Conclusion

Several issues have been identified when a consumer takes on the task of customizing a design. The findings are mostly in the form of questions and open up new spaces for research. The design of a solution space and toolkit is not a straightforward task; too much design freedom will overwhelm the user; too little design freedom will not lead to a sense of competence. There is a trade-off between giving the user freedom and setting up constraints.

4. INTRODUCING A MODEL FOR EVALUATING MASS CUSTOMIZATION TOOLKITS

In mass customization the consumer has an active role in the design of the product. The consumer interacts through the use of a toolkit. In trying to understand the role of the consumer in mass customization one can look at the toolkit. In order to compare and evaluate mass customization toolkits with each other, a model is proposed in this paper. The model analyzes mass customization toolkits with a focus on freedom. In any toolkit, there is a tradeoff between the freedom of the

consumer and the control of the designer over the process and the product.

The freedom an user has in a toolkit can be seen as the creative space one has. I use a pragmatic interpretation of experiential creation as defined by Dahl & Moreau consisting of the factors: (1) the level to which the target outcome is dictated and (2) the amount of guidance provided when creating an outcome [7]. I also built on the definition by Walcher & Piller [8] who define creativity in a similar way: (3) the amount of freedom the toolkit offers to the user and (4) the ability to let one's creativity reign free. I will use target outcome and guidance as the two factors describing experiential creation in mass customization toolkits. The model proposed in this paper analyzes toolkits by presenting five questions:

1. Target outcome
    a. Which *hard* and *soft product attributes* can be customized?
    b. Which *mechanisms* enable the user to customize product attributes?
    c. How much *freedom* does the user get when customizing?
2. Guidance
    a. How does the user *start* the customization process? What is the *start point*?
    b. How many *instructions* does the user receive when customizing?

In the following sections, the five questions that form the basis for the model are discussed more in detail.

4.1 Target outcome

Target outcome is characterized by soft and hard product attributes, mechanisms and the amount of freedom in the solution space.

4.1.1. Product attributes

In a mass customization toolkit, the user is able to customize a product to his or her own needs and desires. One can for instance pick red as a color for a smart phone cover, one can determine the size and fit of a custom shirt or choose to make the shirt of 100% thick cotton. In all these cases, the user is making decisions about product attributres, i.e. color, dimensions and materials properties. Therefore, customization can be seen as defining one or more product attributes. Product attributes are the characteristics or qualities of a product.

These attributes can be divided into hard and soft [14] or physical and appearance properties [15]. The hard attributes make up the physical product, e.g. color, texture, material. The soft attribute is the meaning derived from the physical product. In this paper, I regard hard product attributes as layers of a product, ranging from core, *function*, to skin, *surface*. I use a division derived from current toolkits, starting with *function*, *features*, *structure* or arrangement of components, *material* and its properties e.g. color, strength, stiffness, texture, conductivity, transparency, *shape*, *dimensions* to *surface* including color, engraving, etching, embroidery, graphical prints. I will give an example to explain how this division can be used, a toolkit enables you to pick the color of a handle or it enables you to choose the material for a cupboard. An attribute can either be customized in a discreet or continuous way. Discreet is meant as a limited number of options, for example the attribute color has 10 instances. Whereas continuous is used as that it varies over a range; color on a screen consists of the three components red, green and blue that each range from 0 to 255. Soft or intangible product attributes are a combination of physical properties that give a product a certain appearance and meaning. They can be divided into sensory, symbolic and stylistic attributes [14,16]. Sensory attributes are aesthetic properties such as feel, texture and form. Symbolic attributes are verbalized by words like aggressive, cheap, trendy or exclusive. Stylistic refers to the different stylistic movements such as Art Nouveau, Modernism or Retro.

4.1.2. Mechanisms

Mass customizatin deals with offering unique products to consumers. In the definition from Tseng & Jiao it states that mass customization does this with near-mass production efficiency [2]. In order to offer unique products at a large scale efficiency is reached by highly flexible systems. One of these, and probably most common way of doing this, is modularity. Modular systems are just one of the mechanisms to gain efficiency and flexibility. A mechanism is the enabling technique to gain the high level process flexibility needed for offering mass customization.

I propose four different mechanisms (A-D) that were derived from current toolkits. Veneer (A) is a mechanism for customizing products by adding a visual, decorative layer to mass produced products. It is a very common way of mass customization in today's industry. Companies like Zazzle [17] use it and print custom texts and graphics on a large variety of mass produced products, ranging from coffee cups, t-shirts to smart phone cases. Besides printing on products, engraving, etching and embroidery are common methods. The second mechanism, modularity (B), is realized by assembling mass produced modules or components to form a customized design. Von Hippel states that a mass customization toolkit consists of modules [4]. Modularity is a common way to achieve flexibility in the production process. The freedom in a modular toolkit is limited by the number of options. In reality however, this number is often extremely high. Parametric customization (C) is based on a virtual design which can be altered by changing parameter values. Rather than veneer or modularity, the manufacturing of the design is entirely postponed until after customization. An example of parametric customization is the study of the kitchen utensil where consumers were given a 3D model of a juice squeezer and they were given the task to customize the shape of the juicer by moving sliders back and forth [13]. The generative mechanism (D) is based on an algorithm that generates a design and the user has an influence on that algorithm. The production of the design in generative customization is also completely postponed. An example of a generative toolkit is FluidVase [18] which allows one to have influence on a virtual stream of liquid poured into a container to form a vase.

4.1.3. Freedom in solution space

A toolkit allows the user to customize certain product attributes and a mechanism is used to produce the

customized design. Every toolkit has its own solution space. Some toolkits are very restrictive, the user is not allowed to come up many different designs where as other toolkits can be used to make a large variety of products.

The size of the solution space is an indicator when determining how much the target outcome is dictated by the toolkit. The size is determined by two factors: (1) the number of options within one product attribute, for instance the attribute color has 78 options, and (2) the level of heterogeneity of these options, a dozen red tones or a range of colors from red, orange, yellow, green to blue. Heterogeneity can be established by having different customizable attributes and offering variety within one attribute. The wider the solution space the more freedom an user has in making the product his own.

4.2 Guidance

Providing guidance is the second factor that defines experiential creation. Target outcome is concerned with the outcome of a mass customization toolkit. Guidance on the other hand, is concerned with the process of customization which is defined by the starting point in the toolkit and the instructions that the user receives along the way.

4.2.1. Starting point

When the user enters a toolkit, a starting point for customization presents itself. Typically, the user either has a range of basis designs to choose from or he faces a blank canvas. These basis designs are used to inspire and jump start the user, for example, when entering NikeID one sees a large variety of customized designs that one can choose from.

4.2.2. Instructions

The customization task can be guided by instructions. This is often realized by having a numbered step process, guiding the user through each stage and providing feedback about the progress of the task. Another feature that is often offered is the option to unlock more detailed information about a specific step or option. One of the characteristics of mass customization toolkits is learning by trial-and-error [4], therefore the toolkit should allow the user to experiment and go-back-and-forth during the customization process.

The proposed model for evaluating mass customization toolkits is based on target outcome and guidance. It provides a framework for evaluating toolkits that allow users to customize products.

4.3 Visualization

The qualitative analysis has also been visualized in order to see an immediate representation of the analysis and to be able to compare the toolkits among each other.

The target outcome aspects have been visualized in a circular graph (Figure 2). The circle is divided in four quadrants, one quadrant for each mechanism. Then, the circle has several layers, from inside to outside, each representing a product attribute. The inner circle is the function, then towards the outside it stands for features, structure, material, shape, dimensions and finally the skin of the product. Besides the physical product attributes (1a) and the mechanisms (1b) that are visualized in the circular graph, the freedom (1c) is depcited as the number of options that the toolkit offers.

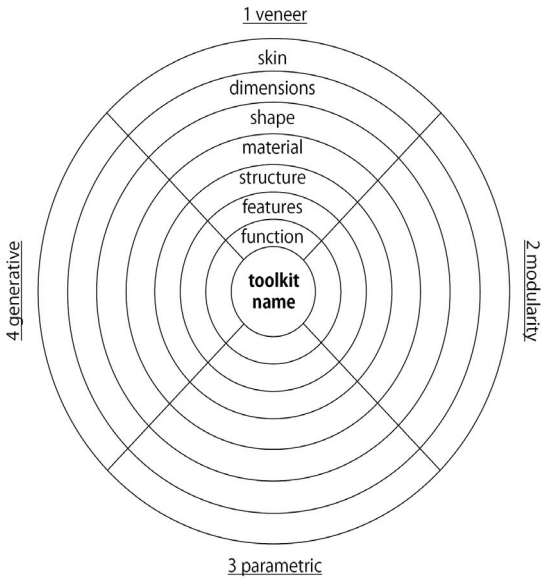

Figure 2: *The model with four quadrants for each mechanism and seven layers for each product attribute.*

5. METHOD

The proposed model is used to analyze current mass customization toolkits. The toolkits have been analyzed on the five aspects mentioned earlier, that are customizable product attributes, mechanisms, amount of freedom, start point and instructions.

A number of mass customization toolkits have been selected (Table 1) according to the following criteria: the toolkit has to focus on consumer products, the toolkit has to enable customization through a web-based interface, and the toolkit has to enable ordering the customized product online. Furthermore, the selection of toolkits has to cover a variety of product categories and all four identified mechanisms. The analyzed toolkits are first discussed and one of them is visualized in a circular graph.

Table 1: *Selected toolkits, veneer (1-3), modularity (4-6), parametric (7-9) and generative (10-12).*

	Company	**Category**	**Website**
1	Oakley	Sunglasses	oakley.com
2	NikeID	Shoes	nikeid.com
3	Case Mate	Accessories	case-mate.com
4	Blancier	Watches	blancier.com
5	Sonor	Drum kits	sq2-drumsystem.com
6	Dell	Computers	dell.com
7	CYW	Furniture	cupboardyourway.co.uk
8	Bivolino	Clothing	bivolino.com
9	Nervous System	Jewelry	n-e-r-v-o-u-s.com
10	Continuum Fashion	Clothing	continuumfashion.com
11	Supabold	Interior	supabold.com
12	Diatom Studio	Furniture	sketchchair.cc

6. ANALYSIS

The analysis consisted of applying the proposed model for evaluating mass customization toolkits to a selected number of toolkits. The five questions of the model are addressed for each toolkit. The results of the analysis are presented by mechanism, starting with veneer, modularity, parametric and ending with generative. For each mechanism one toolkit is discussed in detail with a visualization and the other two toolkits are briefly noted in Table 2, Table 3, Table 4 and

Table **5**.

6.1. Mechanism 1 Veneer

Oakley (Table 1, 1) offers a toolkit that allows the user to customize sunglasses, it focuses on aesthetic customization. The toolkit offers 25 different types of sunglasses in four categories named sports, active, lifestyle and women. For this analysis we focus on the type Radar (Figure 3, top) from the Sports category.

The model for analysis starts with the target outcome. The hard product attributes color, shape and etching can be customized. For the attribute color there are many options specified for each part. The frame has 15 color options, the lens 15, the ear socks 14 and the icon can be customized in 24 colors. The shape of the lens has three variations and the option for etching can either apply to custom text or a standard logo. The toolkit uses the veneer mechanism, since it allows users to change the external layer of the sunglasses. The shape variations use the modularity mechanism. The amount of freedom in a toolkit is defined by the number of options and the hetereogeneity. The freedom in numbers is high, 211.680 possible designs plus the possibility to have etching of custom text or a logo, but the heterogeneity is low since one can only customize two different product attributes.

The second part of the model focuses on guidance. The toolkit opens with one basis design to start from. The user is not explicitly guided through the customization process in a step-by-step manner, rather the interface shows several options where the user can work with.

Table 2: *Analysis of toolkits 2 and 3.*

Aspect	**Toolkit 2 Dunk high iD**	**Toolkit 3 I Make My Case**
1 Attributes	Material, surface color and embroidery	Surface color and graphics
2 Mechanism	Veneer	Veneer
3 Freedom	Options: high	Options: high
	Heterogen. low	Heterogen. low
4 Start point	Basis design	Blank canvas
5 Instructions	Step-by-step	No instructions

6.2. Mechanism 2 Modularity

The Blancier toolkit (Table 1, 4) offers customization of wrist watches. As showns in Figure 3 the customizable product attributes are material and graphics for the clock-face. There are 7 clockworks, 7 pointers, 16 clock-faces, 4 knobs, 2 rings, 8 outer rings and 10 different watch bands and this leads to a total of 501.760 possible design outcomes. The toolkit also offers the possibility for an inscription on the back of the clockwork.The mechanisms modularity for features, materials and graphics and veneer for the optional etching are used. The freedom in numbers is very high and the heterogeneity as well.

The guidance offered by Blancier is minimal. The toolkit opens with a blank canvas and there are no further instructions. All the options are displayed around the canvas without any step numbers or priority.

Table 3: *Analysis of toolkits 5 and 6*

Aspect	**Toolkit 5 Sonor**	**Toolkit 6 Dell**
1 Attributes	Features, material, dimensions, graphics	Features, color
2 Mechanism	Modularity	Modularity
3 Freedom	Options: high	Options: low
	Hetereogeneity medium	Hetereogen. low
4 Start point	Blank canvas	Basis designs
5 Instructions	Step-by-step	Step-by-step

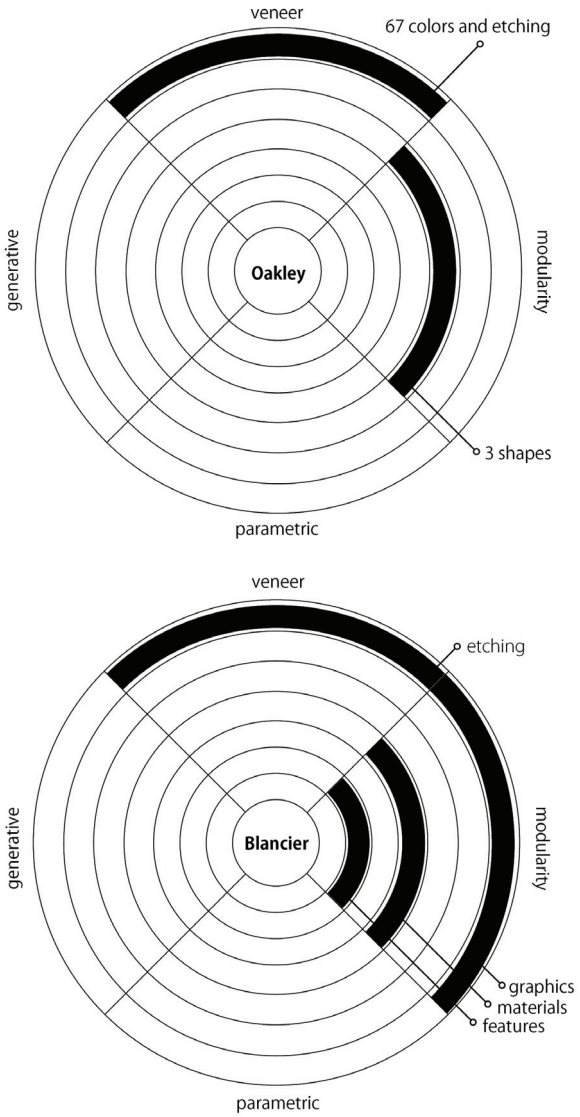

Figure 3: *Visualization of the Oakley toolkit (top) and Blancier toolkit.*

6.3. Mechanism 3 Parametric

Cupboard Your Way (Table 1, 7) offers a toolkit for customizing cupboards and bookshelves. There are eight basic types of furniture that can be customized by the user (Figure 4, top). This can be done through the product attributes features, materials and dimensions. Features lists different elements, shelves, drawers, rails, doors and handles. Material has 8 body finishes, 8 door finishes and 4 knobs. The dimenions are determined by user input. The toolkit uses the parametric mechanism for the features and dimensions and the veneer mechanism for the materials. The freedom in this toolkit is high in numbers as well as in heterogeneity.

The user enters the customization process by choosing from one of the basic designs. Then, a step-by-step process guides the user further.

Table 4: *Analysis of toolkits 8 and 9*

Aspect	**Toolkit 8 Bivolino**	**Toolkit 9 Nervous System**
1 Attributes	Features, material, shape, dimensions, color, embroidery	Function, material, shape, dimensions, color
2 Mechanism	Parametric, veneer	Parametric, veneer
3 Freedom	Options: high	Options: high
	Heterogeneity low	Heterogeneity high
4 Start point	Basis designs	Basis design
5 Instructions	Step-by-step	No instructions

6.4. Mechanism 4 Generative

In the D.dress toolkit (Table 1, 10) from Continuum Fashion the user is able to create her own dress (Figure 4, bottom). The product attributes shape and dimensions can be defined by drawing in a front and back view over a mannequin. The toolkit uses the generative mechanism and calculates the triangular structure when drawing a shape. The toolkit starts with a blank canvas and it offers no further instructions.

Table 5: *Analysis of toolkits 11 and 12*

Aspect	**Toolkit 11 FluidVase**	**Toolkit 12 SketchChair**
1 Attributes	Shape, dimensions	Material, shape, dimensions
2 Mechanism	Generative	Generative
3 Freedom	Options: low	Options: low
	Heterogeneity: low	Heterogeneity: high
4 Start point	Blank canvas	Blank canvas
5 Instructions	Step-by-step	Step-by-step

The results of the analysis used the proposed model to analyze a number of mass customization toolkits. The analysis gives an insight into the customizable product attributes, the mechanisms, the amount of freedom and the guidance a toolkit offers to the user.

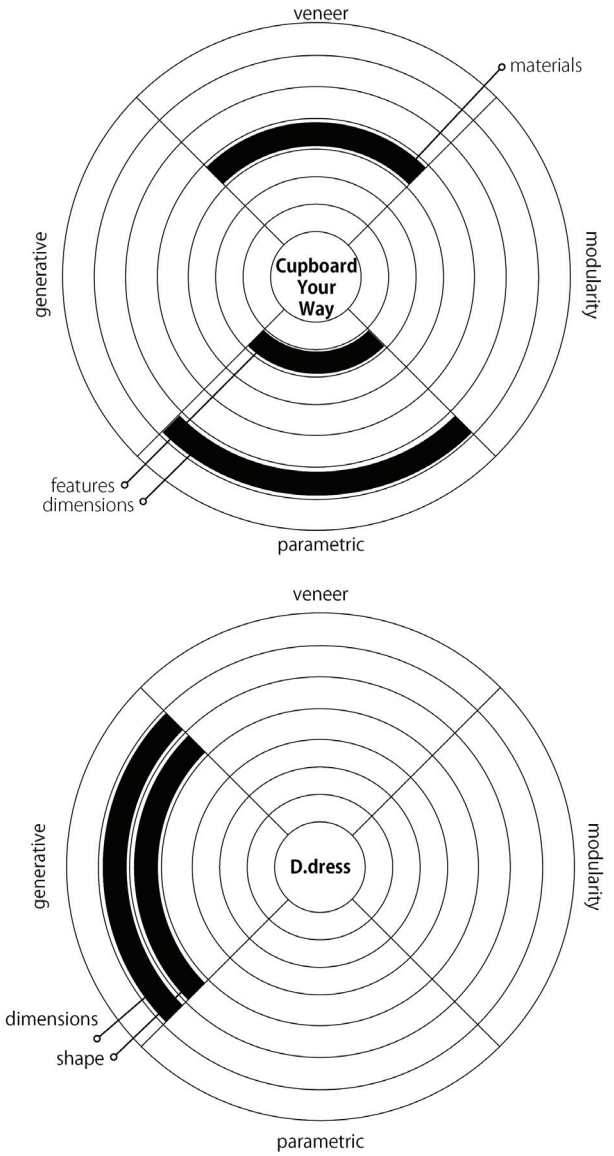

Figure 4: *Visualization of Cupboard Your Way toolkit (top) and D.dress toolkit.*

7. DISCUSSION

This paper proposed a model for evaluating mass customization toolkits with a focus on the freedom an user has in the solution space. This qualitative analysis of toolkits is relevant for those who design and develop toolkits since a deep understanding of toolkits and the role of the consumer in mass customization is lacking.

Three relevant issues are discussed that came up in in the analysis of mass customization toolkits with the proposed model. It concerns the focus of today's toolkits on hard attributes (F1); the emphasis of many toolkits on customizing 'lower-level' product attributes (F2) and finally the lack of uniqueness of the outcomes a toolkit produces (F3). I will discuss each finding more in detail and try to give examples of each of the findings.

7.1. Hard product attributes

The first finding of the analysis concerns the focus in the analyzed toolkits on customizing hard product attributes (F1). All toolkits present the customization

task as a process of selecting from options or altering parameters or algorithms, but they primarily focus on the physical and tangible aspects. The attention focuses on the hard attributes rather than the intangible properties, the semantics of a product; this is partly caused by the enabling mechanisms and production technologies. The mechanisms help to understand how toolkits work and why certain customization is possible. Most current toolkits use the veneer or modularity mechanism combined with conventional mass production techniques. The parametric and generative mechanisms are typically using digital fabrication technologies like laser cutting, CNC milling or additive manufacturing. The flexibility of these technologies is larger than conventional line production techniques. The opportunities of these mechanisms for customization have yet to be fully explored.

7.2. Lower-level product attributes

The second finding concerns the emphasis in many toolkits on 'lower-level' product attributes. This means, that many mass customization toolkits offer the customization of product attributes such as color surface prints rather than material properties, features or functionalities. Figure 2 shows the layers of a product, also referred to as product attributes. The core of a product is its function and the skin or surface of a product is the color, embroidery or prints. Offering the consumer more 'higher-level' product attributes to customize (towards the core of the product, i.e. the *function*), it will give the user more fundamental control over the design (F2).

7.3. Uniqueness of outcomes

The third finding concerns the lack of uniqueness of the outcomes a toolkit produces. The freedom in a solution space can be defined by the numer of options one has and the heterogeneity of these options. The number of options in a toolkit is often very high, for instance the NikeID [1] toolkit offers a very large amount of possible design outcomes. However, the uniqueness of the outcomes is often much lower or sometimes even insignificant. The question is if this matters to the consumer, does he have the feeling he has been tricked or do consumers, even though there is not much difference between the designs, still feel that they can create what they want? If more diversity in the outcomes is desirable, then this lack of uniqueness could be resolved by offering a toolkit that has a combination of diverse customizable product attributes (F3). For instance, besides only offering the consumer to be able to change the color of a product, giving them the option to also alter the material properties, features and shape might give them more satisfaction and the possibility to create something that truly suits them.

The three findings I pointed out result from the analysis of toolkits with the proposed model. These findings are points of attention when designing and developing a mass customization toolkit.

8. CONCLUSION

This paper has shown that it is possible to study mass customization toolkits and that there are differences between these toolkits. I provided one model for evaluating mass customization toolkits and there are probably different approaches to evaluate and analyze the solution space which may reveal other aspects. The qualitative approach used in this paper is suitable for trying to understand toolkits and getting an insight into toolkits with all its richness.

The limitations of the proposed model concern the number of toolkits per mechanism which are not representative for today's offer in industry. The first two mechanisms are far more commonly used. Therefore, the definition of the latter two can be improved and they can be grounded more solidly. The guidance aspect has been paid less attention to in this analysis and it should be developed further in future research. The model and analysis presented are a first step in evaluating the solution space of toolkits and trying to understand the role of the consumer in creating their own products.

To summarize, this paper has shown that differences exist between mass customization toolkits and handing over control and freedom to the user has implications for the task of the designer. This model could inform practice in guiding and developing new toolkits for mass customization.

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CORRESPONDENCE

Guido Hermans
Umea University
Umea Institute of Design
Ostra Strandgatan 30
Umea, Sweden
guido.hermans@dh.umu.se