

Representing product personality in relation to materials in a product design problem

The materials a product is made of play a major role in the user's product experiences. In design research nowadays more attention is given to these qualities of materials, besides the ongoing research on technical aspects of materials. How product designers take decisions about materials is one of the topics of research in this field.

Decisions on materials play a role in different design methodologies. In some methodologies these decisions are related to experience aspects such as product personality. In others, decisions on materials are related to elements such as shape, manufacturing, function and use. However, there is no model that integrates all these elements of design.

In this paper we reviewed design methodology to make an integrated model on how design considerations interact and on how the elements of design causally relate. These models show the complexity of designing when including users' experiences, but help to understand the relations between decisions in designing such as materials and product personality decisions.

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INTRODUCTION

In design, awareness of product experiences is growing [e.g. 1, 2, and 3]. Increasingly manufacturers find they cannot distinguish on technical functioning alone. For example, a Dutch newspaper stated: "Manufacturers more and more cater on emotion, now that technique is no longer distinguishing" [4]. The increasing knowledge in this field helps product designers in making products with a personality that elicits desired experiences (figure 1).

Product experiences include the emotions that users have when they interact with products. Product personality (PP) is one of the aspects that contributes to product experiences. Desmet defines product personality as product appearance and how the user's senses react on this appearance [1]. In addition to product appearance, Ashby and Johnson include the associations the product creates in product personality [2]. According to Goverts product personality refers to the profile of personality characteristics that people use to describe a specific product [3].



My experiences: "It reminds me of my childhood, I feel nostalgic, it looks colorful, it feels robust and not easy to break, the sound is still terrible though"

Figure 1 The product personality influences the experiences the user has with a product.

Materials play an important role in the experiences people have with products [5, page 101]. When users interact with products the users' senses are in contact with the materials of those products. Users see colours of materials, feel texture and weight and hear sound when moving the object. These sensory experiences contribute to the experiences of the user. Product designers use materials to give users a desired sensory experience. In addition, product designers select materials for products to elicit the right associations, for example the metals used in a Rolex expresses status [5, page 68]. So product designers influence product personality by materials considerations.

Product personality and materials are not the only aspects of a product. There are many more such as costs, shape, environment, use and function. Designers use considerations on these and other aspects to guide them in creating a product form, but not by considering them one by one. Many of the aspects interact, which makes designing a balancing act between different aspects. Design methodologists have formulated models to make this balancing comprehensible. They represent different elements of design and relate these elements, e.g. function, form and use.

Attention for product experience and emotion is relatively new, so not all methodologists include product personality in their models. However, many include considerations of materials. For example, Ashby has studied the interaction between materials, making, shape and function [6]. It is assumed that the materials – product personality relation can be combined with the known relations of materials to other elements of design it is possible to formulate an integrated model.

The aim of the study presented in this paper is to make an integrated model that shows the materials - product personality relation embedded in the interactions that materials have with other elements of product design. Therefore, different models from design methodology were assessed for finding the elements of product design. The integrated model was made to help product designers to increase grip on creating user experiences by selecting materials.

This paper consists of three parts. The first part explores the relation between materials and product personality in detail. The second part explores the relation of materials to other elements in product design, e.g. function, form and use. The third and last part presents an integrated model of the considerations involved in choosing materials for desired product experiences. One component of this model shows the design considerations and how they interact. Another component shows the causal relation between the elements of a product proposal.

The authors of the design methodology referred to in this paper use different terms for the elements they distinguish (table 1). In this paper some terms are changed to have the same terminology throughout the paper.

Table 1 Terminology used for different elements by different authors.

Elements termed:					
in this paper		by Roozenburg & Eekels [7]	by Ashby [6]	by Muller [8]	by Ashby & Johnson [9]
F	Function	Function	Function	Function	Function, Technical functionality
M	Materials	Physical – chemical form	Materials	Materials	Materials (dimensions: engineering, use, environment, aesthetics, personality)
S	Shape	Spatial form	Shape	Shape	Form
MP	Manufacturing processes	Manufacturing processes	Process	Process/work	Processes (joining, shaping, finishing)
U	Use	Use	<i>Not mentioned</i>	Use	Use
PP	Product personality	<i>Not mentioned</i>	<i>Not mentioned</i>	<i>Not mentioned</i>	Product personality

MATERIALS AND PRODUCT PERSONALITY RELATION

In the introduction, it was brought in that there is a relation between material considerations and product personality and that product designers can use this relation for designing products that elicit desired experiences. Ashby and Johnson explain this relation between product personality and materials in more detail in [2 and 9].

Materials are initially given two roles by Ashby and Johnson, namely materials make products function technically and they create a product personality (figure 2 and 3) [9, page 2].



Figure 2 Two trashcans made of different materials have a different personality. The left one is made of plastics and people might think it looks ordinary and cheap. The right one is made of metals and people might think it looks exclusive and clean.

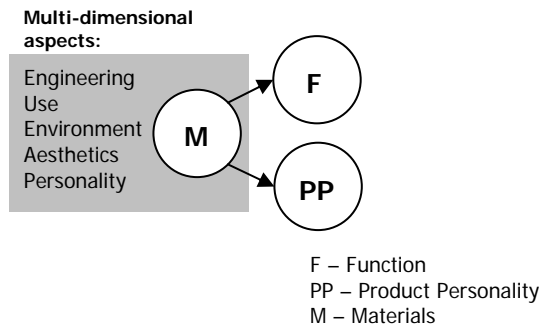


Figure 3 Two roles of materials in products as defined by Ashby & Johnson: to give the product its technical functionality and to give the product its personality [9, page 2]. The multi-dimensional aspects of materials refer to the characteristics of materials that are related to the aspects.

Materials require multi-dimensional information because they affect the engineering, use, environment, aesthetics and personality of products [9, chapter 4].

Engineering dimensions are the technical data that are available on materials such as its physical, mechanical, thermal, electrical and optical behaviour. These properties affect the functioning of the product [9, page 56].

The *use dimensions* affect ergonomics and product interface e.g. weight. Heavy products can made lighter with lighter materials, elastomers can provide grip where needed.

Some materials have a greater impact on the environment than others, which is laid down in the *environmental dimensions* e.g. toxicity or scarcity of materials.

The *aesthetic-dimensions* influence the five senses. These dimensions are the tactile attributes such as hardness or softness of materials, visual attributes such as transparency or colour and acoustic attributes.

Moreover, a product is perceived and a user can have associations with it. Materials play a role in this with their *personality dimensions*¹. For example, metals might seem clean, cold and precise [9, page 74] and polymers are sometimes perceived as imitations. Note that personality here is only referred to as the associations people have.

¹ There is a difference between the personality dimensions of materials and the personality aspects of products. The personality dimensions of a material are characteristics that contribute to the product personality, such as colour, texture and associations people have with a material. Product personality is the combination of aspects including materials and e.g. shape that elicits desired user experiences.

In the introduction was stated that aesthetics are part of product personality as well as associations. This is similar to what Ashby and Johnson define in [2] where they define product personality as aesthetics, associations and perceptions. However, Ashby and Johnson make a distinction between these two in the dimensions of materials.

Ashby and Johnson consider manufacturing processes as important to the design problem as materials [9]. Ashby and Johnson distinguish three different processes; shaping, joining and surfacing. Shaping gives the product its form, joining gets parts together and surfacing is about textures, finishes and coatings for protection and decoration [9, page 89]. All three contribute to the product personality. Surfacing can enhance the visual and tactile qualities of products and can so contribute to the ergonomics, aesthetics and perceptions of products. Functional requirements give boundaries to the form, but within these boundaries a lot of variation is possible with shaping, which in turn contributes to the product personality. With different joining techniques different expressions can be given to products such as craftsmanship.

According to Ashby and Johnson consumers buy products they like. Consumers do not only expect the products to function properly, but also to be convenient to use and to have a personality that is attractive for consumers. They state that balancing between use, function and product personality is key to innovative product design (figure 4) [9, page 2].

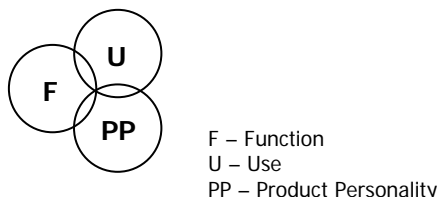


Figure 4 Balance between function, use and product personality in a product adapted from Ashby & Johnson [9, page 2, figure 1.1]

Summarising, materials used in a product fulfil the role of technical functioning and of product personality. The aesthetic and personality dimensions of materials influence the product personality. Other dimensions of materials are the engineering, environmental and use dimensions. Designers use considerations on these five dimensions while selecting materials. Technical functioning and product personality are interwoven with the product's possibilities of use.

MATERIALS IN PRODUCT DESIGN

Materials are related to other elements in design in various models of which three were assessed here. Ashby's model shows *design considerations* as elements of mechanical design, or better materials selection, and how these elements interact [6]. Roozenburg and Eekels' model represent the causal relations of elements defined as the *design problem* [7]. An extension of Roozenburg and Eekels' design problem is described by Muller [8].

Material considerations during a design project

Ashby describes the design process as an introduction on a methodology for selecting materials. According to Ashby, the starting point for a design project is function. Function dictates the choice of materials and shape. Shape includes both the external shape (macro-shape) and the internal shape (e.g. honeycombs) [6, page 13]. Manufacturing processes give materials their shape, but are influenced by the choice of materials e.g. their weldability or machinability. These four elements, function, shape, materials and manufacturing

processes interact. Ashby terms these interactions as the central problem of material selection (figure 5) [6].

In figure 5 the elements represent design considerations, so the M stands for thinking over and deciding on materials. The arrows indicate an interaction. So considerations in materials influence considerations in shape, manufacturing processes and function. Although designers start with function, they should check how considerations on other elements affect function.

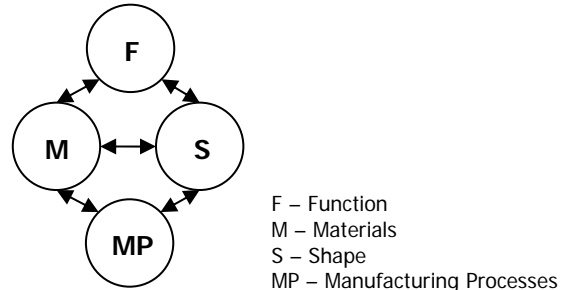


Figure 5 Representation of the central problem of material selection in mechanical design (adapted from Ashby [6, page 13, figure 2.5]). The arrows illustrate how the design considerations of the four elements interact.

Ashby does not mention a 'use' element in his model. This can be a result of the focus on mechanical design in contrast to product design where users play a larger role. But there are more aspects that Ashby does not include such as cost price, environmental issues or life in service. So is his model with only four elements sufficient for representing the problem of materials selection? The four elements of Ashby's model are sufficient when many aspects of design are covered by the model. For example, Pugh defines a checklist for aspects that need consideration when specifying a product design. This checklist contains as much as 32 aspects of attention for product designing and is referred to by Pugh as the product design specification (PDS) [10]. To assess the completeness of Ashby's model for product design we compared this model of four elements with the aspects of a design specification of Pugh. In table 2 is shown how the elements and aspects can be combined.

Table 2 Combination of the four elements of Ashby (figure 5) [6] and the aspects of Pugh's product design specification [10]. Many aspects of specification influence more than one design consideration.

Elements	Aspects of the product design specification of Pugh
F, M, S, MP	Product life span, Quantity, Safety, Testing, Environment, Packing, Competition
M, S, MP	Performance, Life in service, Documentation, Standards & specifications, Legal, Patents, Quality reliability, Product costs, Disposal
M, S	Installation, <i>Aesthetics</i> ² , Maintenance, Weight
F, S	<i>Ergonomics</i> ² , Market constraints, Politics, <i>Customer</i> ²
M, MP	Company constraints ³
M	Materials
S	Shipping, Size
MP	Manufacturing facility, Processes
none	Shelf life storage, Time scale

² These aspects are related to the user, but only in broad outlines

³ This aspect can contain many facets such as investment possibilities, number of employees, materials on shelf

Table 2 shows that most of Pugh's specification aspects can be combined with more than one of Ashby's elements. For example, 'weight'-specifications concerns materials plus shape and 'product costs' concern materials, shape and manufacturing processes.

Some of Pugh's aspects could not be combined with elements of Ashby e.g. 'shelf life storage' and 'time scale'. These aspects concern logistic facets of designing, which are not included in Ashby's model.

The only topic that is both mentioned by Ashby and Pugh are 'materials'. However, there is a slight difference between the two. Pugh state that the material aspect is only relevant if it restricts the design, e.g. when special materials are necessary or when materials can not be used due to legislation [10, page 55]. In Ashby's model materials represent the design considerations on materials and are thus always relevant. Note that Pugh's aspects of design specifications are used to give boundary to a specific design. Within these boundaries product designers consider function, materials, shape and manufacturing processes. So Ashby's model does not exclude aspects like costs and environmental issues, but sees these as design specifications in which product designers can balance their decisions.

Pugh does mention aspects in the PDS that concern the user, namely Aesthetics, Ergonomics and Customer, but only in broad outlines. Some of the aspects of product personality are covered by the 'aesthetics, appearance and finishing' aspects [10, page 55]. Although Ashby does not include a use element, the aspects that concern the user of Pugh fit in Ashby's model (table 2).

Summarising, Ashby represents a model of material selection in which four elements interact. These elements express the design considerations of the designer on function, materials, shape and manufacturing processes, within the boundaries of a product specification that include many more aspects than the four defined by Ashby.

Design problem in general design methodologies

According to Roozenburg and Eekels products are designed to provide in a certain need of e.g. a user or a salesman [9]. Product designers translate these needs into functions, for which they make a product form (characterized by its shape and its materials) [7, page 53]. Product designers reason in this from function to product form [7, page 51]. Manufacturing processes are used to make the product form by making changes to materials until the designed product form is reached. For example, by milling the product can get its shape and e.g. by hardening processes its material form. During manufacturing shape goes hand in hand with materials: changes in one result in (small) changes in the other, although mostly these changes are not aimed at simultaneously [7, page 53]. Figure 6 represents the relation between manufacturing and form: Manufacturing processes make the product form.

Roozenburg and Eekels give two conditions for a product to function. Firstly the product form (both shape and materials) and secondly the way a product can be used (figure 7) [7, page 56]. The arrows in figure 7 indicate a causal relation between form, use and function. Product designers reason in the opposite direction: Based on a needed function they design form and use in such a way that when the user utilizes the product as defined in the prescription of use the needed function is realised. So based on the functions the designer chooses the form and the way of use. Roozenburg and Eekels define this as *the core of the design problem* [7, page 56]. The elements they define as being part of the design problem are thus function, use and form (both shape and materials).

Manufacturing processes are indirectly related to the design problem (figure 6), so they also form an element.

Muller follows the definition of a design problem of Roozenburg and Eekels, but he introduces a relation between product form and use (figure 8). Muller adds this relation to indicate the following. At first use, the user will associate how to use the product based on its function, but as soon as a new product is being used the user will start to associate the product form with its use. New products often have similar product forms for similar functions, so users learn how to use the product based on the product form [8, page 59]. So indeed there is a relation between product form and use.

Summarising, Roozenburg and Eekels define the design problem as designing the causal relations between product form and a way of used based on the functions of a product. The form is made by manufacturing processes. Muller adds a relation between use and product form.

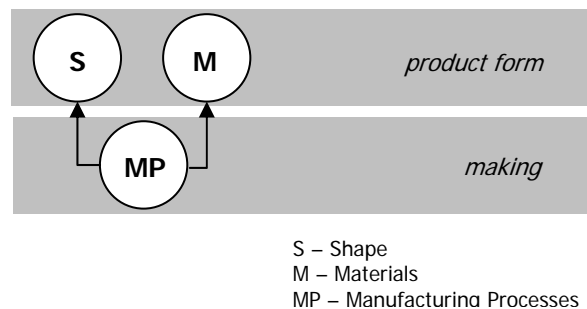


Figure 6 Causal relations between manufacturing processes and product form as defined by Roozenburg and Eekels [7, page 53]

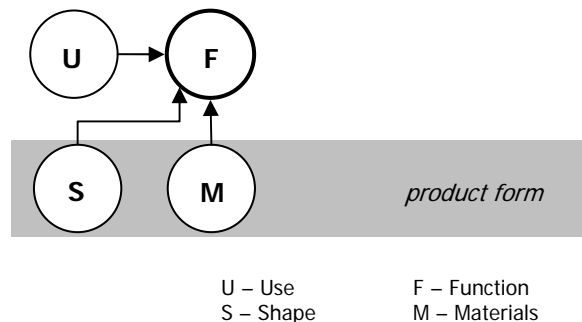


Figure 7 Representation of the causal relation of the elements in the core of a design problem (based on Roozenburg and Eekels [7, page 55, figure 4.3]). Designers reason from function to form (Spatial and Physical & Chemical) and to prescription for use.

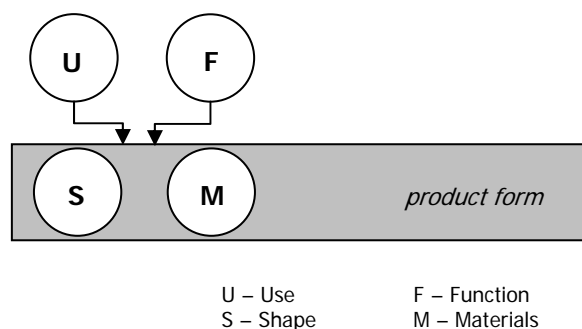


Figure 8 Causal relation of shape, use and function according to Muller [8, page 59, based on figure 3.7b].

AN INTEGRATED MODEL OF DESIGN

In this part, the integrated model will be generated and presented. The first step was to establish the elements in product design. The second step was to combine the elements based on the relations found in the previous parts. In some of the assessed models the elements were a topic for consideration e.g. the materials elements indicates a materials selection (figure 5). In other models the elements were a result of considerations e.g. the final result of materials decisions. This two meanings cause a difference in the relations between the elements. Therefore, two integrated models were made. The first shows the interaction of design considerations. The second shows the causal relations of the elements when the considerations have resulted in decisions.

Elements of design

Materials and product personality were the basis of the integrated models. Besides those we found the following elements in the first part: function, use and manufacturing process. In the second part we found function, use, shape and manufacturing process. The main elements for the integrated models are thus these six elements (figure 9).

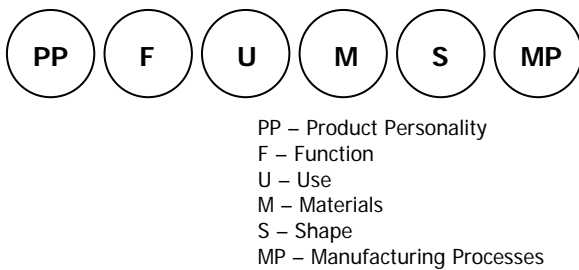


Figure 9 Elements of the integrated models of design.

In the integrated models:

Product personality is defined as the appearance of the product and how the user's senses react on the appearance as well as the associations it elicits in the user.

Function is defined as the aim of the product and the way it operates. The function of a product is what you can do with it and what you achieve e.g. writing is the function of a pen.

Use is defined as the designed interaction the user can have with the product. The interface of a product enables utilisation.

Materials are defined as the physical and chemical substances the product is made of. Materials have characteristics on different aspects including e.g. strength, colour, possible glosses and textures.

Shape is defined as the geometry of the product including details such as texture or finishing. Printing and patterns are also part of the shape of a product.

Manufacturing processes are defined as the processes that are needed to make the product including tooling, assembling, shaping, joining and finishing.

Elements of considerations in design combined

How the design considerations interact during a design project was summarized in figure 10. In this figure, the interactions that were found in the part describing materials and product personality are indicated by dotted arrows, the interactions found in the part describing materials in product design with normal arrows.

The interaction of function, materials, shape and manufacturing processes was adapted from Ashby (figure 5). The interaction

of function, product personality and use was adapted from Ashby and Johnson (figure 4) as also the interaction of materials, product personality and use and the interaction of manufacturing processes and product personality. From Muller the interaction of use and materials and shape was adapted (figure 8).

Figure 10 illustrates that almost all elements are at least related to four other elements. There are three interactions of elements that were not found, namely of manufacturing process and function, of manufacturing process and use and last of shape and product personality.

Manufacturing processes interact with materials and shape as they are used to change materials in a way that they get a certain shape. But do they also interact with function or use? Ashby does not indicate such a relation [6]. The relation between manufacturing processes and function is intermediated by the product form and thus by materials and shape. This means that manufacturing processes do interact with function but only indirectly by interacting with materials and shape which in turn interact with function. Therefore, no interaction was found between manufacturing processes and function. The same holds for the manufacturing process and use interaction.

For the interaction of manufacturing and product personality Ashby and Johnson do find a relation, although one might argue that also here product form intermediate between manufacturing processes and product personality. In addition, results of the manufacturing processes, e.g. polishing stripes, are in our opinion, aspects of the element shape. So only through materials and shape, manufacturing processes can influence product personality. That means that we change the found interaction between design considerations in manufacturing processes and product personality into an interaction between shape and product personality (figure 11). It is possible to do so because shape forms a strong visual aesthetic aspect of a product and product personality is defined as the aesthetics, perceptions and associations [2].

Two interactions were found both in part one and two. Finding these double interactions confirm the idea that it is possible to make an integrated model by combining the different interactions.

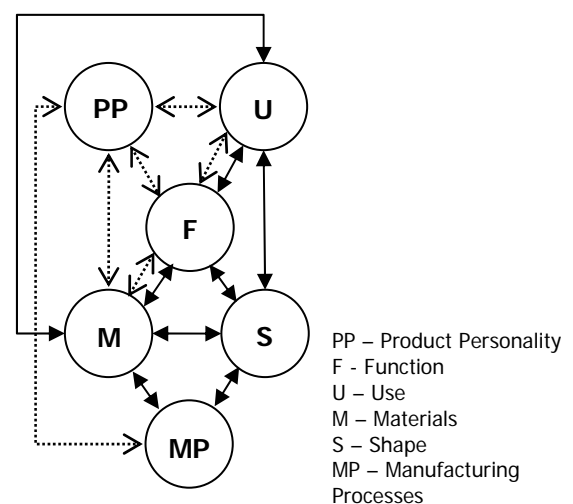


Figure 10 Combination of the different models that represent design considerations assessed in this study. Dotted arrows represent the interactions found in the part describing materials and product personality and the normal arrows represent the interactions found in the part describing materials in product design.





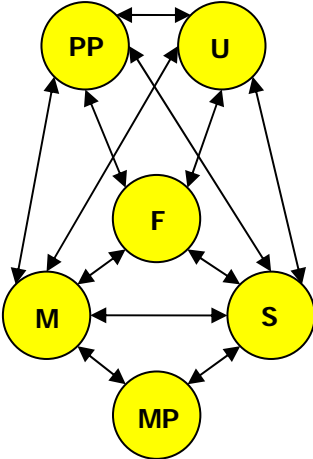







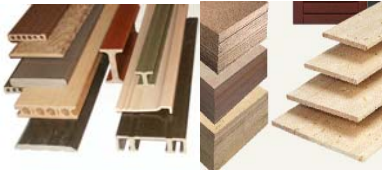
<p>1. Product Personality ↔ Function</p> 	<p>2. Product Personality ↔ Use</p> 	<p>3. Use ↔ Function</p> 
<p>4. Product Personality ↔ Materials</p> 	 <p>PP – Product Personality F – Function U – Use M – Materials S – Shape MP – Manufacturing Processes</p>	<p>5. Use ↔ Materials</p> 
<p>6. Product Personality ↔ Shape</p> 		<p>7. Use ↔ Shape</p> 
<p>8. Function ↔ Materials</p> 		<p>9. Function ↔ Shape</p> 
<p>10. Materials ↔ Manufacturing Processes</p> 	<p>11. Materials ↔ Shape</p> 	<p>12. Shape ↔ Manufacturing Processes</p> 
<p>1. Product Personality ↔ Function Party shoes have a festive look while running shoes look sportive and comfortable</p>	<p>7. Use ↔ Shape The shape of these volume controls require another way of using it (pressing vs. rotating)</p>	
<p>2. Product Personality ↔ Use Serious cassette players have another use and interface than funny and childlike ones</p>	<p>8. Function ↔ Materials Packaging for microwave ovens needs other materials (polyethylene) than for salads (polystyrene)</p>	
<p>3. Use ↔ Function Use and interface differ for a basic calculator and an advanced calculator with graph-function</p>	<p>9. Function ↔ Shape A bottle with all-purpose cleaner requires another shape than a bottle with toilet cleaner</p>	
<p>4. Product Personality ↔ Materials Transparent and rubbery materials for a sportive look and metallic for a classy</p>	<p>10. Materials ↔ Manufacturing Processes Plastics are processed here by injection moulding and metals by sheet forming</p>	
<p>5. Use ↔ Materials ABS gives hard keys in contrast to the soft flexible keys of a keyboard made of ElekTex™</p>	<p>11. Materials ↔ Shape Materials (plastic, metal) cause a different shape of this dish drainer</p>	
<p>6. Product Personality ↔ Shape A luxurious watch has another shape than a sunny and happy watch</p>	<p>12. Shape ↔ Manufacturing Processes Extrusion of wood gives another shape than sawing and milling of wood</p>	

Figure 11 The integrated model which represents design considerations. The elements are equivalent, which means that these can be mirrored or changed in place. For every relation between two elements a product example is given (nr. 1 to 12). Pictures were taken from various internet catalogues.

The integrated model on design considerations

Figure 11 shows the results of the combination of design considerations concerning product personality and materials the other elements found. The arrows represent the interaction of those design considerations. The elements are equivalent, which means that the positioning of elements can be changed, e.g. mirrored.

Product examples illustrate how the considerations on two elements have influenced each other. For every couple of elements two products were found that differed in the two elements but were similar for the other elements. For example, the products that illustrate the interaction of use and shape the other elements are kept the same by choosing two volume control buttons (same function) that are made of the same materials (plastics), made by similar manufacturing processes and have a similar personality (figure 11, nr. 7). However, it was not always possible to find examples that only differed in two elements, simply because the elements do not only interact with one other element but with more elements. As a consequence, some of the examples illustrate the interaction of two elements, but also have parts of other interactions e.g. the dish drainer of (figure 11, nr 11).

1. Product Personality and Function Products with the same function can have different personalities, for example there are many different models of mobile phones and MP3-players. But the function of a product can also influence its personality. Party shoes and running shoes both have a function of protecting and supporting your feet, but in addition party shoes have a function to make you look elegant and running shoes have a function of shock absorption while exercising. These differences in function influence product personality: party shoes have a festive look while running shoes look sportive and comfortable. Product personality can in turn influence function. E.g. sporting shoes have become fashion objects that are not longer only worn at aerobic classes.

2. Product Personality and Use How a product can be used interact with product personality. It can go hand in hand, for example in cassette players with a simple use and a childlike personality or a complicated use for an expert like and serious personality. However, product personality can also be in the way of use, for example the famous lemon juicer of Philippe Starck has a strong personality but is not easy to use without making a mess.

3. Use and Function To achieve a function, a product needs to be used in a prescribed way. This use and the interface of the product differ for a basic calculator with limited functions and an advanced calculator with many and complicated functions including a graph-function: it needs more buttons and likely a menu structure in the interface. A complicated use is not always necessary for a complicated function; it might even be a challenge not to make the use complicated.

4. Product Personality and Materials Materials have different aesthetics and expressions e.g. rubbery materials look matt and flexible and porcelain looks fragile. Materials can so influence the product personality: Transparent and rubbery materials contribute to a sportive look and metals contribute to a classic personality. However, materials are not the only element that influence product personality and the same materials may contribute to other personalities in other products or contexts.

5. Use and Materials Users interact with the materials of a product when using it. They touch the buttons, see how heavy or breakable a product is or get burned by too warm kettle handles. Materials give the user feedback on the use of the product. For example, a keyboard with hard plastic keys might give better feedback when you position your finger than a keyboard with soft and flexible keys made of ElekTex™.

6. Product Personality and Shape The shape of a product influences the personality of products. For example, rounded forms are experienced as more feminine and angular forms as more muscular. Shapes can also refer to a style or time period in fashion such as a luxurious watch that has a shape similar to old clocks. In the flower watch the shape of a flower is used for its associations it elicits to give the product its sunny and happy personality.

7. Use and Shape The shape of a product or part of a product (e.g. a button) relates to the possibilities for using it. The shape of a product influences the way users can hold a product. For example, a volume control button with a round shape can be used by rotating the button while a rectangle shape can be used by pressing.

8. Function and Materials The function of products affects the materials that can be used. A function of packaging food to be heated in microwave ovens needs a material that is not toxic, makes it able for the microwaves to reach the food, be cheap and so on. A packaging for salads does not need to function in a microwave oven, so other materials might be more sufficient. Materials influence the functioning of a product, for example the materials used in tableware dictate whether the tableware can be cleaned in a dishwasher.

9. Function and Shape The shape of a product influences how it can function, but a specific function can also requires a certain shape. For example a bottle with toilet cleaner where the cleanser is used under the edge of the toilet requires a shape that is suitable for reaching under the edge while a bottle with all-purpose cleaner is used in a bucket can do with a simpler shape.

10. Materials and Manufacturing Processes Not all materials can be processed in the same way for example it is not usual to injection mould metals. Small changes in materials also influence the manufacturing processes for example mould times are influenced by additives in plastics. These bicycle lights are made of different materials and are also processed differently (plastics and injection moulded versus metals and sheet formed).

11. Materials and Shape Material properties may restrict the shapes that are possible, for example glass has a limit in thinness and elastomers can not form sharp edges. Materials have different properties that limit the smoothness of a surface. Plastics that are used in a dish drainer make another shape possible than when metal threads are used.

12. Shape and Manufacturing Processes Manufacturing processes cause the shape and different processes are used to make different shapes. For example rotation milling is suitable for large hollow shapes while injection moulding is suitable for smaller solid parts. With the same materials different manufacturing processes can be used, resulting in different shapes. For example, extrusion of wood gives another shape than sawing and milling of wood.

Causal relations between elements in the design problem

The causal relations that were found in the assessed design methodologies were summarised in figure 12. The elements were categorised into three main groups, namely making, product form and meaning. The black arrows represent the causal relations between the groups and the white arrows represent the way product designers reason.

The element manufacturing processes is categorized in the making group. Manufacturing processes make the product form by making changes in materials and shape. This product form gets a meaning when users recognize its function, how they can use it and when they sense the product and get associations with it (its personality). Function, use and

personality are elements that can be seen in relation to a user perspective; without a user, the product form is meaningless.

The core of the design problem as defined by Roozenburg and Eekels is a product designer who starts with a function and from there reasons to a product form and a way of use [9]. Product personality can be added in this definition. Then, it becomes a designer who reasons from function to form, a way of use and a product personality. But is that the only way product designers reason? We think not.

A design project often starts with a certain need, which is translated into a function [7]. Designers reason therefore from function to the other elements until they have laid down the characteristics of the product in terms of making, product form and meaning. For example, when the need is to listen to music, the function is to play music in a way the user can hear it. There are many product forms that are sufficient for this function (figure 13). But a design project can also start from a wish, for example to make a music player that people love to buy because of its fashion statement. Then the starting point might not be the function, but product personality or use.

As seen in the integrated model on design considerations in the former paragraph, the elements product personality, function and use interact. Therefore, it is most likely that product designers start with a combination of these three elements and then reason to a product form that is suitable for the meaning of the product the designer has formulated.

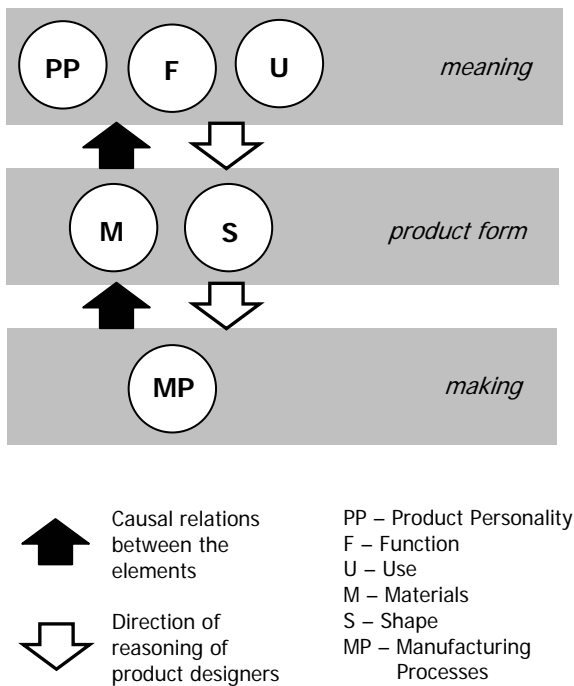


Figure 12 Integrated model of a design problem. Manufacturing processes result in a product form that has a personality, can function and can be used.



Figure 13 Different interpretations of the function to listen to music [11].

According to Muller the product designer can also follow another path: designers search for shapes and an intention for use based on their knowledge on materials and processes [8]. For example, designers are inspired by a new material or manufacturing processes and try to find a shape and a meaning for it. For example, Selle Royal, a bicycle seat manufacturer came across the new material TechnoGel®, a material that was used in a limited production of cushions that prevented the formation of decubitus lesions in long stay patients. They got inspired to use this material and found a product form and meaning, namely a bicycle seat [12].

Note that product designers often integrate both paths [8, page 55].

DISCUSSION

In this paper the balancing of product designers between product personality, materials and other elements in product design was shown by two integrated models. The first represent design considerations and how these interact and the second represent the causal relation between elements in the design problem.

From the integrated model of design considerations can be learned that almost every element interacts with all the other elements. The only exception is the manufacturing processes. These processes interact with product form (materials and shape) which in turn interacts with function, use and product personality. The product form thus has an intermediate role between manufacturing processes and the other elements.

The many interactions between design considerations makes designing very complex. This model can therefore help product designers, especially those who are learning the skills of designing, to gain insights in their design considerations and how these interact.

The integrated model on design considerations was evaluated by finding product examples that illustrate the interaction of the elements. We were able to find examples for every interaction, but it was difficult to find examples that only differed on two elements because we illustrated that all elements interact with more than one other element.

The product examples contribute to understanding the complexity in a way that these help to visualise the results of the interaction of two elements of consideration. In addition, these examples show the impact of playing with the elements, for example how material considerations can contribute to product personality.

Product designers will not continuously focus on all the elements, but sometimes focus on one element at the time. When design considerations on one element lead to a decision, product designers can use the model to check whether they have to reconsider decisions on other elements as well.

Every product design project is different. In some projects, e.g. where the focus is on technical functioning, the elements use and product personality might not need to be considered. In these projects some elements can be left out.

One might argue that representing only six elements of design is too limited. For example, the costs aspects are considered as a very important aspect in product design and is not included in the integrated models. As we illustrated with the comparison of Ashby's model and Pugh's aspects of the product design specifications, one view does not exclude the other. An aspect such as costs provides the boundaries of a design. Within these boundaries design considerations on e.g. materials, shape and manufacturing processes take place.

Ashby uses the model of the central problem in materials selection (figure 5) as a starting point for materials selection.

Dependent on the design project the materials selection starts with one or more elements, e.g. a combination of materials and shape [6, chapter 7]. The integrated model presented in this paper can also be used in this way: The designer can pick a few elements to start with and then fills in the others. For example Muller describes that the image of the designed product is based on the designer's knowledge on possibilities and restrictions of materials and processes and the knowledge on spatial characteristics of shapes in relation to their intention for use. Designing is thus in a way combining these sources of knowledge and the product designer starts with material, manufacturing processes, shape and use considerations. In the model that shows the causal relations of the elements it was also mentioned that the starting points for design can be several, e.g. from meaning (product personality, function or use) to product form and to making, or from a combination of product form and making to function, use and product personality.

This paper is an important element of the research activities of the authors, which are focussed on supporting product designers with selecting materials, while taking into account the growing interest in product personality. The paper illustrates that materials selection plays an important role in designing product personality. However, designing product personality is very complex due to the interactions with other elements. Because of these interactions selecting materials requires an integral approach in which material considerations are assessed in the light of product personality and considerations of other elements.

Further research includes evaluating this model by discussing it with experienced product designers in the field. Topics of evaluation will be the relevance of the models for different product categories and how the models can support materials selection.

CONCLUSION

The integrated models on design considerations and the causal relations of elements in design illustrate that the relation between product personality and materials fits in methodologies that include materials among other elements of

design. The models clarify the complexity of interactions between function, use, product personality, materials, shape and manufacturing processes. The integrated models contribute to the product designers' understanding of designing and selecting materials to create product personality.

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