# Integrated design process of branded products

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# Conception Intégrée de Produits de Marque

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**Résumé:**

La conception de produits de marque nécessite de considérer en même temps les aspects qui concernent la perception du produit (lié à l'évaluation et les émotions des consommateurs et les valeurs de la marque), ainsi que les aspects techniques et d'ingénierie, comprenant les fonctionnalités, les performances, le coût du produit et sa fabricabilité. Dans un contexte pluridisciplinaire, les designers de produits et les ingénieurs doivent collaborer et communiquer entre eux pour obtenir un produit satisfaisant qui plaise émotionnellement aux consommateurs et qui réponde techniquement aux performances attendues et qui est faisable à fabriquer. Cependant, cette collaboration entre les designers et les ingénieurs est difficile à cause de leurs différentes connaissances, approches et responsabilités au cours du processus de conception. Cette recherche s'intéresse aux questions du comment soutenir la communication entre les designers et les ingénieurs de produits et comment soutenir l'intégration de point de vue l'ingénierie au plus tôt dans le processus de conception de produit de marque. Les résultats de cette recherche contribuent à la proposition d'une approche pour intégrer le point de vue de l'ingénierie au point de vue de design (émotions et esthétique). Une proposition et évaluation de trois approches pour soutenir la communication entre les designers et les ingénieurs est étudiée dans cette recherche. De même une approche d'intégration est proposée suivant des trois étapes de modélisation, transformation et intégration des connaissances d'ingénierie à la connaissance de design. Par notre travail, nous avons contribué au projet SKIPPI, dans le développement d'un logiciel d'aide à la génération d'idées et à la prise de décision dans les phases amont de la conception.

**Abstract:**

Design of branded products involves consideration of both perceptual aspects of the product appearance (related to consumers' evaluation and emotions and the brand values) as well as the technical and engineering aspects including manufacturing feasibility, performances, and cost. Within a multidisciplinary design context, product designers and engineering designers need to collaborate and communicate together to achieve a satisfactory product that is emotionally appealing to the consumers and is technically performing the intended functions, and is feasible to manufacture. However, such collaboration between product designers and engineering designers is difficult due to their different knowledge background, work approaches and responsibilities during the design process. This research deals with the questions of how to support the communication between product designers and engineering designers and how to support the integration of the engineering viewpoint earlier in the design process of branded product. Proposition and evaluation of three potential approaches to support communication between product designers and engineering designers is investigated in this research. Likewise an integration approach is proposed following the three steps of modeling, transforming and integrating the engineering knowledge to design knowledge. The results of this research contribute to the SKIPPI project, in the development of a software to support idea generation and the decision-making in the upstream design phase.

→
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*Soyons reconnaissants aux personnes qui nous donnent du bonheur ; elles sont les charmants jardiniers par qui nos âmes sont fleuries.*
*Marcel Prouset*


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*What do we live for, if it is not to make life less difficult for each other?*
*George Eliot*

# Introduction

A design agency in France designs a "high-tech" tennis bag to *look light* and *rigid* while being *flexible* to handle. The product designers send the sketches (and other specifications) to manufacturers in China. After three weeks the design agency receives the prototype with some changes: the bag looks *cheap* and *heavy and doesn't feel right*. This causes long and costly iteration loops between the design agency and the manufacturers to finally obtain a product that *feels right* and is technically feasible to manufacture (Figure 0-1).

Another example is the Beta Motors' project in 1990 for the release of the newest most powerful engine in the vehicle platform (Carlile, 2004). The new release was supposed to be a breakthrough for the company because it was the result of several years effort to produce significant horsepower while maintaining suitable fuel consumption. The problem accrued when the size and the shape of the engine caused the hood go upper than what it was initially designed by the stylists. The raise of the hood level was critical because at that time the "aerodynamic-looking" vehicle was the heart of the market demands and the challenging point among competitors. This generated costly design changes and downstream delays for the company (Carlile, 2004).

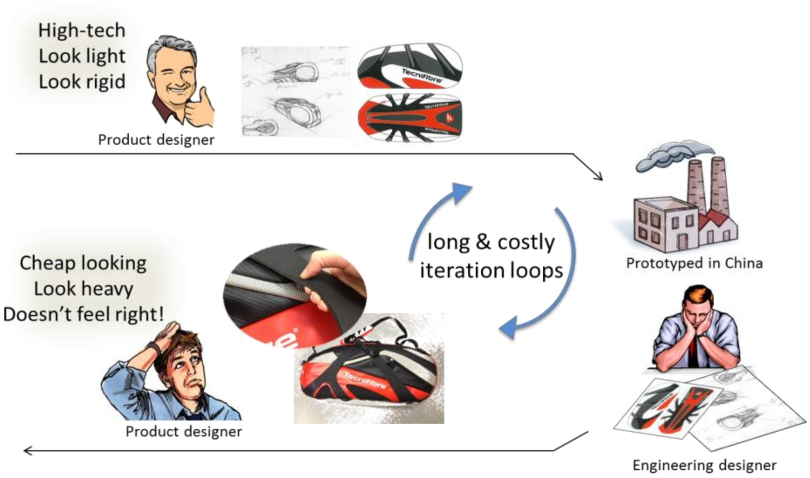



Figure 0-1: **An example of a problem leading to additional iteration loops**

These two simple examples point out one of the actual problems of companies in the new product development process when both aesthetic (and appearance) and technical aspects of the product should be carefully considered and be tackled throughout the design process. To better define, understand and analyses this problem, this thesis takes into account three challenging points:

- The competitive global market, the rapid changes and advances in technology and the increasing consumer demands and its variety create a challenging environment for the companies. The key to the success is to get to market faster than competitors, to introduce products with an acceptable cost point and to satisfy the needs of a wide range of people. In such environment the importance of efficiently managing the design process to new product success is widely recognized. Companies are exploring means to solve the problem of unclear relationship and collaboration between design team and other groups in order to avoid serious consequences of financial losses, wasted time and failed projects.

- In today's market consumers face a large variety of choices of products that have almost the same or very similar functionalities. The purchases decision is no more influenced only by the price or the functionality and quality but rather by the "eye catching" attributes and attractiveness of a product and the image and emotion it creates for its owner. Within this, companies that are able to provoke certain emotional responses through the product appearance and create a bond between consumers and the product, gain competitive advantages on the market and increase their product success. To obtain such results companies require an effective understanding of target consumers and the way they perceive a product.
- Brand - that is an identifier of the products of a company from others - is a factor that influences strongly the choices for consumers. People are generally willing to pay rather for a branded product, than they are for a similar unbranded product because brand elevates a product, and the company behind the product, from being just "one among the others" to a "unique identity and promise". Therefore for the brand companies it is vital to maintain their identity and to communicate the brand values to the consumers through all the branding aspects (e.g. advertising) as well as products themselves. In this way the product design and its appearance can act as a mediator to create brand recognition and to remind the brand values through the physical properties of the product.

A product development process contains a set of activities or steps that usually lead to milestones and deliverables that are scheduled according to the overall project planning. The aim of the activities is to elaborate a product from the ideation to development and manufacturing phases. Design process has been also seen as a problem-solving process that requires the involvement of specialists from different disciplines who have separated responsibilities and goals but work together to achieve a final solution to the design problem.

From the early $80^{th}$, to be more cost benefit and to reduce the elapsed time required to bring a new product to the market, companies are driven to replace their traditional sequential design process (i.e. progressing through a linear flow of steps and starting the next activity only after the end of the previous one), by an integrated approach aiming to take into account the needs of all the product life cycle stakeholders as soon as possible in the design process.

In the $90^{th}$, a new industrial organization called concurrent engineering appeared, allowing management of projects by parallelization of activities (i.e. performing activities simultaneously). It revolves around the ideas of proceeding design activities at the same time and concurrently by a team of experts and to take into careful consideration the entire steps of the product life cycle (e.g. manufacturing, assembly, maintenance, environmental impacts) from the very beginning of the design process. Identifying, predicting and addressing the downstream issues (e.g. manufacturing constraints) earlier, when the project is still flexible, can save a significant amount of money and time, reducing the risk of costly late design changes.

Product life cycle experts who are involved in the design process include (but are not limited to), product designers, engineering designers, manufacturers, marketing responsible, environmental expert, ergonomist and so on.

Among them, product designers are primarily responsible of creating concepts and specifications with a particular concern towards the appearance of the product, aesthetics and values and consumer related aspects of the product. The responsibility of product designers can be extended to market trend analysis, usability studies, innovating and developing concepts. For design of branded products, product designers should have a good grasp of the market, the brand, the user (and their emotional responses) and engineering requirements, and consider these into a holistic solution.

Engineering designer is a term that may include multiple engineering disciplines such as electrical, mechanical, chemical, software, structural and manufacturing engineers. Engineering designers are responsible of technical activities that establish and define technical solutions to problems applying scientific rules and knowledge. Engineering designers have particular concern towards the mechanical structure and technical functions of the product to meet the target objectives and specifications, considering the feasibility of manufacturing and assembly in efficient and economical way. The responsibility of engineering designers can be extended to taking into account other phases of product life cycle such as transportation and logistics, environmental considerations and maintenance.

The engineering activity covers the development of products and processes with a primary emphasis on functionality. For most of the products the contribution of engineering is instrumental in developing the technologies and manufacturing process that allow the product to achieve its performances, size, shape and other physical properties. The companies would then market the product on the merits of its technology alone, although consumers certainly evaluate a product base on more holistic judgments including appearance and style. Therefore engineering designers and product designers need to collaborate together to achieve a satisfactory product. However there often exists a communication gap between product designers and engineering designers, in confrontation of the engineering knowledge that is based on measurable facts and quantifiable criteria on one hand, and the subjective and non-measurable criteria coming from the brand knowledge and consumer related factors on the other hand.

For design of branded products (with an emphasis on both the brand and emotional aspect and the engineering and technological aspects of the product), the interaction between product designers and engineering designers, and integration of product design and engineering design viewpoints are highly important. This thesis research goes around this interaction and aims to reduce the gap between product design and engineering design.

Considering the examples of the tennis bag and the Beta motors' project, it seems that the application of a concurrent engineering approach is a promising way to reduce the long and costly iteration loops between design, engineering and manufacturing during the design process. However, two important questions immediately appear:

- How to cope with the collaboration and communication among various disciplines, and particularly between product designers and engineering designers?

- How to integrate the engineering and manufacturing needs and constraints earlier in the design process? In other words, how to link the upstream needs (e.g. brand and emotion) and downstream needs or constraints (e.g. technical and manufacturing) together when the product doesn't even physically exist and all the ideas are merely and lexical description of potential solutions?

The design of branded products requires an effective understanding of the brand values and the brand image and its relation with the consumers' emotional responses to a physical product. This information provides an important input, which can highly affect the specifications of upstream needs and constraints. Therefore modeling the relation between brand and consumers' emotional responses can help to better understand product designers concerns in the proposition of design concepts. The sub-question that contributes to find the answer of the above questions (both bullet points) is the following:

- How the brand values are related to the consumers' emotional responses?

The answer to this sub-question provides also a primary reflection on the confrontation between engineering and product design viewpoints when considering linking of brand/emotional responses to engineering product/process properties.

In addition, the answer to the first question (first bullet point) requires an effective understanding of the communication challenges in multidisciplinary design process , to characterize the reasons leading to the gap between product designers and engineering designers. The sub-question related to the first bullet is:

- What are the communication challenges in design of branded products?

This thesis provides a reflection on understanding and handling the complexity of implementing brand values and emotive concepts (coming from the customer analysis) into a new product during multidisciplinary product development process. The types of products we are talking about are mass produced consumer products that an individual can buy in a store (that are physical and industrially manufactured objects rather than services and art objects like paintings and so on).

In this dissertation four main contributions are distinguished:

1) Theoretical framework for understanding branded product emotions (addressing the sub-question, both bullet points)
2) Theoretical framework for understanding communication challenges in design of branded products (addressing the sub-question , first bullet point)
3) Proposition and evaluation of three potential tools to support communication between product designers and engineering designers (addressing the question, first bullet point)
4) Proposition of an approach to support the integration of engineering designers and product designers' view points earlier in the design process and an application of the approach (addressing the question, second bullet point)

The structure of the dissertation is illustrated in Figure 0-2.

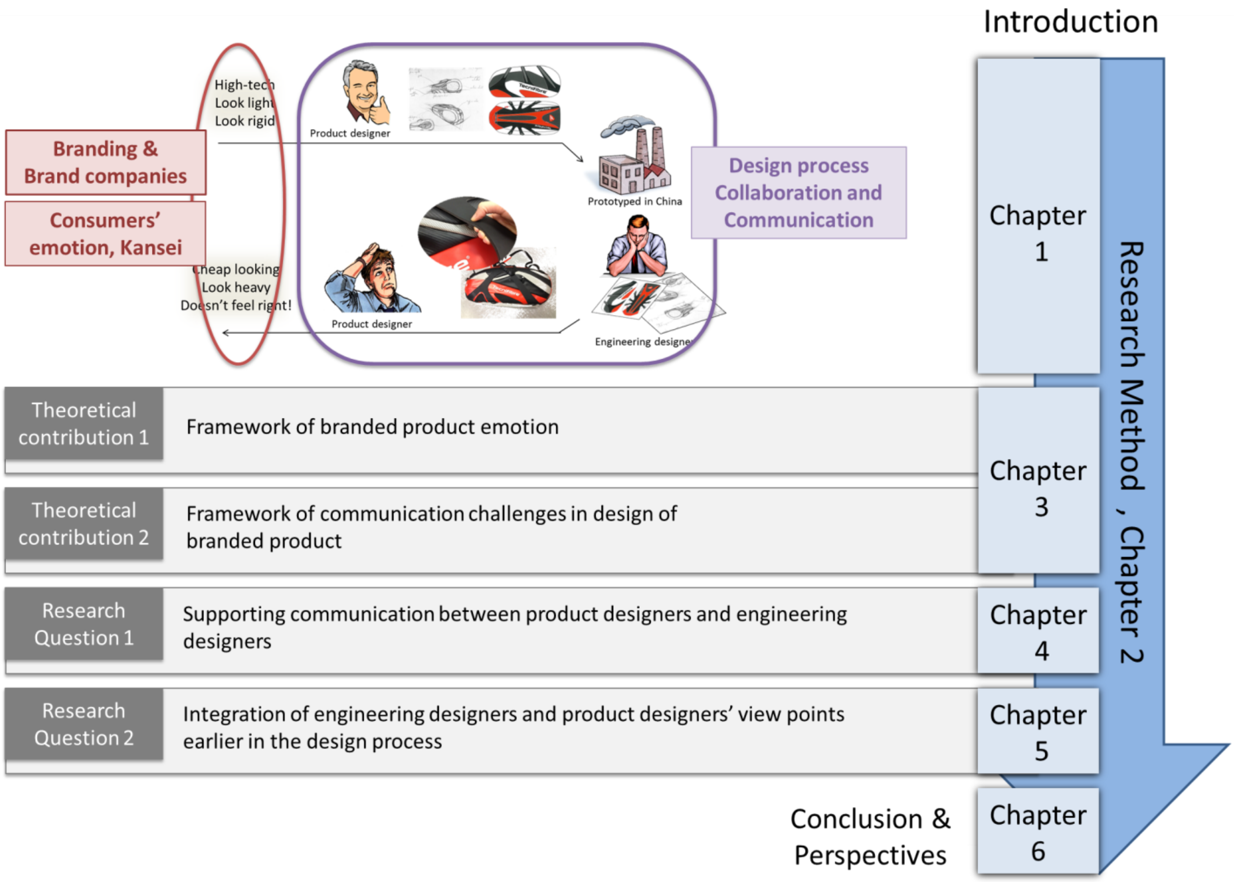



Figure 0-2: **The structure of this dissertation**

**Chapter 1** provides a literature review on the key concepts that are employed all along this dissertation: branding and brand companies, consumers' needs and emotions (including Kansei engineering approach), and the design process and design actors involved during the design process and their collaboration and communication. Two research questions related to communication and integration support are formulated in the end of this chapter.

**Chapter 2** describes our research methodology and the way this research was conducted as well as the research tools and the research environment including both industry and academia.

**Chapter 3** highlights our theoretical contributions through the proposition of two frameworks. The branded product emotion framework helps to understand the relation between brand values and perceptive concepts (Kansei) by modeling consumer's emotional responses to a new product. The second framework structures an overview of different communication challenges related to emotive aspects of design between product designers and engineering designers during the design process of branded products.

**Chapter 4** deals with our first research question related to supporting the communication between product designers and engineering designers. The chapter begins with the analysis of the problem in two French companies and then evaluation of problem in a more general context. To support the communication three different tools namely annotation, multiple-domain matrix (MDM) and word mapping are presented and then evaluated among product designers, engineering designers and academics.

**Chapter 5** deals with our second research question of integrating engineering designers' view point into early design phases of branded products and build connection to product designers' view point. An integration approach is proposed and the application of the approach in the context of a national French project called SKIPPI project is described.

**Chapter 6** recapitulates the main discussions of the thesis and provides a summary of contributions. The chapter points out the limitations as well as the opportunities that our research creates for further works.

# Chapter 1 : State of the Art

This Chapter provides a literature review on the key concepts that are employed all along this dissertation: branding and brand companies, consumers' needs and emotions (including Kansei engineering approach) and the design process and design actors involved during the design process of branded products. Then we argue that the implementation of brand values and emotional concepts into physical product is critical in the design process of branded products and can be problematic to achieve with multidisciplinary project teams coming from different backgrounds. We particularly focus on the collaboration between product designers and engineering designers in the context of concurrent engineering and formulate our research questions in the end of this Chapter.

## 1.1 Part one: Branding and Brand Companies

It is difficult to distinguish most products purely on the basis of their technological functions or built quality (Desmet, 2002) , as many competing products offer the same or very similar functionalities. Within this, brand is one factor that influences the choices for consumers. For example both iPods and Mp3 players can play digital audio files in the mp3 format. The iPod is indeed a specific brand of mp3 players, made by Apple Company and has "Apple-specific" visual design (Figure 1-1). Since the release of iPod in 2001, Apple has introduced many variations of iPods such as iPod Classic, iPod Touch, iPod Shuffle, iPod Mini and iPod Nano. Although iPods are more expensive that other mp3 players, industry statistics in 2007 showed that iPod has sold more than 110 million units worldwide, that made the iPod the best-selling product in the history of digital audio players.

Figure 1-1: **iPod shuffle, designed and marketed by Apple Company**

Brand simplifies purchasing decisions, offers quality assurance and reduces risks involved in the purchase (Karjalainen , 2003) and therefore contributes to elicit emotional responses through the kudos the brand bestows on the consumer. Sometimes consumers have no way of assessing functionality or quality in a new product, so that the brand becomes a guarantor for quality. Companies use design to create brand recognition (Karjalainen & Snelders, 2010) and also to make consumers feel more attached to products (Aaker , 1996) .

The fundamentals of branding and brand identity are widely discussed in the management, marketing, economy and business literature. Brand is a combination of tangible and intangible elements (Chernatony et al., 1998). Tangible elements refer to brand representation trough the name, logo, advertising slogan, product's design and performances. Intangible elements refer to emotional values and beliefs related to brand's personality (Kapferer, 2008) and the meaning created in the minds of consumers (e.g. for Volvo it is safety and security; for Nivea it is love and protection). Brand is the vision that drives the creation of products (Kapferer, 2008). Companies also use the design of their products as a tool to foster brand identity and to create brand value (Montaña et al., 2010). To be clear in terminology, the definition of brand identity, brand image and brand values are explain below.

### 1.1.1.Brand Identity

According to Kapferer (2008) brand identity is the vision and the key belief that drives the creation of products under the brand's name. Aaker (1996) states that the brand identity is a unique set of brand associations that represent what the brand stands for and imply or promise to consumers from the brand company. Building brand identity is a powerful means for differentiating the company and its products from those of competitors (Warell, 2001).

### 1.1.2.Brand Image

Brand image is how consumers or others perceive the brand (Aaker ,1996). It is the opinions that consumers form and the ways they interpret what a company does (Robinette et al., 2001). According to Kapferer (2008) brand identity is on the sender's side whereas brand image is on the receiver side.

### 1.1.3.Brand Value

Brand injects values into products in order to differentiate them from the competitors (Mozota, 2003). Brand values are the part of the brand identity to be actively communicated to a target audience (Aaker ,1996).

To better understand the relation between brand identity, brand image and brand values, in this thesis the *brand identity* is what the company aspires to be (Robinette et al., 2001) and how the strategists want the brand to be perceived (Aaker ,1996). The company represents its identity through communicating a set of values to the consumers *(brand values)*. The consumers then interpret the values and form an image of the brand and the company in their mind *(brand image)*.

### 1.1.4.Communicating the brand values

For many brands the objective is employing design to create recognition and also to foster brand identity, to create brand values and to communicate that to the consumers through the products (Montaña et al., 2010). However brand is more than physical products. According to Aaker (1996), the brand is structured into four perspectives: brand as product, brand as organization, brand as person and brand as a symbol. Products are the first source to present the brand value. The introduction of a product creates an image of a brand which should be emphasized through all aspects of the product. Brand as organization includes organizational attributes such as innovation, strive for quality and the value of the company. Brand as person contributes through adding personality to the brand and its products which can create self-expressive benefits. People may use a product to expresses who they are. The brand as a symbol (anything that represents the brand such as visual imagery, metaphors and so on) facilitates recognizing and remembering the brand.

Products are not the only ways that consumers come in contact with the brand. Advertising, factors such as brand name, its logo, packaging and all other forms of media and promotion together with more indirect message transmitted from retail stores, internet websites , word of mouth and social interaction generally support the brand to influence the consumer's emotional responses towards the brand (Rompay et al., 2009). It is very important that the product's design convey the same message that has been transmitted through the other media. Otherwise, it is very difficult for consumers to form a favorable image of product and brand (Rompay et al., 2009).

### 1.1.5.Branded products

Many branded products are incremental versions of either other products of the same brand or of competitor products and brands are known for a key product or product type. Product design firms however also design branded products for products ranges which are not the type of product usually associated with the brand and where no precedence exists. For example (Karjalainen, 2007) discusses the design of a thermos flask for Toyota. Companies designing and producing a range of products have to consider common styling features to maintain a clear identity on the market (Warell, 2001). This applies to ranges of products typically associated with the brand and in particular to totally different products that are sold under the brand label (Figures 1-2 and 1-3).

For example the core brand values of Caterpillar are comfort and performance (Karjalainen & Snelders, 2010).This is communicated through its advertising, website and slogan as well as the design of its products (as much to the heavy machines the company produces as to its shoes, Figure 1-2)


Figure 1-2: **Comfort and performance are Caterpillar's brand values implemented in its products**


Figure 1-3: **Different PUMA products**

It is important to distinguish between those elements that are typical for the brand and those that are not. For example, in the case of the PUMA cellphone (Figure 1-3), there are elements common to all the PUMA products (e.g. the use of the red line, common color scheme), and there are elements common to all the cellphones (e.g. display, keypad or touch screen). It is not just about collection of separate elements (e.g. typical brand elements) but also about the global impression of the product, in terms of the balance between product elements. Brand companies must develop products that carry distinctive references to their brand identity and brand values (Karjalainen, 2007) both to create recognition and to communicate to consumers. But the question is how the brand values can be implemented into physical properties of the product. The following section reviews some approaches from the literature.

### 1.1.6.Implementing brand values

Several approaches exist for formulating and assisting the expression of brand value into the physical domain. McCormack et al. in (McCormack et al., 2004) propose a system for capturing the essence of Buick brand in a shape grammar (application for Buick vehicles). Another approach called Design Format Analysis (DFA) was developed by (Warell, 2001) to capture and explore the occurrence of design elements among a variety of product. Karjalainen (2007) suggests a framework of explicit and implicit references to value-based design elements. While explicit references are embedded to be immediately perceived and recognized, implicit references cannot be distinguished but, when used, make sense (for example being user friendly or the quality). Implicit cues can be embedded in a variety of different elements. They can change in form from one product to the next. A logo is the fastest way to create recognition. However in many cases consumers do not like to have products with a strikingly noticeable logo. “People do not want to have a big Schneider logo on their light switches or outlet plugs, but if you take off the cover, there is a clearly visible Schneider logo on the electrical parts inside for those who are expert clients and maybe not the final consumers" says one of the product designers we interviewed in Schneider electric.

A company's strategy of consistent or flexible use of elements is another dimension (Karjalainen, 2007). New market tastes require the product to be improved in terms of for example additional functions, cheaper manufacturing or new features while keeping untouched what made the product gain success in the market (Mengoni & Germani, 2008). Balancing between familiarity and novelty and choosing between static, evolutionary and revolutionary design approaches are key success factors (Karjalainen, 2007).

However, brand design knowledge is explicable only to a certain degree (Karjalainen, 2003). Applying this implicit knowledge to the design of products is almost exclusively an intuitive process (Warell & Young, 2011). It is gained through experience of the brand company or exposure to their products. It may take a long time for an individual designer to absorb a brand's design culture and thus be able to fully capture the idea behind brand references (Karjalainen, 2003).

#### 1.1.7.Summary of part one

For brand companies it is vital to communicate their brand identity to the consumers through all the branding aspects as well as the product itself. In this way the product design and its appearance can act as a mediator to create brand recognition and to remind the brand values through the physical properties of the product. Although there are some approaches to assist the transformation of brand value into the physical properties of products, this domain relies highly on experience and can be explained and formulized only to a certain degree. The successful communication of the brand values to the consumers, needs an understanding of how consumers perceive and interpret products. In the next part we are going to explain the importance of taking into account consumers' needs and emotions following by a review of several approaches for that.

## 1.2 Part two: Consumers’ needs and emotions

In today’s market, the product success is determined by consumer satisfaction that is achieved by satisfying the consumer needs (Smith & Smith, 2012). The visual attributes of products attract consumers and lead them to inspect a product more closely and to consider a purchase (Seva & Helander, 2009) . Consumer’s choice of the product then depends on a number of factors. According to Mantelet (2006) the purchase decision for a consumer can be affected by two basic types of motivations: The objective criteria such as the cost of the product, its functionality and performances, the guaranty and other after sale services ; The subjective (or affective) criteria such as personal image or status , affirmation and generated feeling and emotions (Mantelet, 2006).

### 1.1.1.Design for needs

Understanding consumers’ needs is an important phase in the design process and contributes to the product success however it is not an easy task. Consumers are not always able to describe what they want. As one of the product designers from the Diedre Design company stated, they are more likely to know what they do not want rather than what they want. Even if consumers describe their needs they generally use non-technical words (Smith & Smith, 2012) which should later be translated and matched to technical design descriptions.

Among the approaches that are developed to take into account the consumers’ needs we can refer to User Centered Design (UCD), Participatory Design, and Scenario Based Design. These approaches tend to involve consumers in the design process rather than explicitly deal with consumers’ emotional responses.

**User Centered Design (UCD)** is an approach that tends to focus on the consumers’ needs, wants and limitations at all the stages of the design process. The basis of UCD is presented by the international standard ISO 13407 in four main steps that are: understanding and specifying the context of use, specifying the consumer and organizational requirements, proposing product design solutions, evaluating designs against requirements. UCD approach has the advantage to make a deeper understanding of the psychological, organizational, social and ergonomic factors on the use (Rasoulifar, 2009). However the lack of clarity on the process and the methods or tools to capture and analyze inputs, encouraged researchers to reformulate and adapt the UCD for specific contexts (Jokela, 2002).

**Participatory Design (PD)** is an approach that tends to integrate the consumers in the design process, to shift the design attitude from designing for consumers to designing with consumers (Sanders, 2002). The absence of a common vocabulary can limit the dialogue between the designer and the consumer (Luck, 2003).

**Scenario Based Design (SBD)** revolves around the idea of using scenarios to clarify what the product usage supposed to be and how the design can clarify the predicted use through a concrete use description. The narrative descriptions of what consumers will do and experience with the new product can help the design team to understand the use-related constraints earlier in the design process development. However SBD is a relatively lightweight method for envisaging future use possibilities compared to other well specified approaches (Rosson et al., 2002).

UCD, PD, and SBD aim to guide the focus of design work in regard to how people will use the product to accomplish an activity. These approaches can give a better understanding of the consumers’ needs. But these approaches are more usage oriented and still focus on quality and functional performances and do not consider consumers' emotions.

### 1.1.2.Design for emotion

Human needs are limited but the field of desires is without limit (Mozota, 2003). Percy et al., (2004) consider emotions as the base neurological process and emotional responses the experience and articulation of our emotions. Emotion is a complex set of interactions among subjective and objective factors which can give rise to feelings, trigger cognitive processes (such as appraisal) and lead to specific behavior (Kleinginna & Kleinginna, 1981). The consumer's emotional responses are generated by becoming aware of a physical object through the senses (e.g. vision, smell, touch, hearing) and then understanding and making sense of it (Warell, 2008).

Over the last 20 years a steady growth in design research has been published that focuses on understanding the emotions of product consumers and on the development of tools and techniques that facilitate an emotion-focused design process (Desmet & Hekkert, 2009). The motivation behind this movement was acknowledging that all products elicit emotions and not being aware of the effect of design on consumers' emotion can generate unexpected consumer responses to the new product (Desmet & Hekkert, 2009).

Many studies have been carried out on how consumers perceive and make sense of products (Blijlevens, 2009; Crilly, et al., 2004; Crilly, 2011; Petiot & Yannou, 2004) and how the consumers' emotions are affected by a product. The objective of these studies was to provide designers with useful information about the "side-effect" of their decisions (about the product's design) on the way consumers will emotionally respond to the product. This information can help designers both in anticipating (and avoiding) the unwanted emotional responses and to stimulating the intended emotional response and then make a better product (Desmet & Hekkert, 2009).

From the literature, two different approaches appear in the studies that take into account the consumers emotions: theory-based and pragmatic-based approaches. While the theory-based approaches aim to provide insights to facilitate the study of emotional responses by characterizing the emotion elicitation process (Desmet & Hekkert, 2007) and modeling how consumers perceive and experience a product (Crilly et al., 2008; Crilly et al., 2004; Warell, 2008), the pragmatic-based approaches aim to identify and capture the direct linking between the consumers emotional responses and the product properties (Desmet & Hekker, 2002; Nagamachi, 1995).

#### 1.2.1.1 Theory-based models

In the following we are going to have a brief review on three theory-based models from the literature but the readers are encouraged to see works of (Blijlevens, 2009; Crilly, Moultrie, & Clarkson, 2009; Cupchik, 1999; Ho & Siu, 2009) for more theory based models.

Desmet's **model of product emotion** (Desmet, 2003 ; Desmet and Hekkert, 2007) presents four main parameters that contribute in the eliciting process of emotions, including appraisal, concern, product and emotion (Figure 1-4). The main proposition of this model is that the emotional responses are result of an appraisal process in which people appraise (i.e. evaluate) a product based on their concerns. In this model the appraisal is a non-intellectual and automatic evaluation of a stimulus and the meaning that a person attaches to that stimulus. Concerns are the points of reference in the appraised process that can match or mismatch a product. For example the reason of attractiveness of an umbrella for a person can be due to his/her concern for staying dry.

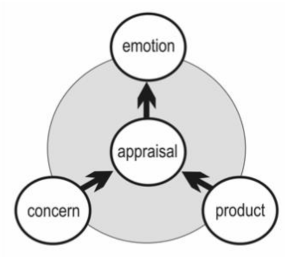



Figure 1-4: **Model of product emotion, after Desmet & Hekkert (2007)**

The **Visual product experience (VPE)** of Warell is inspired from the basic product emotion model of Desmet and provides a model for perceptual and visual product experience (Warell 2008). The VPE model offers a theoretical model and a methodical approach that acknowledges and relates the various modes of multi-modal visual product experience. The term “multi-modal” refers to visual stimuli giving rise to a variety of experiences related to the perception, understanding and judgment of the product. In VPE model the product experience is composed of sensorial, cognitive and affective modes (Figure 1-5, center). Through the sensorial mode we experience the product with all our senses. We see an unusual looking mobile phone, we hear the sound of motor or the clacking doors in a car, we feel delicate balance and weight of a TV remote control. In the cognitive mode, we understand, organize, interpret and make sense of what we perceived. For example we feel the low weight of a bag or suitcase and understand that it is useful if we don’t want to carry too much weight travelling. The affective mode includes associations and notions that people attribute to products, such as brand association based on personal beliefs, values and emotions. For example some people believe all Apple products are user friendly and intelligent so they might associate the new Apple product to what they believe as a prejudgment.

The experience model (Figure 5 center) has two dimensions of “presentation” and “representation” that are seen as two sides of the same coin. The presentation stands for the hedonic, pleasure-based experience of the product, whereas representation is the meaningful part of the experience and is dependent on semiotic interpretation. The two dimensions of presentation and representation are intimately intertwined but are important for understanding various aspects of product design when thinking about appealing.

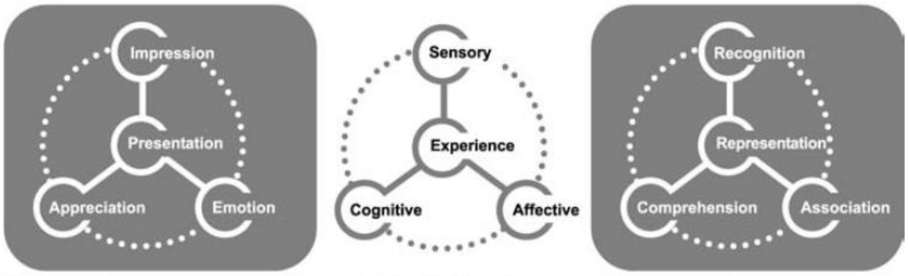



Figure 1-5: **Visual product experience model, after Warell (2008)**

Crilly et al., (2004) propose **a framework for the consumer response** (Figure 1-6) to product visual form, using the basic element of Shannon theory of communication (Shannon, 1948). In the model of Crilly et al. (2004), the design process is seen as a process of communication in which the intention of designer (or the design team) is embedded into the product. The product is then the media through which the design intention can be communicated to consumers. The product is perceived by the consumers within an environment. This perception leads to cognitive, affective and behavioral responses, where cognitive response is composed of aesthetic, semantic and symbolic aspects.

Response to the design message takes place within the consumer's culture context. In this model the environment within which the product is to be perceived by consumers refers to the physical conditions of the interaction context (or the context of consumption, e.g. cultural influences) and the way the product is represented (e.g. packaging, photographic marketing).

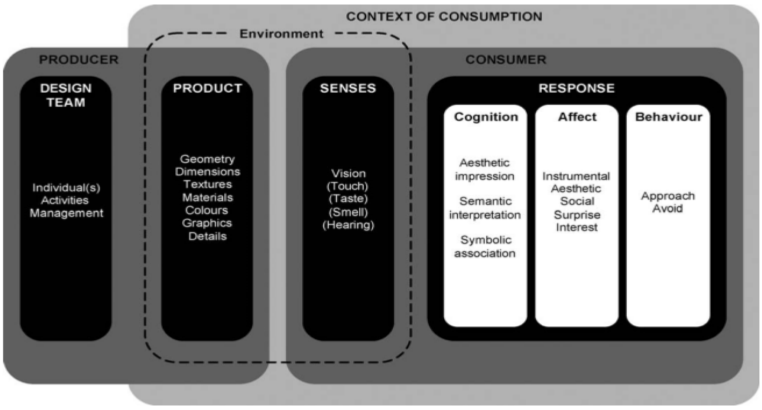



Figure 1-6: **Framework of consumer responses after Crilly et al. (2004)**

The three theoretical models presented above help to understand the factors that contribute to the elicitation of emotions and provide analytical framework for consumers' emotional responses. We will refer to the theory-based models in Chapter 3 when we are presenting our framework of new branded product emotion.

#### 1.2.1.2 Pragmatic-based models

Pragmatic-based approaches aim to identify and capture consumer emotional responses and provide methods to evaluate products based on the consumer's emotion. Many of pragmatic-based approaches rely on verbal and non-verbal questionnaire. Alternative techniques such as facial expression coding and infrared thermography are also helpful. For example readers may want to see the work of (Jenkins et al., 2009) on the use of infrared thermography for capturing emotions and the work of (Pieter Desmet, 2002) on the use of non-verbal self-reporting approach that is implemented in a software called product motion measure (PrEmo). In the following we are going to describe the Kansei Engineering approach because our discussion is going to rely upon the verbal description of emotions.

## ***Kansei Engineering***

Kansei Engineering (KE) takes the consumers' feelings and emotions into account through the Kansei (Japanese for emotional / affective) words and helps the product designers to find out what the design concept should or should not include to respond to the consumers' feelings. For example the relationship between the different coloured areas and the aesthetic measurement of the product can be studied by KE approach (Hsiao et al., 2008). The use of KE is broad from measuring the product experience in food industry (Kang & Satterfield, 2009) and packaging (Barnes et al., 2008) to the design of E-commerce website for visualizing the information (Lokman & Noor, 2006).
Kansei Engineering (KE) was founded in Hiroshima University around 1970 with the works of Nagamachi (Nagamachi, 1995). The typical steps in KE consist of:

1) Collection of Kansei concepts related to the product domain from journals, web sites, target consumers, brainstorming and so on. The Kansei concepts (that are essentially represented by words) are grouped into pairs of semantic differentials, i.e. opposite attributes (e.g. traditional-modern, stable-unstable, flashy-discreet, and soft-hard).

2) Collection of product samples. For each sample product elements and properties are identified (such as size, colour, width, total shape etc.), that can have more details (such as red, yellow, green etc. for the “colour”).
3) Establishing links between Kansei concepts and product elements (or properties). A large number of consumers evaluate the product elements and properties using the Kansei concepts and semantic differentials. Figure 1-7 summarizes the three steps and an example from a case study conducted by Kongprasert (2010) for design of leader bags.

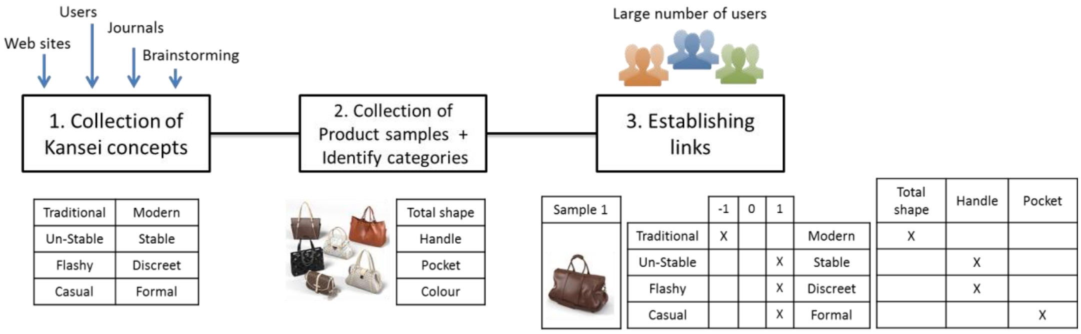



Figure 1-7: **Typical steps in KE approach**

The Kansei concepts, product elements and the links are then integrated into Kansei Engineering Systems (KES) through data bases and calculation rules and algorithms for associations. Various KES have been developed. The core idea behind KES is to seek to construct a relationship between the psychological space of human evaluation and the attribute space of the specified objects, which is often difficult or impossible to define (Yang, 2011). The hybrid KES for instance is an expert system for product design which consists of two sub-systems namely “Forward Kansei Engineering System” used to generate product alternatives and “Backward Kansei Engineering System” to predict the emotional responses of new product design (Figure 1-8).


Figure 1-8: **Backward and Forward Kansei Engineering System**

Kansei concepts in this thesis refer to perceptual concepts and the semiotics that are used to express the consumers’ perception of products. Both Kansei concepts and brand values generate emotional responses, but the relation between brand values and Kansei concepts needs to be clarified. The relation between Kansei concepts and brand values is explained in Chapter 3, through the framework we propose for new branded product emotion.

### 1.1.3. Summary of Part two

Considering the consumers' needs in the design of a new product is necessary but not sufficient. It has been well established that products generate emotive responses. Being aware of how consumers perceive and make sense of product properties can help to reduce the gap between the designers' intention and the consumer's interpretation.

Design for emotion includes two different approaches, the theory-based and pragmatic-based ones. The initial attempt of these approaches is to develop tools, methods or insights to provide inputs for the design of a new product and to help designers in better understanding the effect of their design on the consumers' emotions. Kansei Engineering is a largely developed approach to capture the link between emotional responses and product physical properties. We will rely on the notion of Kansei concepts as perceptual concepts in this report.

The theory-based and pragmatic-based approaches do not precise how to deal with the emotional concepts during the product development process. In the next part we will present the results of our literature review on the design process and design actors. Our objective is to find out how and where the emotive concepts are considered in the design process.

## 1.3 Part three: Design process

In engineering design literature, product design is usually described as a process (Ulrich & Eppinger, 2004). A product development process contains a set of steps that usually flow the milestones that are scheduled according to the overall development project. The steps include (but are not limited to) the study of consumers' requirements and the market opportunity, the development of concepts, detailed design of the selected concept, manufacturing and assembly plan and the following production development.

Several models of design process are proposed in the literature. Systematic design process of Pahl & Beitz (1996), design and development process of (Ulrich & Eppinger, 2004), Total design process of Pugh (1991) and Axiomatic design process of Suh (2001) are among the key references in the literature.

To explain briefly the design process we use the generic product development process by Ulrich and Eppinger shown in Figure 1-9. The process consists of five phases. In Ulrich and Eppinger model, the process begins with a planning phase which is the link to advanced research and technology development activities. The output of the planning phase (phase 0) is the statement of the project mission that serves as required input to begin the concept development phase and a guideline to the whole development team (Ulrich & Eppinger, 2004).

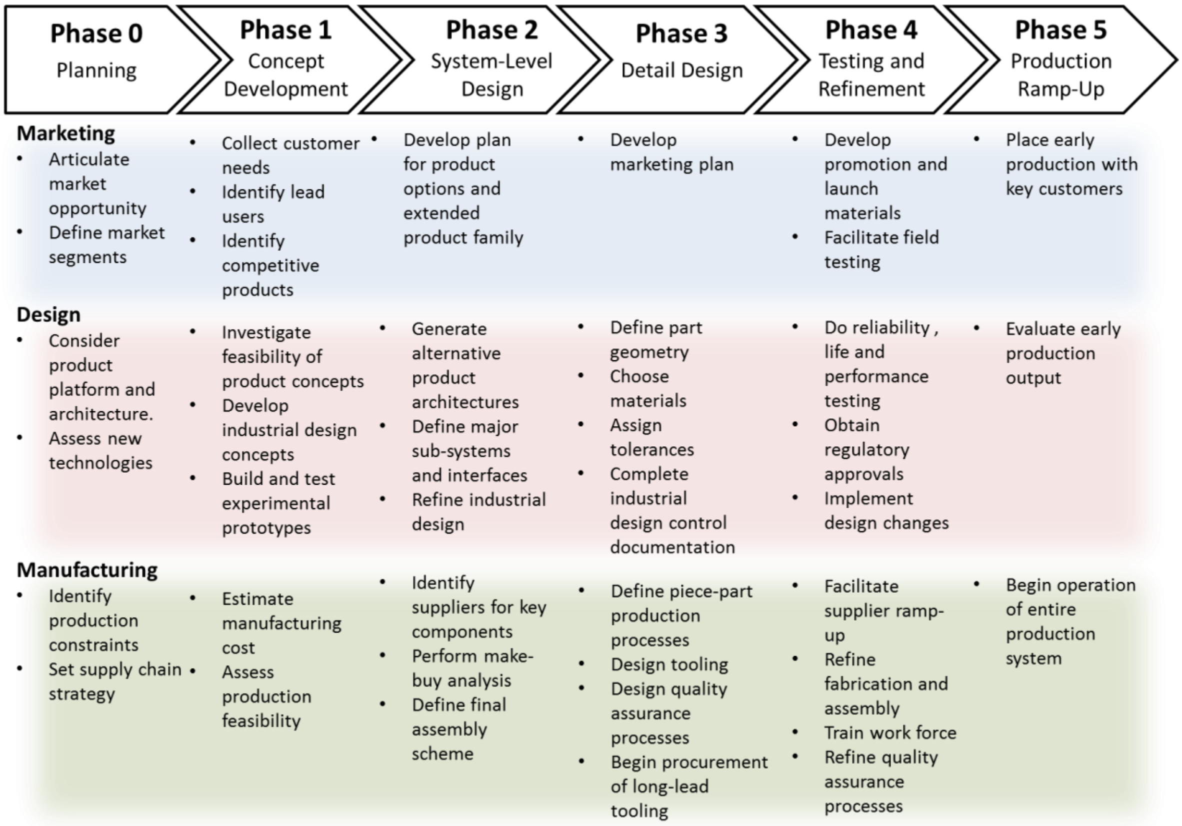



Figure 1-9: **The generic product development process after Ulrich and Eppinger (2004)**

### 1.3.1 Central activities and responsibilities

In the Figure 1-9 the role of actors from marketing, design and manufacturing services are articulated for each phase. According to Ulrich and Eppinger's view, marketing, design and manufacturing are continuously involved in the design and development process and are central activities.

***Marketing actors*** act on matching consumer needs with satisfying products or services (Mozota, 2003). Marketing often facilitates the identification of product opportunities, the definition of market segment and the identification of consumer needs (Ulrich & Eppinger, 2004).

***Designers*** define the physical forms and technical solutions to achieve a product that can meet the consumer needs. This activity includes product design and engineering design (Ulrich & Eppinger, 2004).

***Manufacturing*** acts upon designing and actors of this field design the production system in order to produce the product (Ulrich & Eppinger, 2004).

Other company services can include research and development, project management and financial service. Design activities are carrying out by expert people from different disciplines such as design, ergonomics, quality, reliability, creativity and engineering (Aoussat et al., 2000). Ergonomics for example call upon psychology, physiology and other mankind related knowledge to assure maximum comfort, safety and efficiency of consumer interaction with products (Aoussat et al., 2000).

Experts who are involved in design process are called design actors. Product designers, engineering designers, marketing responsible, and project manager are all considered as design actors. Sometimes individuals with a multidisciplinary background accomplish two or three activities (Dykes et al., 2009). For example product designers may perform marketing and engineering design activities. The specific composition of a development team and the task definition depends on the particular characteristics of the product (Ulrich & Eppinger, 2004).

In any design process, at the beginning the consumer expectations and needs get interpreted into a merely definition of product (Yannou, 2004) that is called the design brief. Later in the design process a more concrete definition of the product appears that specifies more detailed and technical information about the object of design and is called concept specifications or technical specifications. The specifications then become more refined and precise to be served in the construction of manufacturing prototypes (Aoussat et al., 2000).

Depending on the product sector and the company's organization, there is some variability in ordering in design handovers (Eckert & Stacey, 2001) . Marketing (after identifying the consumers' needs and analyzing the competitive products) comes up with the design brief and hands it over to product designers, who create some concepts based on the briefs and hand these over as specifications to engineering designers. In another situation marketing hands over the design brief both to engineering designers and product designers. In more integrated design situations marketing, product designers and engineering designers all participate in defining the design brief and design specifications.

In many organizations specifications are revisited several times throughout the development process (Ulrich & Eppinger, 2004).This happens essentially because when assessing the actual technological constraints and the expected production cost, some of the initial specifications may fail to be met and design actors need to make hard trade-offs among different desirable characteristics of the product (Ulrich & Eppinger, 2004).

### 1.3.2 Product representations

As the final product does not usually exist during the design process in physical form, product models or representations are used instead to structure knowledge and information related to the product. Product representations are a vital communication media within and outside of the design team (Stevens, 2013). Designers employ various types of representation such as sketches, physical and digital models, diagrams, graphs, notations and object samples (Gül & Maher, 2009). The design representations are also addressed in literature under the name of boundary objects (Star, 2010) and intermediary objects (J. Boujut & Blanco, 2003) because they are considered as objects at the boundaries of different expertises or objects that play an intermediary role between different expertises. In the following four main groups of product representations are identified based on the work of Pei et al., (2011).

#### 1.3.1.1 Sketches

Sketches are graphical illustration of ideas or concepts (Purcell & Gero, 2006). Sketches are made rapidly without any rules to respect and therefore they allow the facile manipulation of ideas (Ullman, Wood, & Craig, 1990). Pei et al identify four sub-groups for sketches; Personal sketches that allow to externalize the thoughts quickly; Shared sketches that are used to convey information to others to build a common understanding of the idea; Persuasive sketches that are a realistic representation of the look and the appearance of the product; Handover sketches that allow to communicate the required information for the work of other member of the design team (Pei et al. 2011). In general, sketches are rough representations without precise details and scales that are free-hand sketched two dimensions, and do not follow precise rules.

#### 1.3.1.2 Drawing

Drawings are graphical representations that follow a set of rules and are drafted with tools such as Computer Aided Design (CAD) (Ullman et al., 1990). Pei et al (2011) classify drawings based on the purpose of using them, into industrial design drawings and engineering design drawing. Industrial design drawings are used for visual aesthetics purpose and show the intended final look of the product in color and with precise lines for better understanding of clients and other actors in the design team. Engineering design drawings on the other hand are used to provide technical data such as dimensions and relations between the parts. These technical drawings can provide single or multiple views of the product (or a component) and provide required manufacturing information. In general, drawing are highly structured and two dimensional representations to formalize design elements.

#### 1.3.1.3 3D Models

Three dimensional models are either non-functional representations that are used to investigate aesthetics and ergonomics aspects of the design or functional representations used to highlight functional and technical aspects (Pei et al. 2011). 3D physical models or mock-ups help product designers and engineering designer to quickly represent their idea in a tangible way (Pei et al. 2011). Digital models help to create the object in 3D space giving the ability to rotate and digitally manipulate the object. Sometimes when the digital 3D model is created, a rendering process is applied to obtain a two dimensional image in order to show the final look and appearance of the product. In this thesis we classify such rendering in drawing category rather than 3D models. Therefore 3D models are either digital (e.g. CAD models) or physical (mock-ups, 3D printing) representations of the product that help to visualize technical and aesthetic aspects of the design but they are not full scaled.

#### 1.3.1.4 Prototypes

Prototypes are made to concretize the ideas and to evaluate the spatial effects of shapes (Mengoni & Germani, 2008). Prototypes can serve different purposes. Product designers use prototypes to evaluate the look and the feel of a design while engineering designers use prototypes to analyze technical and functional properties (Pei et al. 2011) and to verify the assembly of components and their manufacturability before full scale production (Hannah et al. 2008). Prototypes are also useful to verify how the product would be used in its intended environment and whether it conveys the design intent effectively from designers to consumers (Ulrich & Eppinger, 2004). In this thesis prototypes are three dimensional physical representations that are functional and are built to full scale.

Pei (2009) identifies two types of information usually presented in product representations: design information and technical information. Design information is concerned with aspects such as the design intent, product external form and appearance, consumer interaction with the product (or scenario of use), color and texture and aesthetic details. Technical information is concerned with aspects such as construction and assembly, measurements of parts, angles and tolerances, materials and their technical properties and technical functions of the product. We will refer again to these two types of information is Chapter 4.

### 1.3.3 Integrated Design

Traditionally the activities of different stakeholders during the design project were held separated and in a sequential way. Integrated design is an approach that suggests taking into account the needs and constraints of all the product life cycle stakeholders as soon as possible and from the early design phases (Tichkiewitch & Brissaud, 2004).

The Longman dictionary gives three definitions for integration; "the combination of two or more things so that they work together effectively", "when people become part of a group or society and are accepted by them", and finally "the process of getting people of different races to live and work together instead of separately".

In the field of engineering design, integration was initially seen as a transfer of 'knowledge' from the later stages (manufacturing for example) to the earlier phases (Palh & Beitz, 1984). Because of the difficulties to formalize and transfer the knowledge of actors from downstream phases, and difficulties of making use of this knowledge by actors from upstream phases, another form of integration appeared in the $90^{th}$. This second vision of integration led to concurrent engineering approach aiming to integrate actors (i.e. the owners of knowledge) and to enable the collaboration and the knowledge exchange among stakeholders by the proposition of supporting methods and tools (Tichkiewitch & Brissaud, 2004).

The upstream integration of the different stockholders who are involved in the product life cycle, into early decisions and problem definition has the objective to minimize the downstream issues such as conflict between the engineering and design groups, launch delays and costly rework.

Both multidisciplinary design context and the global product development -in which stakeholders involved in design projects are geographically dispersed- give raise to the importance of applying integrated design approach. The question of how companies can enable and facilitate integration and how they can cope with the issues coming from the integration has been the subject of several studies.

Albizzati et al. (2012) describe three levels for integration under the name of "integration mechanisms". The levels include strategy, organization and technology:

- In the Strategic level , the definition of clear goals , common vision , areas of focus and establishing a long term trust enhance integration by giving a sense of direction to individuals who are involved in the design project and act as a guideline for decision making.
- In the Organizational level the definition of the work process, the schedule of activities, the supervisions and monitoring activities, providing the means of formal and informal communication and organization arrangements enable and facilitate the integration.
- In the Technological level, the understanding of different disciplines requirements and how they use their knowledge and experience to execute their job helps to investigate appropriate methods, techniques and tools to support the integration.

In the following we will define the knowledge integration after a review on the meaning of knowledge, data and information. Then we review briefly integration tools and approaches.

#### 1.3.3.1 Knowledge integration

According to Kleinsmann (2006) the creation of a new knowledge is the goal of knowledge sharing and needs knowledge integration. Davenport & Prusak (1998) define **knowledge** as "*fluid mix of framed experiences, values, contextual information and expert insight that provides a framework for evaluating new experiences and evaluation*" (ref word file). Knowledge emerges when someone combines different information to accomplish a task and therefore consists of beliefs about reality, description, hypothesis, concepts and theories (Burkhard, 2005).

A common view in literature distinguishes between data, information and knowledge. **Data** is a set of discrete, objective facts about events (Davenport & Prusak, 1998) and can be represented in form of numbers, characters and images that can be further processed or interpreted by a human or put into a computer (Burkhard, 2005). For example "the color of the tractor cabin in yellow" can be considered as data.

Data on its own has no meaning but when it is put in a context, it becomes **information**. In more conceptual way, information is a message. For example "the yellow color of tractor cabin makes brand recognition for caterpillar tractors" can be considered as information.

In differentiation between knowledge, data and information, Davenport states that:

"*Unlike data and information, knowledge contains judgment. Not only can it judge new situations and information in light of what is already known, it judges and refines itself in response to new situations and information*".

Information is dynamic since it needs both sender and receiver. Knowledge is something that exists in individual's memory and can be applied or can evolve when the individual is performing a task (Kleinsmann, 2006). Polanyi (1996) divides knowledge into explicit and tacit knowledge. The explicit knowledge is codified and can be transmitted in a formal systematic way whereas tacit knowledge is personal and difficult to be fully expressed. For example the knowledge of riding a bike is hard to explain or to learn by a book because it is more experience based. However according to Nonaka (1994) the articulation of tacit knowledge, is a key factor for creation of new knowledge.

Different type of Knowledge can also be viewed as declarative knowledge (know-what or know-about), procedural knowledge (know-how), located knowledge (know-where), casual knowledge (know-why) and relational knowledge (know-who or know-with) (Burkhard, 2005).

**Knowledge integration** is defined as the process of incorporating new information into a body of existing knowledge (Murray, 1995) . This process involves identifying and evaluating the interaction between new and existing knowledge; then analyzing how existing knowledge should be modified to accommodate the new information, and how the new information should be modified in light of the existing knowledge (Murray, 1995).

Kleinsmann (2006) states that the knowledge sharing between actors from the same discipline differs from knowledge sharing between disciplines since actors from the same discipline think more similarly.

#### 1.3.3.2 Integration tools and approaches

Several approaches and tools are developed to support the knowledge integration in the concurrent engineering context by capturing data and information that then can become knowledge for design actors. Tools such as computer aided design and manufacturing (CAD/CAM), the collection of software tools and working methods under the name of PLM (product life cycle management), and product data management (PDM) helps to enable and to facilitate the integration.

Design for X (DFX) family is also among the effective approaches that provide guidelines to be taken into account earlier to avoid issues that may occur in later development phases. In this approaches X may stand for manufacturing, assembly, reliability, environment, and so on. The objective of design for manufacturing is to enable design team members to weight alternatives, assess manufacturing costs and make trade-offs. Effective DFM can lead to lower manufacturing costs without sacrificing product quality (Ulrich & Eppinger, 2004). Examples of the rules or guidelines that Design for Manufacturing (DFM) and Design for Assembly (DFA) provide include considering less separated parts to be assembled, avoid unnecessary tight tolerances, avoid parts with a geometry that need several manufacturing steps.

Other tools and methodologies are proposed to structure and to capture the knowledge of different experts about the product under development. Example of these include MOKA "Methodology and software tool Oriented to Knowledge based engineering Applications" initiated under the ESPRIT project (Brimble et al., 2001) , CPM "Core Product Model" developed in NIST laboratory (Fenves et al., 2007; Sudarsan et al., 2005) , IPPOP "Integration of Product Process Organization for engineering Performance improvement" (Noël & Roucoules, 2008) and CoDeMo "Cooperative Design Modeler" developed in France (Brissaud & Tichkiewitch, 2001; Tichkiewitch & Véron, 1997). A common point in these studies is their convergence to use product models. However some of them are more oriented toward capturing data and information (MOKA, CPM) and some other are more oriented toward supporting the collaborative design activity (IPPOP, CoDeMo).

#### 1.3.3.3 Product Model

Product model is a common key-word in many researches that aims to structure data and information related to the product. Different product models represent these data and information about the product at different levels of abstraction.

The Function, Behavior and Structure model (FBS model) of Gero & Kannengiesser (2002) presents an ontology for design activity by definition of Function, Behavior and Structure domains and the relations between the domains. Other models such as Core Product Model (CPM) were proposed to improve the FBS model. The CPM model (Fenves et al., 2007; Sudarsan et al., 2005) takes into account the geometry, the function, the material behavior, the functional and structural decomposition and the relations between these concepts in order to model the product. MOKA (Brimble et al., 2001) uses the multi-view notion for product modeling. It considers the structural, functional, behavioral and technological views. The PPO (Product, Process, Organization) (Noël & Roucoules, 2008) model of IPPOP project, goes further by adding organization of system (collaboration view) to the product model. The multi-view product model (Tichkiewitch & Véron, 1997) used in CoDeMo is another product model that, by considering several viewpoints specific to each design actors' expertise, aims to support the integrated design methodology. All the mentioned models carry on the three main concepts of Function, Behavior and Structure. The differences appear in the final objective of the model and the representation language.

The range of product models can also include detailed 3D models of geometric and electrical properties, functional models such as FAST diagrams (Tassinari, 2006), component breakdowns (e.g. bill of material ref), QFD "Quality Function Deployment" diagrams ("QFD Institute," n.d.).

Product models are useful because they point out the different interactions between components and parts of the products that are connected through mechanical, electrical or thermal relations. Product models are very useful for example in risk analysis and predicting change propagation (Clarkson et al., 2004). Furthermore in several cases it was observed that models of previous designs (products) were used as a starting point for future designs and to train novice designers (Keller et al., 2006).

In this thesis we base our work on Multi-View product model because of its research history in G-SCOP lab.

***<u>Multi-View product model</u>***

The research history leading to the proposition of Multi-View product model in G-SCOP lab began by the works of Belloy (1994) on the formalization of knowledge, rules of production and the know-how of design actors, aiming to propose a new design process approach that allows the integration of manufacturing process and constraints into the design process as soon as possible. The work was followed by Chapa Kasusky (1997) who proposed a methodology to integrate actors who are involved during product life cycle earlier in the design process. The notions of entity, actors' view, product model (including data model and knowledge model) were employed in her work. Roucoules (1999) continued to develop the notions of entity and product model and the association of knowledge model to data model. The concepts of multi-view and multi-representation were proposed and the development of a design tool named CoDeMo (Cooperative Design Modeller) was investigated (Roucoules & Tichkiewitch, 2000). The further development and the use of the CoDeMo tool for the integrated design of furniture made of particle-board and fiber-board was tackled by Pimapunsri, (2007).

The concept of product model based on the study of Chapa Kasusky (1997), includes knowledge model and data model (Figure 1-10). The knowledge model allows capturing the knowledge or information related to the product during the design process and consists of entities and production rules.

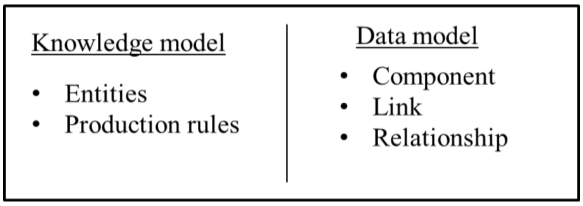



Figure 1-10: **Product model consist of data model and knowledge model**

Entities (or *features* according to Pimapunsri) can be described by name, characteristics and behavior. A *Cylinder* for example is an entity that can have characteristics such as radius, length and area. A behavior of this entity is the dependency of the area value to the values of radius and length.

Production rules (or *temporal knowledge* according to Pimapunsri) are the rules described under a premise that leads to a conclusion “if *premise* then *conclusion*” (Roucoules & Tichkiewitch, 2000). For example if the thickness of the horizontal part is T then the diameter of the dowel is not more than T/2 (Pimaprunsri, 2007).

The data model is the instantiation of the knowledge model that contains descriptions of the product based on components, links and relationships. Components are defined as set of material, a set of parts, a unique part or even a portion of a part (Tichkiewitch & Véron, 1997). Components are schematically represented by rectangles in Figure 1-11. Links are defined as characteristics of specified components that allow an external consideration of the component. Links are represented by ovals hung below the specified components. Relationships are defined as connections between two or several links of the same or different component(s). Relationships are shown by rounded corners rectangles (Tichkiewitch & Véron, 1997).

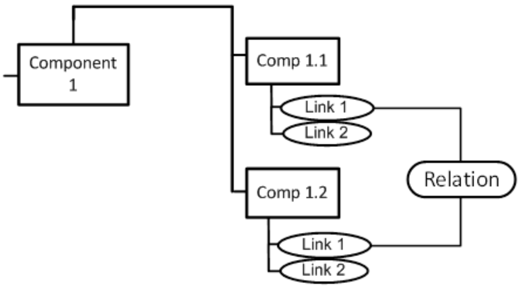



Figure 1-11: **Components , links and relations in multi-view product model after Tichkiewitch & Véron, (1997)**

The model is called multi-view because it describes the same product through several views according to the needs of each expert involved in the design process (Figure 1-12). Component decomposition in the multi-view product model provides different level of abstraction. The upper level gives a view of the product in its totality and as the level decreases more details about the specification of parts and their assembly appears.

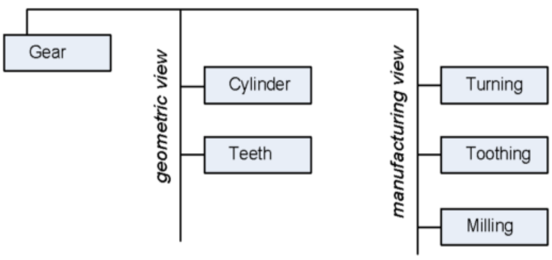



Figure 1-12: **Example of multi-view after Pimapunsri (2007)**

Further in this manuscript (in Chapter 5) we will pick up on the multi-view product model and will use the concept for modeling the engineering information.

Integration of actors in the context of concurrent engineering calls upon the collaboration and communication. Through the communication and the flow of information, design actors can share individual knowledge and their insights and discuss the design problem and the proposed solutions. Generally the design activities are carrying out through collaboration across disciplines. In the following paragraphs we will first define collaboration in general terms and then we will focus on the collaboration of two particular actors involved in design process: product designers and engineering designers.

### 1.3.4 Collaboration and Collaborative design

According to Oxford dictionary, collaboration means the action of working with other people to produce something. The collaborative design is defined according to Kleinsmann (2006) as a process in which actors from different disciplines share their knowledge about the design content and the design process. The objective of such collaboration is to create shared understanding and to achieve the common goal of creating a new product. In the context of concurrent engineering, collaboration brings together the important concepts of coordination, cooperation and communication (Nicolas et al. 2007), (Anderl et al. 2009), (Salber et al. 1995).

### 1.3.5 Communication

People who are subject to interact in a working group, communicate together to exchange information and ideas from one to another. Communication is identified as one of the most important aspects for completing design projects successfully (Maier, 2007). It allows to exchange ideas, enrich them, combine points of view, acquire knowledge and generate new knowledge (Maranzana et al., 2007). Effective communication can happen through face-to-face conversation, video conference, telephone , email or internet chat (Ostergaard et al., 2005). Members of a design team can also employ sketches, drawing, prototypes and other intermediary objects alone or combined with gesture and speech to communicate to other colleagues (Eckert & Stacey, 2001). Working in a collaborative context enhances the communication flow but more communication does not necessarily enhance collaboration because collaboration involves sharing of goals and resources (Pei , 2009).

### 1.3.6 Coordination

Coordination is more management concern and is defined as a group of rules and procedures to make it possible for a group to work efficiently and in harmony (Maranzana et al., 2007). It incorporates managing multidisciplinary groups, planning activities , decision making and scheduling in respect to the resources and the timing (Andreasen & Duffy, 1998). It can also be defined as the management of dependence among activities and resources (Carlile, 2004).

### 1.3.7 Cooperation

Cooperation is the process of working together to the same end (Oxford Dictionary) and the action of jointly building goals and the means to achieve the goals (J. Boujut & Laureillard, 2002). Cooperation differs from coordination because it requires shared knowledge and goal whereas coordination links stakeholders (with or without shared set of goals) together (J. Boujut & Laureillard, 2002). Although the terms cooperation and collaboration are sometimes used interchangeably in the literature, yet there is distinction between them. According to Kleinsmann (2006), studies on cooperation focus on quantity that is the frequency of interaction and the amount of information shared between stockholders whereas studies on collaboration focus on the quality of shared information, shared understanding and vision on the design and the process to be followed. Denise (1999) considers collaboration as the missing connection between communication, coordination and cooperation and states:

> *Collaboration is distinct from each of the "C" words…. Unlike communication, it is not about exchanging information. It is about using information to create something new. Unlike coordination, collaboration seeks divergent insight and spontaneity, not structural harmony. And unlike cooperation, collaboration thrives on differences and requires the sparks of dissent.*

On line with (Denise, 1999; Marin, Mechekour, & Masclet, 2006) we consider collaboration as a broader context that encompasses the concepts of communication, coordination and cooperation.

### 1.3.8 Characteristics of collaborative design

Actors who are involved in design have different responsibilities and different perspectives. This is due to their different educational backgrounds and work experiences. They have their individual and disciplinary view, beliefs and interests. As Bucciarelli terms in his book "Designing Engineers", each work within a different *object world* (Bucciarelli, 1994). Disciplines see the object of design according to their world of technical specialization, language, metaphors and symbols (Bucciarelli, 1988)

Different disciplines may employ different tools and product representations (i.e. sketches, drawing, 3D models, prototypes) or they may use the same type of representation for different purposes. Different product representations can provide different type and amounts of information (Hannah, Joshi, & Summers, 2012). Each representation makes some aspects of design explicit and hides others. Information can be obscured by the representation (Eckert et al., 2001).

The representations designers use to express their ideas and other information and the skill of understanding the representation that designers possess have a powerful influence on design communication (Eckert & Clrakson, 2004). Having different object worlds can lead to conflicts for example when an engineering designer cannot interpret information from a product designer's sketch (Pei , 2009). Sometimes the interpretation of ambiguous information is based on the context (Eckert & Clrakson, 2004).

Although collaborative design has the advantage of jointly constructing the design solution (Gül & Maher, 2009) , it also has some limitation. Communication is vital for constructing a common reference point within a group of collaborators (Détienne et al., 2012). Looking at design as a process of negotiation among disciplines (Bucciarelli, 1988), communication with colleagues from other disciplines can be difficult and delicate (Kleinsmann et al., 2010).

When studying the challenges in communication across interfaces and the required support, Maier et al. (2006) found general issues such as lack of awareness of what tasks other team member are working on and how the information flows. The shared background among design actors coming from their previous design project and their shared experience is important in their communication. Previous designs form a vocabulary both for thinking about the new design and for describing designs to other actors (Eckert & Stacey, 2000).

Actors may be geographically dispread and have different languages and cultures (Eckert & Stacey, 2001). The geographically dispersion and differences in culture and language (Anderl et al., 2009) cause difficulties in creating shared understanding. A lack of shared understanding can cause unnecessary iterative loops and reduce the quality of final product (Kleinsmann & Valkenburg, 2008).

Although communication and collaboration breakdown cannot be eliminated, it can be well managed through communication strategies and support (Pei , 2009). For the purpose of this thesis we focus on the collaboration between product designers and engineering designers because in the design of branded products, both appearance and technical properties are critical and the interaction of the product design and engineering design disciplines becomes important.

### 1.3.9 Product Designers and Engineering Designers

The interaction between product designers and engineering designers has been identified as critical in several studies (Mengoni & Germani, 2008; Pei, 2009; Persson & Warell, 2003, Warell 2001, Anderl et al 2009). These researches address the collaboration barriers and communication problems between product designers and engineering designers arising from different educational backgrounds and conflicts in goals as well as different design representations customarily used.

Attempting to find a clear definition for "product designers" and "engineering designers" in the literature we faced several fuzzy terminologies and a lot of knowledge overlapping that distorts the obvious distinction between the boundaries of the two disciplines. In a spectrum from the fine art to the science, product designers and engineering designers can be positioned in opposition, somewhere between the middle and extreme edges (Figure 1-13).

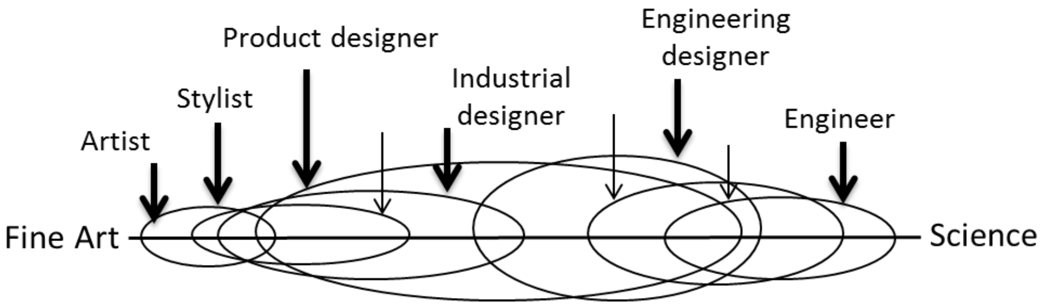



Figure 1-13: **Knowledge overlapping on a spectrum form fine art to science**

The terms product design and industrial design are often used interchangeably in the literature. According to the Industrial Designers Society of America (IDSA), industrial design is defined as the professional service of creating and developing concepts and specifications that optimize the function, value and appearance of products for the mutual benefits of both consumers and manufacturer. The term industrial designer according to its usage in the literature seemed to be as broad to include the activities of the entire product development. However, we decided to use the term product designer in this research, to put an emphasis on their attention upon the form and consumers' related aspects of the product (such as perception and emotional responses).

In this thesis we consider that for most consumer products, while their roles overlap, product designer are primary responsible for the overall design and the specification of product form including aesthetic, attractiveness, user interface, semantics and meanings with consideration of brand values and intended emotional responses. Engineering designers deal with mechanical, electrical and electronic aspects and consider cost, robustness and available technologies (for manufacturing, assembly, maintenance etc) when trying to find the technical solution to the design specification.

Although the role and responsibilities of product designers and engineering designers can be extended to other activities (related to product life cycle), we follow the above definition in this thesis and characterize their interaction and work approaches in the following paragraphs.

The timing, the effort and the level of involvement of product designers and engineering designers in the design process depends on the nature of products. For “Technology-Driven” products the engineering and technical aspects dominate the development process because the primary characteristics and the core benefit of product is based on its technology or its ability to accomplish a specific technical task (Ulrich & Eppinger, 2004). The role of product designers is limited to packaging the core technology while still considering aesthetic and ergonomic aspects.

For the “User-Driven” products the role of engineering designer is still important to determine technical features of the product but since the technology is often already established the focus is on the external appearance and the aesthetic appeal of the product (Ulrich & Eppinger, 2004). The role of product designers and their involvement is more important.

Product designers through their inherent creativity, can form new images and establish shapes that ensure the market and consumers’ needs while for the technological aspects their work rely upon the engineering designers’ skills (Aoussat et al., 2000).

Product designers and engineering designers have different training and knowledge background and apply different ways of thinking, problem solving and justifying.

Engineering designers are taught to employ systematic problem solving strategies, whereas product designers are taught to solve problems intuitively, rarely relying on quantitative data (Pei et al. 2010).

If several engineering designer perform mathematical calculation, all of them would obtain the same results whereas if product designers are asked to design a product, not all of them would come up with similar propositions. Intuitive methods help product designers’ creativity and avoid limitation in their work (Anderl et al., 2009) whereas systematic methods help engineering designers to approach the problem step by step in a logical and comprehensible manner (Pahl & Beitz, 1996). Product designers typically produce a range of varied ideas with preliminary layouts in order to find out the most aesthetic product (Anderl et al., 2009). Engineering designers, on the other hand, aim to achieve solutions regarding the physical and production constraints, without knowing whether it would appeal to consumers or not (Michalek et al. 2005).

Product designers normally start from the big picture or the overall form of their idea about the design concept and add more details to it gradually (Jaafar & McKay, 2010) whereas engineering designer use abstract analysis to pinpoint product properties without the need to recognize the bigger picture or the overall product form (Anderl et al., 2009).The overall form is obtained later when all the technical attributes are set up. In contrast to product designers, the engineering designers may see the product as the assembly of interacting components for which a set of parameters and values should be defined and be manipulated to achieve the optimal performances (Michalek et al., 2005).

To communicate the ideas, engineering designers often use technical terms and facts including calculations, technical information and specifications (Pei 2010) and symbol-based graphics of the developing product (Anderl et al., 2009). They use scientific methods for testing and rely upon facts to justify their solutions (Persson & Warell, 2003). Product designer employ free hand sketches (Pei 2010) , use metaphors (Cila & Hekkert, 2009) and contextual information to communicate and justify their design (Eckert and Stacey 2003) relying upon their personal views and values (Persson & Warell, 2003). Product designers’ decision making are often intuitive and is hard to describe verbally or to document (Anderl et al., 2009).

Product designers use inspirations and cultural observation to translate feeling into product properties (Barnes et al., 2008).The believe in the design and the strength of conviction with which product designers present their design idea is an important factor in concept selection. This can pose a problem in product development when design concepts are evaluated against technical criteria, which are objectively assessed and motivated based on scientific knowledge and validated tools (Warell, 2004). An example of this is when the product has costly features that are not even necessary for the components intended function but are raised out of esthetic consideration.

Mengoni & Germani (2008) argue that the communication problems are particularly critical when the product designers create a physical mockup and engineering designers apply reverse engineering techniques to obtain its digital representation. It is also critical when a product is subjected to restyling in order to meet new emerging requirements. The engineering activity is important to achieve feasible product with an acceptable cost. In both reverse engineering and restyling situations communication breakdown can occur because the available representations do not emphasize design and aesthetic constraints.

Whether product design is "engineering" led or "product design" led affects how design intent is preserved in later phases. Montaña et al. (2010) argues that design can have three levels of involvement in a business strategy. It can play a minor role and be limited to typical design activity (developing the visual, aesthetic and some of the technical aspects of the offering) or have a more central role by establishing relationship with other actors involved in the process. Design can also lead the whole new product development process (as for design-oriented firms).

#### 1.3.10 Summary of part three

Design process in concurrent engineering context involves collaboration and communication of actors from different disciplines who need to interact, share their knowledge and negotiate to achieve the common final goal of designing a new product. Barrier and enablers related to the communication across disciplines has been the subject of many studies. The focus of our research is particularly on the communication between product designers and engineering designers. We will refer again to the communication barriers - that we identified in this section- between product designers and engineering designers, in Chapter 3 for the construction of our framework of communication challenges in design process of branded products.

## 1.4 Research questions

So far in this Chapter we reviewed the concepts related to branding and branded products; consumers' emotions and Kansei concepts; and the design process and the design actors involved during the design process.

As established in previous sections, for design of branded products, not only the technical aspect of the product is important but also the external appearance is crucial to differentiate the product from competitors, to communicate the brand values and create pride of ownership for consumers and to elicit emotional responses.

The successful implementation of brand values and emotional and Kansei concepts into physical product is critical in the design process of branded products. The implementation of brand values and Kansei concepts can be problematic to achieve with multidisciplinary project teams coming from different backgrounds and training. Kansei concepts and brand values and aesthetics play an important role in the product designers' rationale behind their design choices. Communicating them affects the engineering designers' understanding of what exactly should be designed and what the appropriate technical and manufacturing choices are. However the communication of brand and emotional aspects of the design intent between product designers and engineering designers is challenging and needs to be supported by appropriate tools.

Many of the studies on capturing the brand essence and consumers' emotions for the design of a new product do not address the issues associated with communicating these among the actors during the design process. On the other hand, studies on collaboration and communication among design actors do not specifically address difficulties arising from the content of the communication being subjective and implicit information about the brand and emotive aspect of the product.

Based on this discussion our first research question is:

1) **How to support the communication of brand and emotional concepts between product designers and engineering designers in the design process of branded products?**

To answer this question it is useful to form an understanding of the relation between brand and emotional concepts. Based on the literature review a framework is presented in Chapter 3 to clarify this relation.

In addition the difficulties and the factors contributing to the communication breakdown should be analyzed from both theoretical and empirical viewpoints. From the theoretical aspect, we identify these factors from the literature review and gather them in a framework presented in Chapter 3. The framework structures a theoretical view on the origins of the difficulties that the product designers and engineering designers confront for the implementation of the brand and Kansei concepts into the new product in a collaborative design context.

From the empirical aspect, we identify the current difficulties based on the results of in-depth interviews in two French companies. Chapter 4 presents the results of the empirical study. Likewise, our approach to investigation tools that help to formalize and support the communication of brand and Kansei concepts between product designer and engineering designers is presented in Chapter 4.

On the other hand, the improvement of the implementation of brand values and Kansei concepts into the new product can be addressed in the context of concurrent engineering. Companies are recognizing increasingly that integrating design and manufacturing contributes to improved quality , lower cost and acceleration in the design and development process (Coughlan, 2002). According to the context of concurrent engineering, the integration of engineering and manufacturing constraints should be considered from the very beginning phases of the design process. The advantage of integrating engineering designers and product designers' viewpoints early in the design process of branded products is twofold; to provide product designers by the information about what is happening at the forefront of technology in terms of materials and manufacturing methods, and to make the brand values and Kansei concepts more accessible and understandable to engineers, who are not trained in brand design and aesthetics.

The novelty of the design candidates depends mainly on the early and the idea generation phases (Bouchard, Lim, & Aoussat, 2003). Around 75% of the manufacturing cost is committed early in the design process when the knowledge of the product is unclear , incomplete and difficult to represent (Boothroyd et al., 1994; Chandrasegaran et al., 2013). In the earliest design phases the inputs are vague and ill defined (Bouchard et al., 2003; Simon, 1973). The exploration of new ideas both among design actors and between designers and clients is based on words (Lawson & Loke, 1997). The advantage of words in expressing early design ideas is the range of interpretation and the uncertainty involved that is appropriate for a creative design (Lawson & Loke, 1997). The vagueness and verbal-based nature of early design phase and the level of uncertainty involved should be considered while performing the integration of downstream constraints and the engineering information to the early phases.

Based on this, our second research question is:

2) **How to integrate the engineering designers' viewpoint into early design phase of branded products?**

The question of "how to integrate?" primarily calls upon "what to integrate?", that is the content of the engineering information to be integrated. Based on a literature review and the documents collection from the in-depth interviews in two French companies, we determine the content of the engineering information in Chapter 5. In the same Chapter, we address the question of "how to integrate" and propose an integration approach and its application in the context of the SKIPPI project. SKIPPI is a project financed by National Research Agency (ANR) that aims to develop a software to support the idea generation and the decision-making in the upstream design phase. The context of the SKIPPI project and our contribution to the project are described in Chapter 5.

## 1.5 Summary

In this Chapter we pointed out the importance of visual appearance of design in playing a critical role in the initial customer perception as well as the emotional response and evaluation of product properties. For branded products, the design of a product must also have distinctive references to the brand values. Product designers and engineering designers need to work together to create a shared understanding of the brand and the rationale behind the design choices made to implement them. Since product designers and engineering designers have different training, responsibilities and different views on the product, if they are collaborating in creating a branded product with the desired meaning, their communication should be supported. On the other hand, the integration of engineering and design view points earlier in the design process is beneficial.

This research addresses the question of supporting the integration and the communication between product designers and engineering designers during the design process of branded products.

# Chapter 2 : Research method

After formulation of our research questions in previous Chapter, this Chapter presents our research method: the way we gathered data from the research environment including academia and industry and the way we answered the research questions using the collected data.

## 1.1 Research method

In this section we will present a meta-structure in which the research method we have followed in this PhD study, can be explained. Our research methodology is inspired from DRM (design research methodology) by Blessing & Chakrabarti (2009).

According to DRM of Blessing & Chakrabarti (2009), after the clarification of the research goal , the research questions can be formulated. Then the type of research approach suitable to answer the research questions can be identified. The type of research includes descriptive and prescriptive studies. A primary descriptive study, aims at increasing the understanding of design “as-is”, to inform the development of support. Prescriptive study aims at developing support by taking into account the results of the primary descriptive study. Then a secondary descriptive study focusses on evaluating the suitability and applicability of the support and aims to understand the impact of the support.

Inspired from DRM, our research method that is illustrated in Figure 2-1, has the following steps:

Like every research, the beginning is the exploration. The exploration step consists of understanding the concepts, challenges, and trends of the design. Exploration will never finish, but by restricting the system boundaries it falls into identification of the problem and helps building a knowledge set of the problem in its particular context.

After the identification of the problem, the next step is to seek for suitable solutions. Solutions may range from the proposition of supporting tools, or an approach to tackle the problems or even a theoretical framework to provide better insights on the problem. The solutions can then be applied in a specific context or on an example to verify its feasibility and difficulties of application.

The next step is evaluation. The objective of evaluation is to verify the broader application of proposed solutions in other contexts. In this thesis the evaluation step included both the evaluation of the problem and the solution (Figure 2-1).

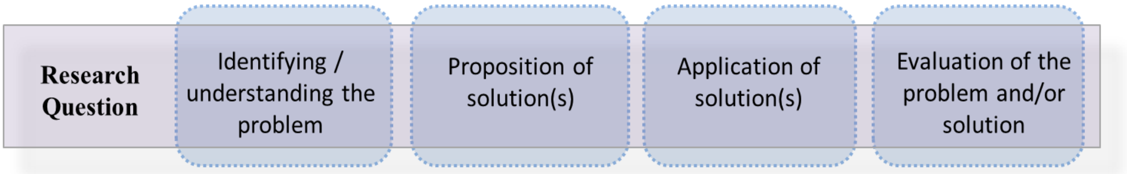



Figure 2-1: **Main steps of research method followed in this thesis**

This meta-structure is followed in addressing the two research questions related to communication between product designers and engineering designers and the integration of engineering view point into early design phases of branded products. Communication question is addressed in Chapter 4 and the integration question in Chapter 5. In both chapters, the research method is specified according to each of the research questions.

## 2.1 Research tools

The research method needs to be supported by research tools for collection of data and information. These tools can be categorized to “Literature Review” and “Empirical Study”. Literature review provides a theoretical overview about the previous researches on the subject, the achievements and the gaps. Empirical studies provide more pragmatic view of the current situation in industry and the needs and difficulties that companies are facing in a real context. In general, literature review is combined with empirical studies to give a more complete vision of the problem and the potential solutions. Since we have conducted both studies, in the following sections we describe those tools and how we used them in this research.

### 2.1.1 Literature review

To gain an understanding of the confrontation between the engineering and design worlds, we have looked through the literature to identify the characteristics of each world individually and the interaction of two worlds coming together during the design process (Figure 2-2). The literature review is provided in Chapter 1.

From the design side of the story, we have looked on the emotion and affective design, Kansei Engineering and branding. From the engineering side of the story we have looked on the product models and design for X methods (assembly and manufacturing).

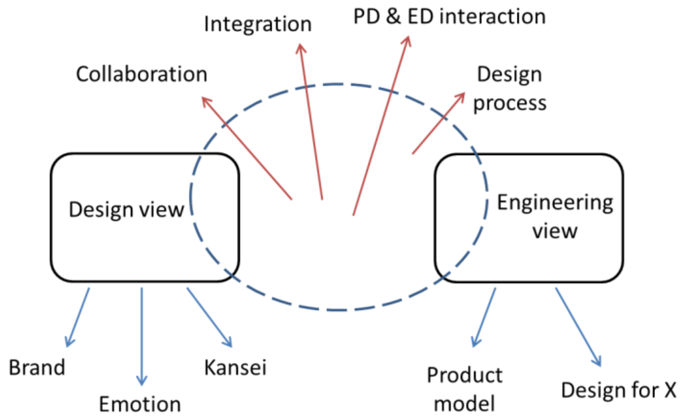



Figure 2-2: **Review of related domains in literature**

During this primary review, we noticed the need to clarify the relation between brand values and Kansei concepts that are both important in the design world. To fill this gap we proposed a framework that is presented in Chapter 3.

Then we considered the research on the design process, communication and integration in general terms and also looked for the studies that focus on the interaction between product designers and engineering designers. Here again we noticed that a gap in literature in addressing the challenges in communication of brand values and Kansei between product designers and engineering designers. Therefore we proposed a framework to gather the inter-related challenges that are usually addressed separately in the literature. The framework is presented in Chapter 3.

### 2.1.2 Empirical study

There are a number of tools that can be used to collect data through empirical studies. The tools include written survey, questionnaire, document analysis, interview, experiential analysis, ethnographic study, protocol study, case study and controlled studies. Table 1 summarizes the application, advantages and limitations of each of the methods (Summers & Eckert, 2013).

| Research method | Application | Advantage | Limitation |
| --- | --- | --- | --- |
| Written survey | Obtain quantitative information from a large sample | Systematic data collection and analysis | Low response rate, results are subjective |
| Questionnaire | Obtain predetermined information from set of individuals (passive) | Systematic collection and analysis | Explanations are rare |
| Documents analysis | When respondent are not accessible and archives are the only record of the phenomenon under study | Provides critical analysis of documents | Documents do not capture the entire phenomenon |
| Interview | Obtain qualitative information from respondents who are personally accessible | In-depth firsthand information. Allows follow-up questions and clarification | Tiresome data analysis |
| Experiential analysis | Propose theories based on researchers own experiences in a particular field | Observer being the respondent saves time and effort for data collection | Validity is questionable |
| Ethnographic study | Study cultural and emotional phenomenon by immersing self into the scenario under study | Precise and in-depth analysis of a scenario | Long duration , High cost |
| Protocol study | Study respondents in a controlled laboratory setup | Uncovers (though) process by behavior analysis approach | Respondents are not studied in their natural setting , many induce biases |
| Case study | Investigates a contemporary phenomenon in its real-life context | In-depth results. Use of multiple research methods | Takes long duration for planning , testing and implementation |
| Controlled studies | Determine influencing factors (and levels). Test theories in controlled environments | Replication logic (well accepted). Statistics and repeatable | Extrapolation of the findings from laboratory environment |

Table 2-1: **Review of research tools, Summers & Eckert (2013)**

From the mentioned research tools, we have used interviews, questionnaire and document analysis (Figure 2-3).

#### 2.1.2.1 Interviews

Interviews were used three times in this research. Two of them were in-depth interviews and the third one was interviewing over a questionnaire. We investigated **in-depth interviews** when the objective was to obtain a deep understanding of the situation and the issues: once to collect qualitative information from two French companies (Deidre Design and Option France), and once to collect information from academics. In-depth interviews were used because they provide time and occasion for the respondents to develop the discussion and give reasons for their individual opinions.

We use the term “primary in-depth interviews” referring to the interviews conducted in French companies and the terms “complementary interviews” for the interviews carried out in academia since they gave us more insights and a complementary vision on what we have learned from the primary in-depth interviews. The details of primary in-depth interviews and complementary interviews are described in Chapter 4.

#### 2.1.2.2 Questionnaire

We used questionnaire when the objective was to obtain a judgment of the way a representative amount of people think and respond to specific questions. The limitation of questionnaire is that how the questions are phrased may make a big difference to the results and also it doesn't involve further explanation on the answers. To overcome these limitations, we used questionnaire but interviewed the respondents about their answers at the same time (**Interviewing over questionnaire**). We asked them to think aloud and to verbalize their understanding of the questions as well as the reasons behind their answers. These series of interviews are called "evaluation interviews" in this manuscript since the objective was to evaluate the problem that we have identified from primary in-depth and complementary interviews in a more general context and also to evaluate the solutions developed to overcome that problem. The details of evaluation interviews are explained in Chapter 4.

#### 2.1.2.3 Document analysis

Despite of interviews, we used **document analysis**. To better understand the design process and the type of information exchanged between product designers and engineering designers, we asked for a list of documents that were created and used during the design process, in two French companies (see Chapter 4 for the list of documents, the state of received documents and the results of the analysis). Further analysis of the collected documents, combined with the result of interviews, helped us to find out what information is formalized and kept trace of, and what information is missing and why.

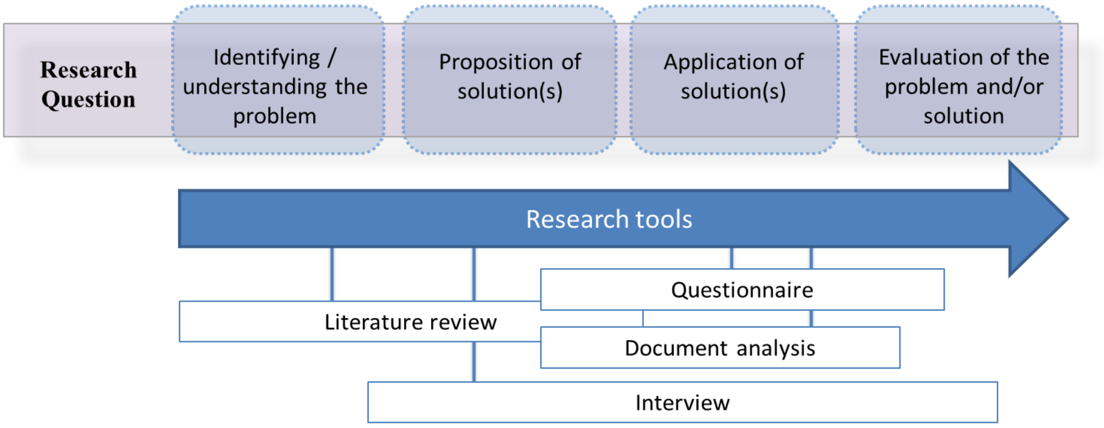



Figure 2-3: **Applied research tools**

After a discussion on the research tools, in the next session we explain where we looked to collect information, which is the research environment.

## 2.2 Research environment

Our research environment included both academia and industry. From academic side this research has its roots in G-SCOP laboratory and the SKIPPI project and is reinforced by a scientific visit at Open University, UK.

### 2.2.1 G-SCOP laboratory

This PhD employment was located in the Integrated Design department of G-SCOP laboratory (Grenoble research center of sciences of design, optimization and production). The Integrated Design department consists of three domains of expertise; Collaborative design, Product-process design, and Information system and multiple product representation.

This research topic was positioned in the intersection between collaborative design group and product-process design group in G-SCOP laboratory. In brief, the collaborative design group is more oriented towards understanding and modeling the interactions between experts involved in the design process of products and services , as well as the development of tools (such as communication platforms, shared environments, visualization and interaction devices) to support collaborative design. The product-process group is oriented toward modeling knowledge about product, clean manufacturing design processes and sustainable development of products and services with the aim of proposing tools for early integration of this knowledge in the design process.

Being on the overlapping part of these two domains of expertise, helped us to build up an engineering vision of design, product life cycle, production and manufacturing systems.

### 2.2.2 SKIPPI project

This PhD thesis was defined in the context of the SKIPPI project (System for Kansei Image Product Process Innovation) that is a national project financed by the French government. The objective of the project was to develop a software to support early ideation and decision making in design process of branded products. Academics from four research laboratories (LCPI, G-SCOP, LIP6, PYCLE) as well as two industrial partners (Diedre Design and Option France) were gathered to collaborate together for the purpose of the SKIPPI project.

The project was founded and supervised by the LCPI research laboratory in Art et Métier Paris-Tech University. Research in LCPI laboratory is more focused on innovative design, human factor and emotional research and stylistic analysis. LCPI has a history of research on Kansei Engineering approaches and tools.

The initial mission of the G-SCOP laboratory in the project was to take part in providing engineering product and processes information for the development of the software. During the SKIPPI project we had the chance to work directly with academics from LCPI laboratory where we realized the challenges raising from the confrontation of two cultures and ways of thinking in academia; engineering culture and design culture.

### 2.2.3 Scientific visit at Open University

Despite the chance of working in a collaborative project environment, the author of this manuscript went to Open University, UK, and stayed with the design group for four months. During this time she was gladly supervised by Professor Claudia Eckert who had been studying communication between different participants involved in the design process in knitwear, automotive and helicopter industries.

This visit gave her also the opportunity to be introduced and talk to designers with design or engineering background and an affiliation to academia (PhD students (current and previous), senior lecturers, professors). She organized a series of interviews with them willing to know about their insights about the engineering and design confrontation and their eventual work or research experience with brand companies.

This visit led to the assumption that a lot of challenges related to the interaction between product designer and engineering designers (and the confrontation of design and engineering cultures) can be addressed from the communication point of view. Therefore we took the research further on the communication and its enablers and barriers, between product designers and engineering designers.

### 2.2.4 Industry

Although an academic environment offered a theoretical and scientific view of the design process and the problem and challenges that should be addressed, going to the industrial world helped to point out some overlooked issues. During this PhD thesis we had the chance to interview product designers and project managers in two French companies (Diedre Design and Option France) both partners of the SKIPPI project (primary in-depth interviews). Later we interviewed product designers and engineering designers from other brand companies to gain a broader view on the subject of the research (evaluation interviews).

Figure 2-4 shows an overview of the research method we followed and the research tools that we use to find the answers to our two research questions. We would pick up on the Figure and describe it in Chapters 4 and 5.

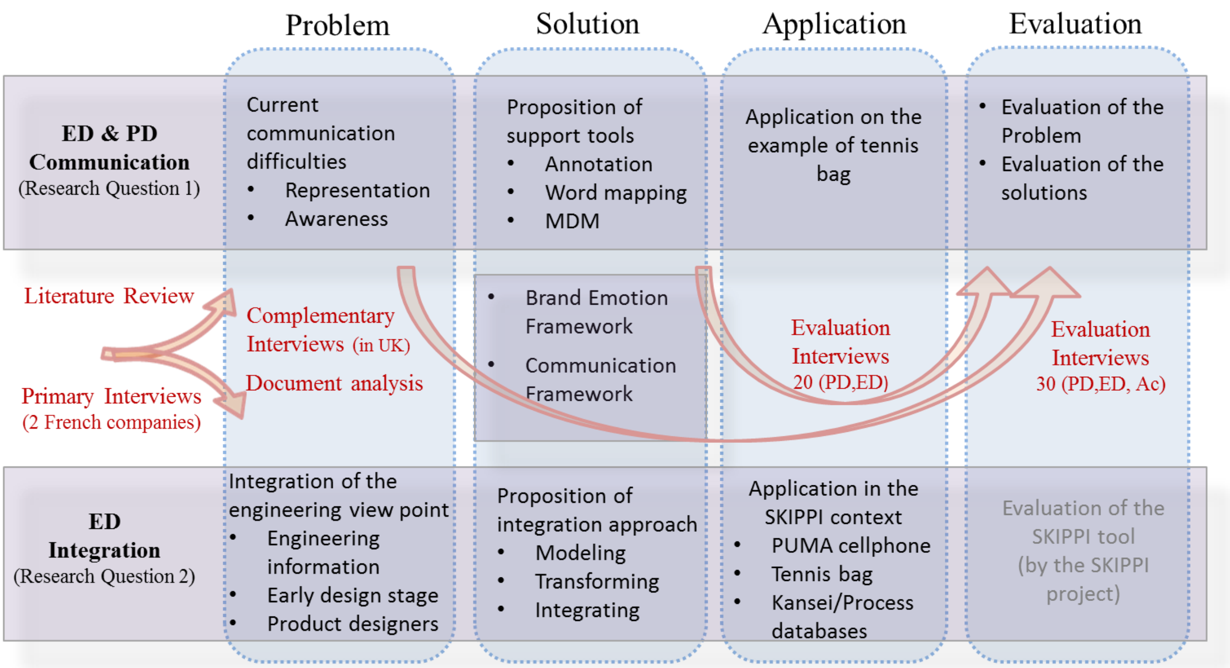



Figure 2-4: **Overview of the research method and research tools**

## 2.3 Summary

For deeply understanding the problematic and deal with the research questions, we investigated gaining a complementary vision of design from both product design side and engineering design side. We followed four main steps from the identification of the problem to proposition of solutions, their application and evaluation. Literature review, interviews, questionnaire and document analysis were used to collect information from both academia and industry.

# Chapter 3 : Theoretical Contribution

After a literature review on emotion, emotional responses and Kansei and some theory-based approach to model the consumers' emotion in Chapter 1, this chapter aims to provide an understanding about how consumers emotionally respond to a new branded product through a framework. This framework is inspired from the theory-based models and the way the term Kansei is applied in Kansei Engineering approaches. The relation between Kansei and brand values is explained through this framework. Then challenges in communicating Kansei concepts and brand values throughout a collaborative design process are described and the key points are recapitulated in a second framework. More detailed review about each axis of this framework is provided in Chapter1, but the framework has the advantage of gathering into a unique structure, factors that have not been addressed together and that are basis for studying the communication challenges in the design process of branded products.

## 3.1 Brand versus Kansei

Previously in Chapter 1 we reviewed the definition of emotion, emotional responses and Kansei. To remind, emotion is a set of objective and subjective factors that can give rise to feeling and lead to a behavior. Emotional responses are the experience and articulation of the emotions. Kansei concepts are the perceptual concepts and are semantics to express how we perceive products.

In Chapter 1 we reviewed some of the theory–based approaches that aim to model the way in which users perceive or experience products and emotionally respond to them. Although these approaches are very useful to understand the factors contributing to the emotion elicitation, they do not provide a clear understanding of the relation between emotional responses to the brand and to the perception of the physical product.

There are a few studies that have distinguished the brand as a separate element that affects the interpretation and making sense of the product physical properties by consumers. For example the relation between brand strategy and product design is established through the "semantic transformation" proposed by (Karjalainen 2004). This model describes how qualitative brand descriptions, that are transformed into value-based design features, generate the intended meaning of products (Figure 3-1). This allows for an in-depth analysis of how design can communicate the brand message. The model suggests a triadic relationship among a *Representamen* (a perceptible object, for example a design feature, shape, color), an *Object* (of reference, brand value), and an *Interpretant* (for example the user). For example Karjalainen (2010) says that:

"…a specific design feature of Nike running shoes (R) can be a manifestation of the dynamic orientation of the Nike brand (O). The context of interpretation (I) comprises the subjective realm of the interpreter and the environment in which the interpretation is made."

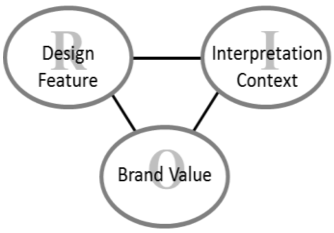



Figure 3-1**: The R-O-I framework for the analysis of Brand references in Design**

According to this model, the product can have elements (or features) that create association and link the product to brand values. Likewise, the brand values (and their representations in different products) affect the interpretation of the product elements (Karjalainen 2010). But from the model the relation between brand values and Kansei concepts are not clear.

Some other researches have looked at the brand values and Kansei concepts (in generation of emotional responses) using the Kansei Engineering (KE) approach. As the original KE approach did not explicitly consider the brand values, the researchers have adopted a method to link the brand values to Kansei words (for example see the works of (Barnes et al., 2008; Dong, Xie, & Ding, 2010; Kongprasert, 2010). A common approach in these researches is that an hierarchy of words are defined in a way that each 'high level' Kansei word is described by some other 'low level' words until they are related to a physical property (see Figure 3-2, ref : (Nagamachi, 2002)). The brand values are taken into account for the Kansei word selection and the highest level is held by the brand values.

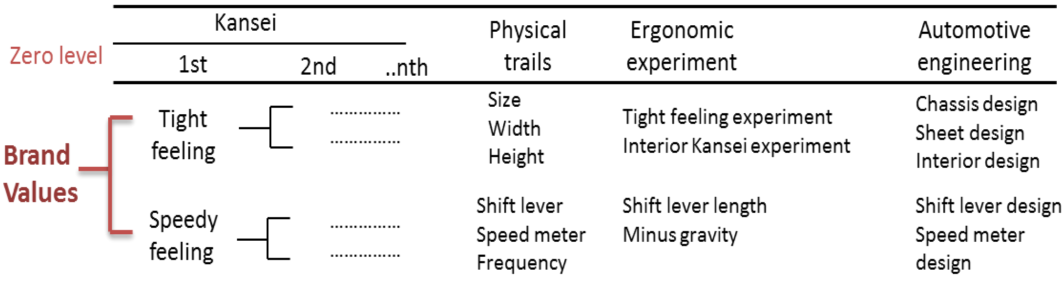



Figure 3-2: **Kansei Engineering flow, Nagamachi 2002**

In such a hierarchical structure of words (as it is shown in Figure 3-2) the high level concepts (brand values) can be assured if the following lower level concepts (Kansei words) are met by the physical properties. For example consider a car company that wants to communicate its brand value and creates the brand image in minds of consumers as “dynamic”. Dynamic image can be achieved by creating the “tight feeling” and “speedy feeling” for consumers of the car. The tight feeling can be generated through specific physical properties such as size and height in the design of the car. This affects the design of engineering and technical parts to achieve that specific size to generate tight feeling and create a dynamic image of the brand.

The risk involved in such a method is that it may lead to overlook those emotions that brand elicits without the intermediation of the product.

Kansei essentially is concerned with the perceptions coming from the product itself. We argue that the emotion related to the brand should be differentiated from the emotion related to the product perception.

It has been well established that products generate emotive responses. But at the same time the emotional responses are influenced by the product class and also by association that users make to the brand, based on personal beliefs, values and emotions toward the brand.

For example see Figure 3-3 for “feminine PUMA sport shoe”. The product is “feminine” not “masculine”. The culture and the user’s background are very important in this interpretation. The feminine perception of the shoe varies with cultures and through the ages. The “PUMA” brand can be recognized from the logo or the red line on the shoe. A direct association to the brand such as previous experiences with other PUMA products can generate emotive responses (i.e. it is a “PUMA” shoe not any shoe). Furthermore the class of the product generates feeling about the expected function (i.e. a “sport” shoe).


Figure 3-3: **Example the emotional responses to a branded product**

## 3.2 Framework for branded product emotions

In order to better understand the relation between brand and Kansei this section presents a framework (Figure 3-4) we built, inspired from the "Visual Product Experience (VPE)" model of (Warell 2008) and Desmet's model of product emotion (Desmet 2003, Desmet and Hekkert 2007) described in Chapter 1 as well as the "Semantic Transformation" model of (Karjaleinan 2004) described in the beginning of this Chapter.

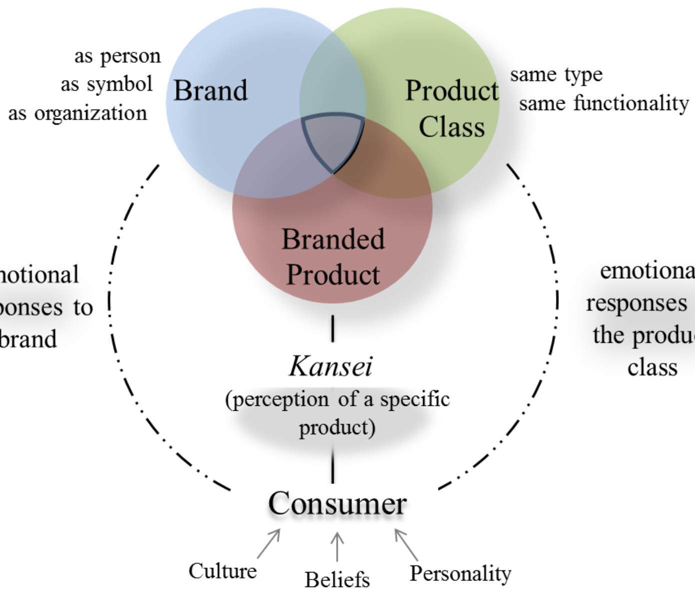



Figure 3-4: **Framework of new branded product emotions**

According to this model the consumers' emotional responses to a new branded product can be evoked by consumers' perception of the physical properties of that specific product, by the associations to the brand and by the association to the product class. In addition , according to (Crilly et al., 2008) factors such as consumers' cultural background, beliefs and values and the personalities are also important to be taken into account because they affect the emotional responses.

In this model Kansei concepts are semantic words to describe consumers' perception of product's physical properties such as shape, weight, specific features or its packaging.

Product class is the label for all the products that can be classified in the same category because of their functionalities (e.g. all the sport shoes, all the mobile phones). Products that are grouped in the same class can have typical basic elements and similar functions. They may have variations of color or shape or brand name. The product class takes parts in the elicitation of emotional responses through the expectation it creates in the mind of consumers and through the evaluation and comparison of the new product to the other products that perform the same or comparable functionality or have similar elements. The range of products grouped in the same class is dependent on how broad is the frontier of the definition. For example for foot wear products, a product class may include sport shoes whereas a broader class may include all type of sport and party shoes as well as slippers.

Consumers' emotional responses can be generated through the attachments users have to brand and their experience of previous products of the same brand. It can be related to the image that consumers have of the brand personality, the organization and what the brand symbolizes for consumers (for example the feeling of buying and using the best).

When the consumer perception of physical properties of product aligns with the emotional responses to the brand values, the brand value and its image is reinforced in consumer's mind. For example if the brand value is honesty (Figure 3-5), a large clear window on a plastic bag that shows the actual product, is a visual indicator that the product and the brand are trustworthy and honest (Kang & Satterfield, 2009).


Figure 3-5: **Intersection, reinforcement of brand image and Kansei concepts**

However consumers' perception of a product (Kansei concepts) is not always necessarily aligned with the brand (see Figure 3-6). For example "modernity" might not be the intended brand image that a DVD-player manufacturing company wants to create. But a DVD-player that is angular, metallic-looking and is made of a smooth material is perceived as modern (Blijlevens 2009).

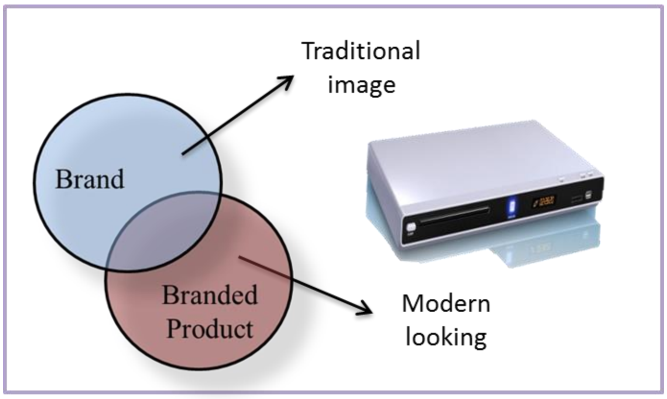



Figure 3-6: **Example where Kansei and brand values are not aligned**

When Kansei (consumer perception of the product) and the intended emotional responses that the brand company wants to create do not coincide, the product perception and the brand image can either complement or contradict each other. For example a brand that conveys the value of prestige and lacks the modernity, can gain the modernity values by introducing products that have modern design. The brand and the new products complement each other by adding the modernity values to the brand's prestige value.

It is especially challenging when consumer perception of product properties and the brand image coming from other aspects of brand value are incompatible and contradict each other. This will cause difficulties for consumers to form an image of product and brand and will negatively affect their attitude towards the brand (Rompay et al., 2009).

The case of complementing or contradicting emotional responses may also happen when some properties of the product do not share the expected functionality as it is expected from the product class. For example as it is shown in Figure 3-7, high heels are not expected for a product in sport shoe class (or shoes grouped in party shoe class are not expected to carry sport looking). This kind of products sends a mixed message that leads to ambiguity for assessing the product to a product class.


Figure 3-7: **Example where the perception of product class and Kansei are not aligned**

Sometimes emotional response arising from the product class might be in conflict with the emotional response coming from the brand value. For example "rigidity" is the intended image that Tecnifibre brand tries to communicate to the consumers (Figure 3-8). Rigidity is embedded in the "inflexible" structure of Tecnifibre tennis rackets. However the design of a tennis bag implies “flexibility” coming from the product class of sport bags. This requires a design solution that incorporates both “flexibility” and “rigidity” in the product.

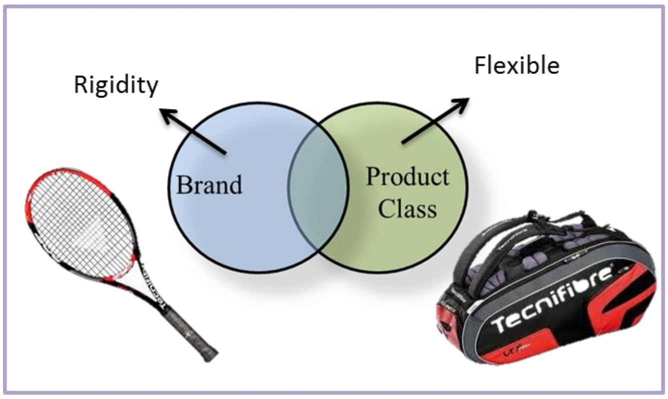



Figure 3-8: **Example of when brand value and the product class are not aligned**

Like other theory-based approaches, our ‘branded products emotion model’ provides insights and understanding for better analysis of the factors that are contributing to generate or affect the emotions and evaluations that consumers make of a branded product.

This model provides the basis for future studies by raising interesting questions about how to identify and manage the compatibility and contradiction related to brand image and the product perception. One can say that introduction of a single new product can hardly affect the brand image as long as the previous products are still used among consumers under the brand name. However it is important to understand the brand evolution and its future objectives defined by brand developers, and consider these objectives in the design of new products. In this thesis the presented framework serves rather as a base for better understanding the relation between brand values and Kansei concepts.

## 3.3 Communication Challenges in Design Process of Branded Products

After a discussion about the relation between brand values and Kansei concepts, this section addresses the challenges in design process of products for which the implementation of brand values and Kansei concepts into the final product is important. Looking at the design process of branded products from the communication angle, understanding the challenges in communicating Kansei concepts and brand values between product designers and engineering designers, brings together three related, but usually unconnected bodies of literature:

- Branding and brand management
- User perception and Kansei Engineering
- Collaborative and multidisciplinary design

We referred to these bodies of literature in Chapter 1. From each body, pertinent factors were identified in this section and summarized in a framework illustrated in Figure 3-9. Besides the separated literature focused on one of the issues several studies cut across topics. McCormack et al. (2004) and (Jaafar & McKay, 2010) pick up the brand issue and present a method (based on shape grammar) for encoding the key elements of Buick into a repeatable language. Although the authors claim that such a method would improve the understanding of brand by marketing, engineering and industrial design, neither the resulting communication issues nor Kansei engineering is addressed.

Barners et al. (2008) and (Dong et al. 2010) deal with brand values using a Kansei engineering approach and respectively present a toolkit to support packaging design, and Analytic Hierarchy Process (AHP) in furniture design. But the communication and collaboration issues are left behind. Warell (2001) proposes an approach called Design Format Analysis (DFA) to capture and explore the occurrence of design elements among a variety of product. Although Warell brings up the issues related to communication around the branded products but the notion of Kansei engineering stays out of the scope.

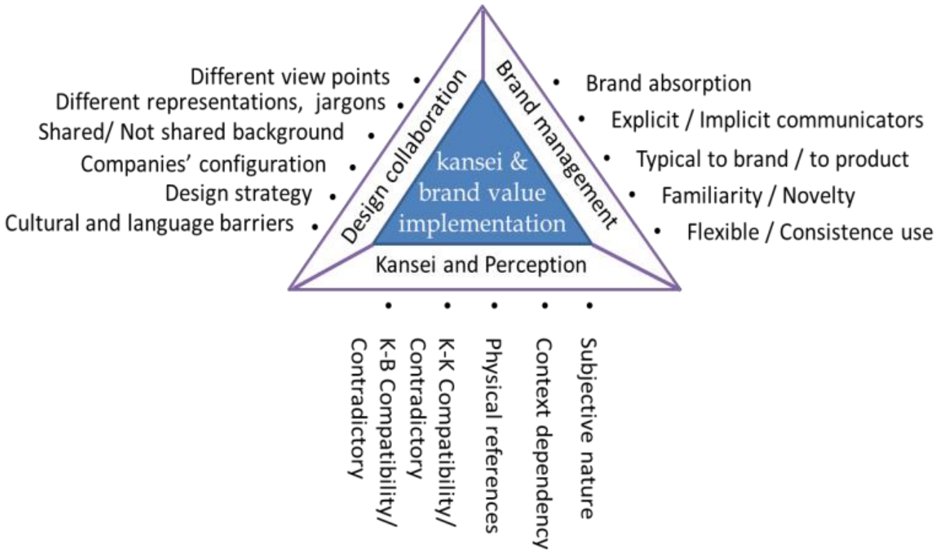



Figure 3-9: **Framework of communication challenges in the design process of branded products**

For the design of a branded product, the product designers and engineering designers should collaborate and communicate together to implement the brand value and the Kansei concepts into the new product throughout the design process.

From the branding point of view, as discussed in Chapter 1, it requires:

- Capturing and absorbing the brand value
- Communicating the brand value through explicit and implicit element
- Identifying elements that are typical to brand and those that are typical to product
- Balancing between familiarity and novelty
- Decisions on flexible or consistent use of references to the brand, over product family

The above points are related to the brand knowledge. Applying this knowledge into the design of a new product is rather an intuitive process. The communication of such tacit and implicit knowledge is difficult.

Likewise the knowledge related to consumers' perception and Kansei is also tacit. Although the Kansei Engineering approach can provide input information and to some extent explicit this knowledge by linking emotions and perceptions to physical properties of product , the implication of such knowledge into the design of a new product is not entirely evident. For example the Kansei concepts are context dependent. The meaning of "soft" changes from one product to other and it is difficult to say that there is an absolute linking between for example the "rounded shape" and the "soft impression" over different products. Furthermore the effect of local product elements or the global shape in generating consumers' perception should be considered. Some local features are more important than others because they might affect the global perception of a product (Chang & Wu, 2009). For example the type and layout of digital buttons in a mobile phone would influence the consumer's judgment on the global image of simplicity or complexity of the product (Chang & Wu, 2009). In case of conflicts between the Kansei related to specific product element (e.g. rounded corners or a material used in a specific part of product) and the Kansei related to global appearance of product, suitable design decision should be made.

The communication of Kansei concepts among the members of the design team is difficult because Kansei concepts are subjective. As Barnes et al state "… *'Soft' could be expressed against the construction of the seat, the aesthetic appearance or the weak construction of the automobile*" (Barnes et al., 2008). Two people can use the same word to mean different things or struggle to find the words to describe what they mean. In addition, different words could mean the same thing. In most of the cases using a physical reference (images or samples of product) is a promising way to better understand the meaning of a Kansei concept.

The subjective nature of Kansei concepts means that different people have different interpretations, which gives room for ambiguity. The wide interpretation of these concepts in the idea generation phase of design, could contribute to creativity and innovation (M. Kleinsmann & Valkenburg, 2008). But later in the design process ambiguity can lead to misunderstanding and disrupt design collaboration (Stacey & Eckert, 2003). People usually interact on the assumption that certain premises are shared until they notice from interactions that this is not the case (Karlgren and Ramberg 2012).

As a summary the following factors are challenging in the communication of Kansei concepts between the design actors:

- Subjective and interpretable nature of Kansei concepts
- Context-dependency of Kansei concepts
- The need for physical references (images or samples of product) for Kansei concepts to support a better understanding of the meaning
- Compatibility of Kansei concepts related to specific product element and to the global appearance of product
- Compatibility of Kansei concepts related to the product and the brand image

In addition to the challenges related to the communication of the brand values and Kansei concepts, the general factors contributing to the communication breakdown between product designer and engineering designer is another axis in our framework.

Since the communication and collaboration challenges between product designer and engineering designers are explained in detail in Chapter 1, here we only recapitulate the key points:

- Different sets of principles, goals and training, thus different viewpoints on the design of the product
- Different design representations expressing different types of information through the design representation
- Different technical languages (jargons)

- Degree of shared background (e.g. shared work experience on previous projects)
- Impact of a company's organization and configuration (e.g. locations of design department and engineering department, task definition of each department, chronologic order of activities etc.)
- Impact of company approach (e.g. design led or engineering led)
- Language and cultural barriers

The framework that we introduced (illustrated in Figure 3-9) helps to structure a theoretical view on the origins of the difficulties that the product designers and engineering designer confront for the implementation of the brand and Kansei concepts into the new product. The framework provides basis for studies that aim to support the communication between product designers and engineering designers. But the proposition of support tools needs both theoretical and empirical insights. The next Chapter presents our investigation on and the results of an empirical study.

## 3.4 Summary

In this chapter we introduced two theory-based frameworks that are our theoretical contributions in this research. The first one helps to understand the relation between brand values and Kansei concepts through a model of consumers' emotional responses to a new branded product. In summary, the purpose of using particular shapes, curves, colours or elements in the design of a new product can be related to the intention of communicating the brand value and foster the brand image in the minds of consumers or create recognition. It can be also related to the intention of generating emotions and perception related to that specific product (Kansei concepts). It is important that physical properties of the product do not generate contradicting Kansei and brand-related emotions. Furthermore, consumers' emotional responses to a branded product might not be generated only due to its physical properties, but also due to the consumers' understanding and evaluation of the brand in general and due to the evaluations of the product class. The consumers' cultural background, personality and beliefs are also contributing to how they perceive and emotionally respond to products.

The second framework structures an overview of the different factors that contribute in the communication problems related to emotive aspects of design between product designers and engineering designers during the design process of branded products. In summary communication across disciplines can result in conflicts and misunderstanding between product designer and engineering designer, especially when the content include subjective and context dependent Kansei and the tacit and implicit brand knowledge.

# Chapter 4 : Communication support

In this Chapter we address the communication issues between product designers and engineering designers. Our discussion in this Chapter is based on the results of primary in-depth interviews in two French companies and then the complementary interviews conducted in UK. From the literature review and the results of the primary and complementary interviews, we identified sources of difficulties which are then specified into two key conclusions. The key conclusions are then evaluated in a larger community to see whether they are generic or not. To support the communication three different tools namely annotation, multiple-domain matrix (MDM) and word mapping are presented and then evaluated by product designers, engineering designers and academics.

## 4.1 Exploring current situation

Our approach in addressing the first rsearch question formulated as “how to support the communication of brand and emotional concepts between product designers and engineering designers in the design process of branded products?” is illustrated in Figure 4-1.

After a littature review on the factros contibuting to the communication problems (provided in Chapter 1 and synthetized in Chapter 3), we conducted primary in-depth interviews in two French companies, and complementary interviews in UK. The results of the primary and complementary interviews and the document analysis (collected during the primary interviews) helped us to set the industrial problem and proposing candidate solutions. We applied the solution on an example and then evaluated both problem and solutions in more generic context. The details of these steps and the interviews are explained in this Chapter.

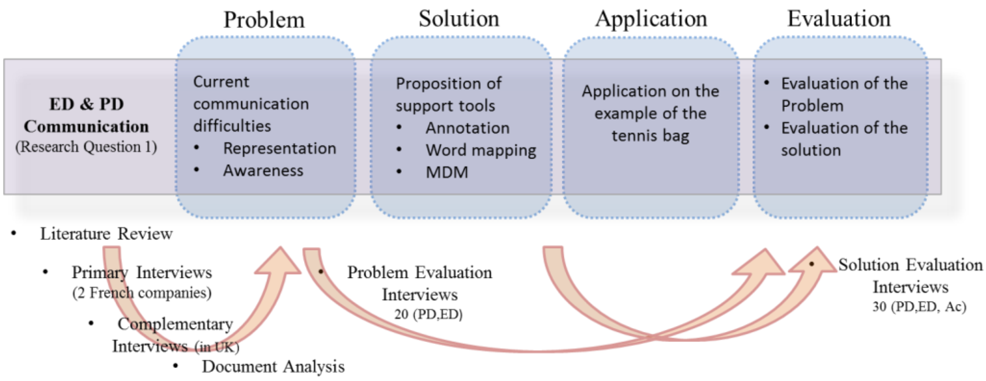



Figure 4-1: **research method to address the communication question**

## 4.2 Primary in-depth interviews

The objective of the primary in-depth interviews was twofold; first to understand how to characterize the engineering point of view from an empirical aspect and to gather data related to products and the industrial processes (manufacturing, assembly, etc.); second to understand the current situation of the collaboration between product designers and engineering designers in both companies.

We interviewed a total of 8 persons (in pairs) from Diedre Design and Option France companies. Diedre Design is an industrial design consultancy that develops product design solutions and services collaborating with brands. Some of the projects include the design of tennis bag for Tecnifibre brand, bicycle brake for Mavic, domestic gas bottle for Totalgaz.

Option France was a developer of communication products (such as cellphones) in collaboration with brands like Diesel, Swarovski and PUMA. The company went bankrupt two years after our study.

Table 4-1 summarizes some information about the two companies and the people we interviewed.

| | Interviewee | Company | Brands | Example of products |
|---|---|---|---|---|
| Primary interviews | Product Designer (2) | Diedre Design | Tecnifibre, Totalgaz , Time, Bebe confort, Renault | Sport products, packaging , toy, automotive |
| | Graphical Designer (1) | | | |
| | Project Manager (1) | | | |
| | Product Designer (2) | Option France | PUMA , Diesel , Swarovski, FNAC | Mobile phone, e-reader |
| | Project Manager (1) | | | |
| | Marketing Responsible (1) | | | |

Table 4-1: **Primary in-depth interviews in two French companies**

To provide proper data, we organized the data collection in three phases:

**Before interview**

We asked both companies for the documents they created and used during the design process of one of their latest projects. The complete list of documents we asked for is summarized in below:

1. The product specifications
2. Documents that helps to trace the product development (functional analysis, envisaged solutions, solution choice matrix, value analysis, QFD etc)
3. The overall plan of the selected solution
4. Bill of material
5. Detailed plan (associated to each component)
6. Evaluation reports or performance testing reports
7. List of manufacturing information for each component (manufacturing operation, cost, time , place of manufacturing)
8. Assembly plan (and operations) for the product

**During interviews**

Interviews took place on the companies' site. In Diedre Design, two product designers, a graphical designer and the project manager, were interviewed to discuss one of their previous projects, the design of a tennis bag for the Tecnifibre brand. Tecnifibre is a sport brand producing tennis rackets and some other sport products. To meet the Tecnifibre demand the bag was designed to be used as a backpack, be light, look light and high-tech and carry visual references to Tecnifibre brand.

In Option France we interviewed two product designers, the project manager and the head of marketing. The designers were interviewed together. The discussions centered on the PUMA cellphone, designed for PUMA brand. Later on the same day we interviewed the project manager and the head of marketing as the second group. As engineering designers were not accessible in both companies and were located in China, we interviewed the project manager to obtain a global viewpoint on the design process.

In the beginning of the interview each participant introduced themselves (name, background, work experience personally and within the company and his/her role in the design project). Although we used a questionnaire to guide the discussion and get precise information (about how they characterize the product, the industrial process and the relation between product and process, see Annex 1), the participants were free to tell their "story" and add comments. They explained the project, choices made about the design of the product, the design process, the tools and methods they used and their collaboration with other stakeholders as well as the brand company. We asked them questions about the design brief and the description of the product from their viewpoint and whether they were satisfied with the final results or not. Each interview took about one and a half hour and was audio recorded. Product samples were also collected for further analyses.

**After interviews**

We transcribed the audio records and analyzed the collected documents and product samples (PUMA cellphone and the tennis bag). The required documents were not all available and in some cases the information was widespread in several documents and therefore it was difficult to extract the information we were looking for (see Table 4-2). Figures 4-2 and 4-3 show examples of collected documents from both companies. Because of confidentiality reasons we are not providing the full scale documents in this report.

| List of requested documents | State of received documents | |
|---|---|---|
| | Tecnifibre tennis bag | PUMA mobile phone |
| 1. The product specifications | 3D model (stp format), image of some components from the catalogues | Presentation document used in review meetings (ppt)<br>Requirement description (Excel) |
| 2. Documents that helps to trace the product development | 2 slides including the historical development (ppt) | Presentation document used in review meetings (ppt) |
| 3. The overall plan of the selected solution | Images | Images , Presentation used in review meeting (pdf) |
| 4. Bill of material | Not available | Presentation used in review meeting (ppt) |
| 5. Detailed plan | Not available | Presentation used in review meeting (pdf) |
| 6. Evaluation reports or performance testing reports | Not available – some was discussed orally during the interview | Presentations in review meetings (ppt, pdf)<br>Test analysis presentation (pdf)<br>Technical check point presentation (pdf) |
| 7. List of manufacturing information for each component | Not available – some was discussed orally during the interview | Not available, some was discussed orally |
| 8. Assembly plan (and operations) for the product | Not available | For some of the parts : presentation used in review meeting (pdf) |

stp: step files , ppt : power point , pdf : portable document format

Table 4-2: **Classification of collected documents from two French companies**

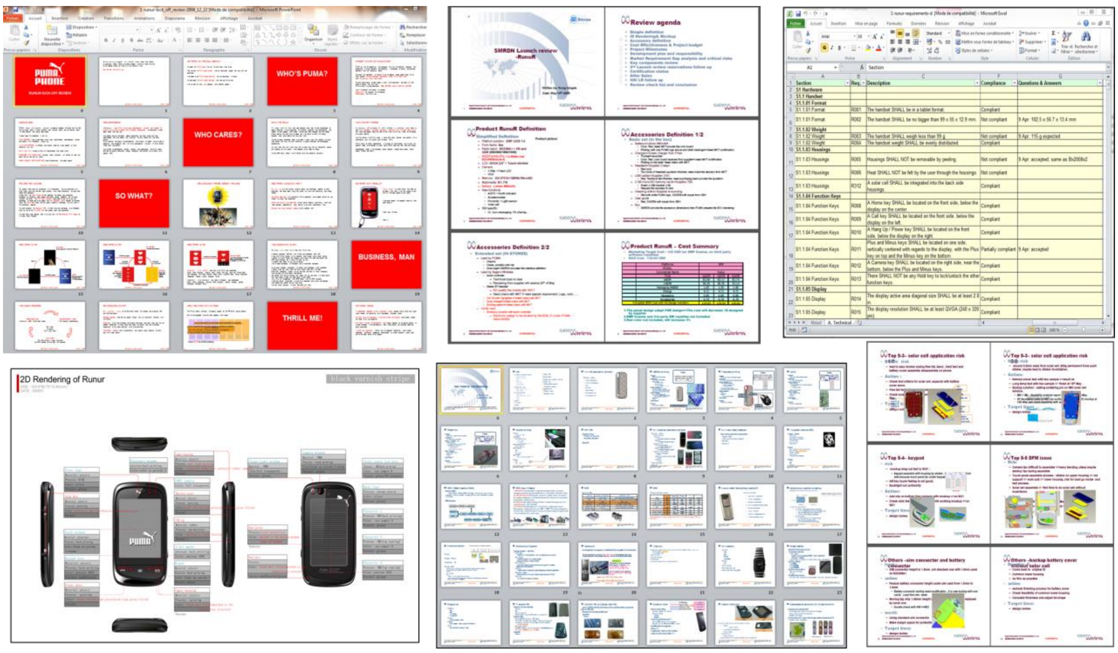



Figure 4-2: **Examples of collected documents from Option France related to PUMA cellphone project**

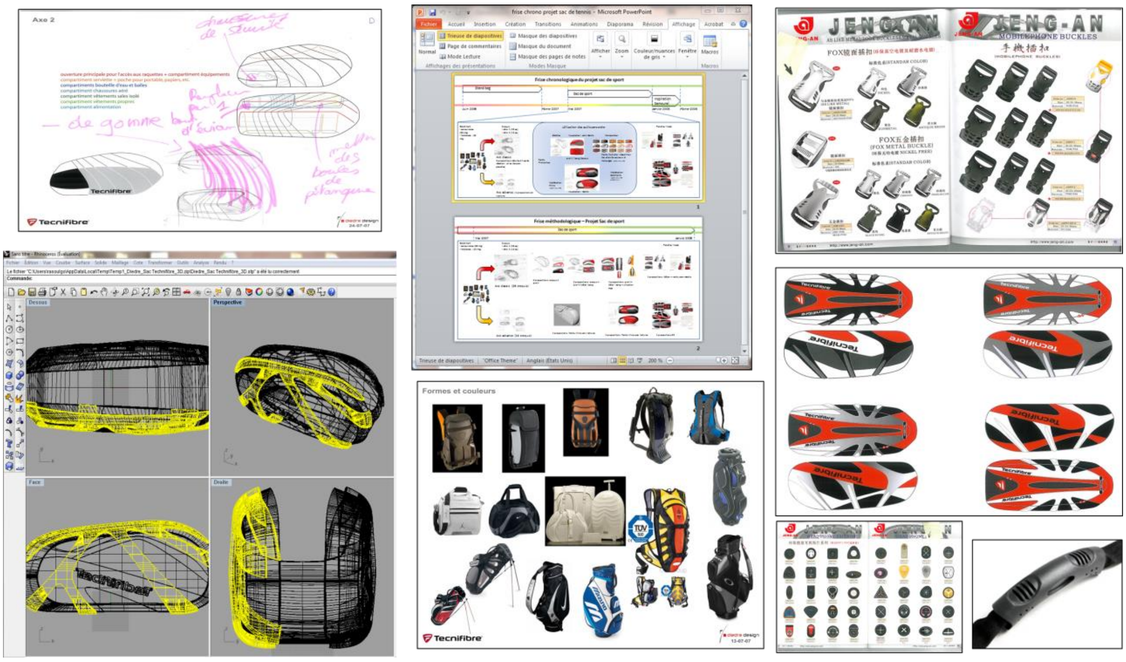


Figure 4-3: **Examples of collected documents from Diedre Design related to Tecnifibre tennis bag project**

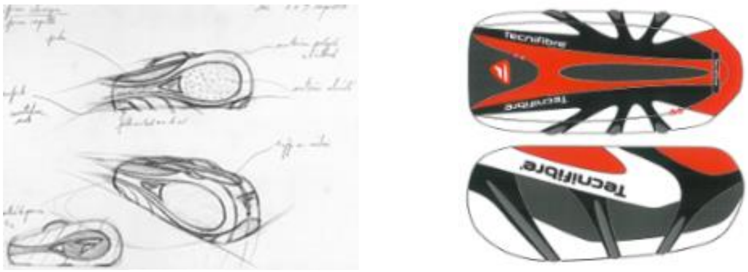
We will pick up on the collected documents again in Chapter 5, for the descriptions of product and industrial process according to engineering view point.

The following section points out our understanding of the actual practice and difficulties related to the collaboration between product designer and engineering designers in both companies based on the analysis of the audio records and the collected documents.

## 4.3 Results of the primary interviews

The first design phase for both companies (Diedre Design and Option France) consisted of analyzing existing PUMA or Tecnifibre products and understanding what these brands are standing for and what elements and identifiers could be used for new products to be perceived as a PUMA or Tecnifibre products. For example Figure 4-4 shows that common color scheme for Tecnifibre products, includes black, red and gray. Likewise, the use of red line is common in different PUMA products as a brand identifier (Figure 4-6). The product designers collected pictures of other PUMA and Tecnifibre products as sources of inspiration.


Figure 4-4: **Tecnifibre products, common color scheme**




(a) (b)

Figure 4-5: **(a) Sketches (in the left side) and (b) drawings (on the right side) provided by product designer**


Figure 4-6: **The use of the red line in design of the new product (e,g, the PUMA cellphone) as an explicit reference to PUMA family**

In Diedre Design, the technical sketches and drawing (e.g. in Figure 4-5) created in Solid works, Rhinoceros or other computer modeling packages in 2D and 3D files are handed over to manufacturing engineers and technicians in China. After two or three weeks the design office received the prototypes from China (e.g. Figure 4-7, next page). As one of the product designers mentioned for the Tennis bag project, prototype comes back with some “surprises” and “things being changed” and to some extent “it doesn’t look right”.

The design process in Option France was slightly different. As the technical aspect of the product was highly important, the design brief was communicated to both product designers and engineering designers. The technical part specifications involved using solar cells in the mobile phone. The product design used visual references to the PUMA brand and implemented PUMA values in the casing of the cellphone (Figure 4-6). Several mock-ups have been made to create the final appearance. The relevant documents were sent to engineering designers and manufacturing engineers in China.

## 4.4 Current difficulties in the companies

Based on our analysis of audio records, similar difficulties were identified for both companies, such as misunderstanding the design representation by engineering designers and long iteration loops due to the limited and indirect interactions between product designers and engineering designers. Indeed intermediaries of the companies were travelling to China to pass information about the design concept to the manufacturing department. The intermediary in both companies had a rather managerial view on the design process and we not able to afford the same rationale as product designers for the presentation and arguments.

The communication language in the review meetings and in the documented handovers was English, which was not the first language of design team members. The language and cultural barriers could also result in the design intent and arguments not being properly communicated.

By comparing the design sketches and the prototypes, we realized that the design concept was modified during the design process in both companies. For example in Diedre Design, the project manager took the unsatisfactory prototype and referred to the bag feet and said “ [translation form French to English by the author] … the feet were supposed to be molded parts joint to four extreme edges to make a better stability (see Figure 4-7 right) but here (see Figure 4-7 left) not only they used another kind of feet but also they are positioned further from the edges… the feet are disproportionate regarding the intended function because they keep the bag folded… maybe they used this kind of feet because they had these in drawer [i.e. available]… and they didn’t notice the effect of bigger height of the feet. Maybe they needed to position the feet here because of the screwing constraints...”

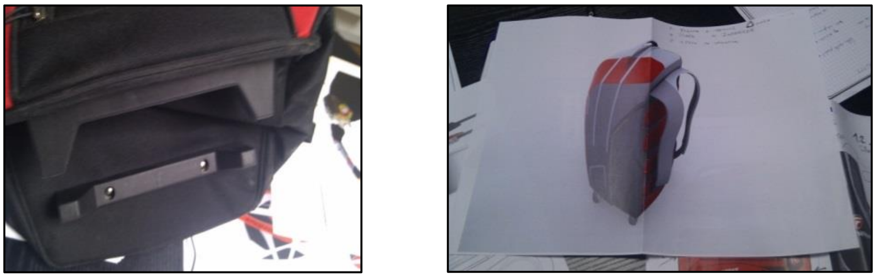


Figure 4-7: **Changes in initial design intent, design sketch (right), unsatisfactory prototype (left)**

The design concept was modified because of choices about manufacturing processes and engineering changes. The modifications were due to cost, time (making the prototype faster than other competitors), available technologies, technical constraints, available solutions and effective functionality. For example the original bag handle designed by product designers was replaced with a predefined handle from the manufacturer’s catalogues. Another example was the resizing of the large PUMA logo on the back of the mobile phone because a large surface was required for maximum effectiveness of the solar cell. It took six months for the product designer and the engineers to reach a compromise about the place and the size of the logo (Figure 4-8)

Figure 4-8: **Looking from left to right, changing the place of the PUMA logo. The final prototype is on the right side of the picture**

Engineering changes might go against the original brand spirit, even when they don't violate the technical requirements of the design brief. The choice of one manufacturing process over others could also fail to deliver the exact look and feel of the product. Product designers and project managers in both companies mentioned several examples. The tennis bag has an external structure element (black element shown in Figure 4-9). It was initially designed to give a "solid structure look" through a rigid and rounded form crossing over the textile parts. It was intended as two lateral molded pieces, heat sealed and compressed at the boundaries. The thin boundaries were important to give a "light" and "high-tech" impression to user. But instead of this processes, the structure element was prototyped using a big plastic sheet with constant thickness, which was cut to shape. The even thickness combined with the sheet cut – which is an easier process- gave a "rustic" and "heavy" feel to the bag. Therefore the "light" and "high-tech" look of the product ended up being perceived as "heavy" and "rustic" by the change of the manufacturing process (Figure 4-9).


Figure 4-9: **Pictures of unsatisfactory prototype, the structure element is shown in the three pictures to give better visibility**

A summary of the difficulties that we identified and the analysis of the reasons mentioned by the interviewees are provided in the Table 4-3.

| | ***Problem*** | ***Reasons*** |
|---|---|---|
| **1** | Misunderstanding of design representation by engineering designers | Different background, different goals, different interpretation |
| **2** | Long iteration loops | Distance, language and cultural barriers, Limited interaction between product designers and engineering designers |
| **3** | Not having a shared understanding of brand | No engineering designers took part when the brand value was captured |
| **4** | Expertise of intermediary | The managerial view on the design process , not having the same rational for the presentation and arguments |
| **5** | Engineering choices of manufacturing processes and engineering changes | Cost, time, available technologies, technical constraints, available solutions and effective functionality. |

Table 4-3: **Problems and the reasons**

Previously in Chapter 3 we presented our proposition of a framework of the communication challenges in the design process of branded products based on literature review. The findings of our empirical studies in two French companies related to current difficulties between product designers and engineering designers are in tune with this framework.

The Table 4-4 summarizes the relation between difficulties both from the literature review (the framework) and in-depth interviews.


| Identified difficulties from interviews | Factors from literature review: Branding and brand management | Emotion and perception, Kansei Engineering | Collaborative and multidisciplinary design |
|---|---|---|---|
| Misunderstanding of design representation | • No capture and absorption of the brand value by engineering designers | – | • Different view point on design<br>• Different representation |
| Long iteration loops | – | • Subjective and interpretable nature of Kansei concepts<br>• Managing the contradiction between Kansei of product and Kansei of brand | • Company's organization & configuration<br>• Language and cultural barriers |
| No shared understanding of brand | • No capture and absorption of the brand value by ED | – | • Different sets of principles<br>• Not shared backgrounds |
| Expertise of intermediary | – | • Subjective and interpretable nature of Kansei concepts | • Different view point of the design, different goal and training |
| Engineering changes and choices of manufacturing process | • No capture and absorption of the brand value | – | • Company organization |

Table 4-4: **Linking problems from empirical studies to factors from literature review**

## 4.5 Complementary interviews

One year after the primary interviews in French companies, we carried out seven interviews (that we call complementary interviews) with designers with a background in design or engineering and an affiliation to academia in UK to gain an academic viewpoint and to build a more generic view of the current difficulties related to collaboration between product designers and engineering designers. Table 4-5 provides more details about the interviewees. We selected them based on their experiences with brand companies on research projects or as product designer. Each interview took about 1hour and was audio recorded. We asked them open questions about their experience and insights about the confrontation between design and engineering in industry and how problems were faced and coped with, in their research projects with brand companies.

| | Interviewee | University | Background |
|---|---|---|---|
| Complementary interviews | 1 | University of Cambridge | Mechanical engineering, Design management |
| | 2 | Open University | Innovation design engineering , Manufacturing engineering |
| | 3 | Open University | Electronic Engineering, Industrial engineering |
| | 4 | Delft University | Mechanical engineering , Consumer product design |
| | 5 | Open University | Jewelry design, Aerospace engineering |
| | 6 | Open University | Mechanical engineering , Industrial engineering |
| | 7 | De Montfort University | Product Design , Industrial Design, Design and Technology |

Table 4-5: **Complementary interviews in UK**

From the complementary interviews we identified the core of the problem as the brand value and Kansei concept gradually getting lost during the design process because of their inefficient communication between product designers and engineering designers.

## 4.6 Setting up the industrial problem

From the complementary interviews in UK, we realized that there is a general common point that has been mentioned by several interviewees: product designers rarely provide an explanation of how the technical specification and external representations expresses Kansei concepts and brand values. Sometimes product designers are not even aware of the importance of providing this information because the meaning of the sketches seems to be perfectly clear to them.

When we reconsidered the collected documents from Diedre Design and Option France companies, it appeared that the Kansei concepts and brand values are not mentioned in design specifications or design representations (technical sketches or other handover documentations).

From the audio records we realized that in both companies the communication and the negotiation around Kansei and brand aspects of design happen later in the design process, as verbal comments on the prototypes.

We set the following key conclusions arising from the empirical studies as the industrial problem:

1. The Kansei and brand concepts generally are not formalized in the external representations which are handed over to engineering designers.
2. Product designers and engineering designers are not aware of the importance of communicating this information.

In order to support the communication and formalization of brand values and Kansei concepts between product designers and engineering designers, we investigated the development of three potential tools . Then we carried out a series of interviews (that we call evaluation interviews) to verify the validity of the problem (the two key conclusion that we set out as industrial problem) and also to evaluate the three potential tools as solutions to this problem.

## 4.7 Evaluation interviews

The objective of the evaluation interviews was to evaluate both the problem (in the first part of the interview) and the possible solutions (in the second part of the interview) at the same time. Based on their work experience in/with brand companies, we selected a total of 20 persons (10 product designers and 10 engineering designers). Table 4-6 summarizes information about the people we interviewed, the brand and the type of products. Among the 20 persons, 2 persons were based on UK, 2 persons on Switzerland, 1 person on Italy and the remaining15 persons were based on France.

A questionnaire was prepared as a Microsoft Word document and sent or given to them at the beginning of the interview. Each of the 20 participants filled out the questionnaire individually. We interviewed them at the same time about their written answers. In seven cases the interviews took place in person (the author went to visit them in the company). For the 13 remaining cases, because of the long distance, the questionnaire was send by email and the interview was carried out by phone. The average time of the interviews for the problem evaluation part was 45 minutes (from 30 minutes for those who focused more on the questions to 60 minutes for those who gave various examples of their own experience while answering the questions). The average time for the second part of the interviews was 30 minutes. For the second part of the interview (i.e. the evaluation of the 3 tools), in addition to product designers and engineering designers, 10 academic researchers were also interviewed, using the same questionnaire and using the same approach. We decided to include academics in the tool evaluation based on the assumption that product designers and engineering designers would rather evaluate the tools in the specific context of their design practice and their design projects, whereas academics would evaluate the tools in a less context-dependent way. The interviews were audio recorded and the filled in questionnaires (either digital or paper-based) were archived for further analysis. The research was carried out over a two months period in spring 2013.

| | | Interviewee | Company | Brand | Products examples |
|---|---|---|---|---|---|
| Evaluation of the Solution (annotation, MDM, word mapping) | Evaluation of the Problem (awareness, representation) | PD 1 | Design Agency 1 | Simire, Arfeo, Ligne Roset Cinna | Furniture, clock , flower pots, protection for boats |
| | | PD 2 | Individual Designer | HUB innovation d'Oxylane | Flexible computer |
| | | PD 3 | Group SEB | Tefal , Calor, Mulinex | Bathroom scales, kitchen scales |
| | | PD 4 | Group SEB , Z.I.lab | Z.I.lab, Tefal, Moulinex | Table, furniture, pan |
| | | PD 5 | Schneider | Schneider | Light switches, outlet plugs |
| | | PD 6 | Design Agency 2 | Samsung Electronics, Mahindra | Home appliances, telecommunication devices, transportation devices |
| | | PD 7 | Design Agency 3 | Obut, Jetti , SIGVARIS ,Visuol | Packaging , sport products |
| | | PD 8 | Design Agency 4 | Revolution Air , NU Air | Packaging , industrial equipment |
| | | PD 9 | Individual Designer | Gridiron | Sensors in gloves |
| | | PD 10 | Design Agency 5 | Naturen | Urban furniture |
| | | ED 1 | Tag Heure | Tag Heure | Watches (and also accessories), glasses |
| | | ED 2 | Homea | Homea | Passive house |
| | | ED 3 | Siemens | Siemens | Circuit breaker |
| | | ED 4 & 5 | Caterpillar | Caterpillar | Truck loader, wheel loader |
| | | ED 6 | Petzl | Petzl | Climbing accessories, frontal lights, sport products |
| | | ED 7 | Rossignol | Rossignol | Skis , snowboard, helmet, outwear |
| | | ED 8 | AIP Primeca | Finoptim, Rossignol | Fireplace |
| | | ED 9 & 10 | Cartier Horloger | Cartier | Watches (plus accessories) |
| | | Academics (10) | - | - | |

Table 4-6: **List of interviewees, brand and product examples designed and developed by the companies**

**PD: product designer, ED: engineering designer**

In the following sections we will first describe the preparation and the results of the problem evaluation interviews, and then we will explain our approach to define a set of requirements for a supporting tool, the development of three potential tools and the evaluation of the tools.

### 4.7.1 Problem evaluation interviews

The first part of the questionnaire was constructed to evaluate the problem, which was to find out whether:

- The product designers and engineering designers are aware of the importance of the communication of the information related to brand and Kansei concepts to each other.
- They think that the current external design representations (sketches, drawings, 3D modes, prototypes) support sufficiently the communication of brand and Kansei concepts.
- They are using other solutions to overcome this issue.

The structure of the first part of the questionnaire is illustrated in Figure 4-10.

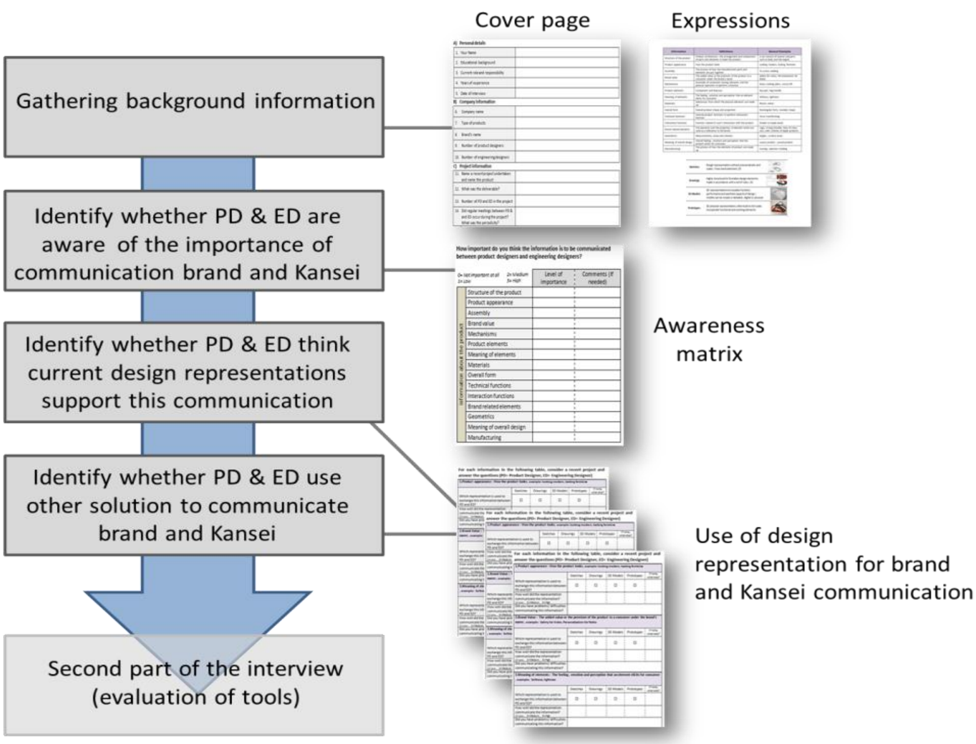



Figure 4-10: **Structure of evaluation interviews, part one; evaluation of problem**

On the cover page the interviewees were asked questions about their educational background, their role and responsibility in the company, years of experience, number of product designers and engineering designers in the company and some information about the collaboration situation in the company (Table 4-7).

**A) Personal details**

| | |
|---|---|
| 1. Your Name | |
| 2. Educational background | |
| 3. Current role and responsibility | |
| 4. Years of experience | |
| 5. Date of interview | |

**B) Company information**

| | |
|---|---|
| 6. Company name | |
| 7. Type of products | |
| 8. Brand's name | |
| 9. Number of product designers | |
| 10. Number of engineering designers | |

**C) Project information**

| | |
|---|---|
| 11. Name a recent project undertaken and name the product | |
| 12. What was the deliverable? | |
| 13. Number of PD and ED in the project | |
| 14. Did regular meetings between PD & and ED occur during the project? What was the periodicity? | |

Table 4-7: **The cover page, background questions**

For the purpose of the evaluation interviews, we gathered a list of information that is usually exchanged between product designers and engineering designers. Based on literature review (basically the work of Pei et al 2010 in definition of design and technical information, and also the concept of product models, see Chapter 1) and the analysis of collected documents from our earlier interviews (Diedre Design and Option France), the list of information includes the information about the structure of the product, product elements, the geometrics of components, materials, functions, mechanisms, assembly, manufacturing, product appearance overall form. To the above list, we added the information that we identified during the early interviews as not been formalized or sufficiently exchanged between product designers and engineering designers. This includes: brand values, brand related elements, Kansei concepts related to elements, and Kansei related to overall design. The list of information, their definition and a typical example is recapitulated in Table 4-8.

Table 4-8 served as an expression table during the interviews to provide respondents by the definition of terms. For example the "technical function" was defined as internal product functions to perform interaction functions, e.g. force transformation, while "Interaction function" was defined as function related to user's interaction with the product, e.g. enable easy stapling. We used the term "meaning" instead of Kansei in the interviews and questionnaire, because Kansei is an academic concept and people outside academy are much less familiar with the word Kansei. Moreover the term "meaning" has been already used in other researches implicitly describing the same concept that Kansei. For more details see the works of (Rognoli, 2010; Rompay et al., 2009). In the expression table provided to the interviewees, the term meaning was used as shorthand to express feeling, emotion and perception that the product elicits for consumers.

| Information | Definitions | General Examples |
|---|---|---|
| Structure of the product | Product architecture , the arrangement and composition of parts and elements to build the product | A car consists of several sub-parts such as body and the engine |
| Product appearance | How the product looks | Looking modern, looking feminine |
| Assembly | The process of how the manufactured parts and elements are put together | To screw, welding |
| Brand value | The added value or the premium of the product to a consumer under the brand's name | Safety for Volvo, Personalization for Nokia |
| Mechanisms | Assembly of connected moving elements and the physical operation to perform a function | Gears, locking pliers, scissor lift |
| Product elements | Component and features | Key pad , bag handle |
| Meaning of elements | The feeling , emotion and perception that an element elicits for consumer | Softness, lightness |
| Materials | Substances from which the physical elements are made up | Plastic, metal |
| Overall form | Overall product shape and proportion | Rectangular form, rounded shape |
| Technical functions | Internal product functions to perform interaction function | Force transforming |
| Interaction functions | Function related to user's interaction with the product | Enable to staple easily |
| Brand related elements | The elements and the properties of element which are used as a reference to the brand | Logo, strong shoulder lines of Volvo cars, color scheme of Apple products |
| Geometrics | Measurements, areas and volumes | Angles , surface areas |
| Meaning of overall design | Overall feeling , emotion and perception that the product elicits for consumer | Luxury product , casual product |
| Manufacturing | The process of how the elements of product are made up | Casting , injection molding |

Table 4-8 : **The expression table**

In addition to the expression table, the respondents were provided by a table containing the definition of product representations and illustrations from our case studies (Table 4-9). The construction of Table 4-9 is based on the four main groups of product representations explained in Chapter 1.

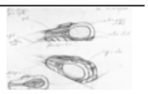
| | | |
|---|---|---|
| **Sketches** | Rough representation without precise details and scales ; Free-hand sketched ; 2D |  |
| **Drawings** | Highly structured to formalize design elements; made in accordance with a set of rules ; 2D |  |
| **3D Models** | 3D representations to visualize function; performance and aesthetic aspects of design ; models can be simple or detailed ; digital or physical |  |
| **Prototypes** | 3D physical representation, often built to full scale; incorporate functional and working elements |  |

Table 4-9: **Classification of product representation handed over between product designers and engineering designers**

The awareness matrix required the respondent to indicate from their point of view to which degree each type of information is important to be exchanged between product designers and engineering designers (Table 4-10). The degree is defined by numbers from 0 (not important at all) to 3 (highly important).

**How important do you think the information is to be communicated between product designers and engineering designers?**

*0= Not important at all* *2= Medium*
*1= Low* *3= High*

| | | Level of importance | Comments (If needed) |
|---|---|---|---|
| information about the product | Structure of the product | | |
| | Product appearance | | |
| | Assembly | | |
| | Brand value | | |
| | Mechanisms | | |
| | Product elements | | |
| | Meaning of elements | | |
| | Materials | | |
| | Overall form | | |
| | Technical functions | | |
| | Interaction functions | | |
| | Brand related elements | | |
| | Geometrics | | |
| | Meaning of overall design | | |
| | Manufacturing | | |

Table 4-10: **The awareness matrix**

Next the respondent considered one of their recent projects to filled in a table indicating which product representation (i.e. sketches, drawing, 3D models, prototypes) or other solution (documents, object samples etc.) they used to exchange the information related to brand and Kansei concepts. An extract of the questionnaire matrix is shown in Table 4-11, for the full matrix see Annex 2. For each representation they used, the respondents provided an indication of the degree of effectiveness (low, medium, high) and the difficulties arising from the representation. The questions were asked only about the brand and Kansei information. The full interview forms are shown in Annex 2.

**For each information in the following table, consider a recent project and answer the questions (PD= Product Designer, ED= Engineering Designer)**

| | | | | | |
|---|---|---|---|---|---|
| **1.Product appearance : How the product looks, example: looking modern, looking feminine** | | | | | |
| | Sketches | Drawings | 3D Models | Prototypes | If none, what else? |
| Which representation is used to exchange this information between PD and ED? | ☐ | ☐ | ☐ | ☐ | |
| How well did the representation communicate the information? 1= Low, 2= Medium, 3= High | | | | | |
| Did you have problems/ difficulties communicating this information? | | | | | |
| **2.Brand Value : The added value or the premium of the product to a consumer under the brand's name, example: Safety for Volvo, Personalization for Nokia** | | | | | |
| | Sketches | Drawings | 3D Models | Prototypes | If none, what else? |
| Which representation is used to exchange this information between PD and ED? | ☐ | ☐ | ☐ | ☐ | |
| How well did the representation communicate the information? 1= Low, 2= Medium, 3= High | | | | | |
| Did you have problems/ difficulties communicating this information? | | | | | |
| **3.Meaning of elements : The feeling, emotion and perception that an element elicits for consumer, example: Softness, lightness** | | | | | |
| | Sketches | Drawings | 3D Models | Prototypes | If none, what else? |
| Which representation is used to exchange this information between PD and ED? | ☐ | ☐ | ☐ | ☐ | |
| How well did the representation communicate the information? 1= Low, 2= Medium, 3= High | | | | | |
| Did you have problems/ difficulties communicating this information? | | | | | |

Table 4-11: **Questions related to communication of brand values and Kansei concepts**

### 4.7.2 Results of problem evaluation interviews

The following section describes the results of our analysis from the collected answers in the questionnaire and the audio recorded verbal comments of interviewees when they were filling out the questionnaire.

#### 4.7.2.1 Results of awareness matrix

To show the results of data analysis collected from the awareness matrix (Table 4-10), we used box plot (or whisker diagrams). The box plot is a way of displaying the distribution of data based on five points; minimum, first quartile, median and third quartile (Figure 4-11). The length of rectangle spans the first quartile to the third quartile and is called interquartile range (IQR). IQR is useful because instead of displaying the range of data (i.e. the difference between higher and lower data) it concentrates on the middle portion of the distribution. This avoids the misleading impression of the data range generated by a single very large or very small value (Upton & Cook, 1996).

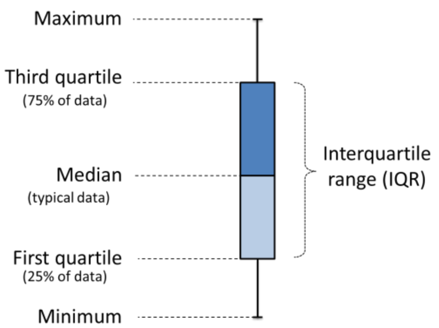



Figure 4-11: **Description of Box plot or whisker diagram**

The results of collected data from product designers and engineering designers are shown in Figures 4-12 and 4-13. The vertical axis shows the level of importance (from 0 to 3) and the horizontal axis shows the type of information from the Table 4-10. The boxes display the distribution of the importance accorded to the communication of each type of information. We also calculated the variance for the collected data, which is presented on the top of boxes in Figure 4-12 and 4-13.

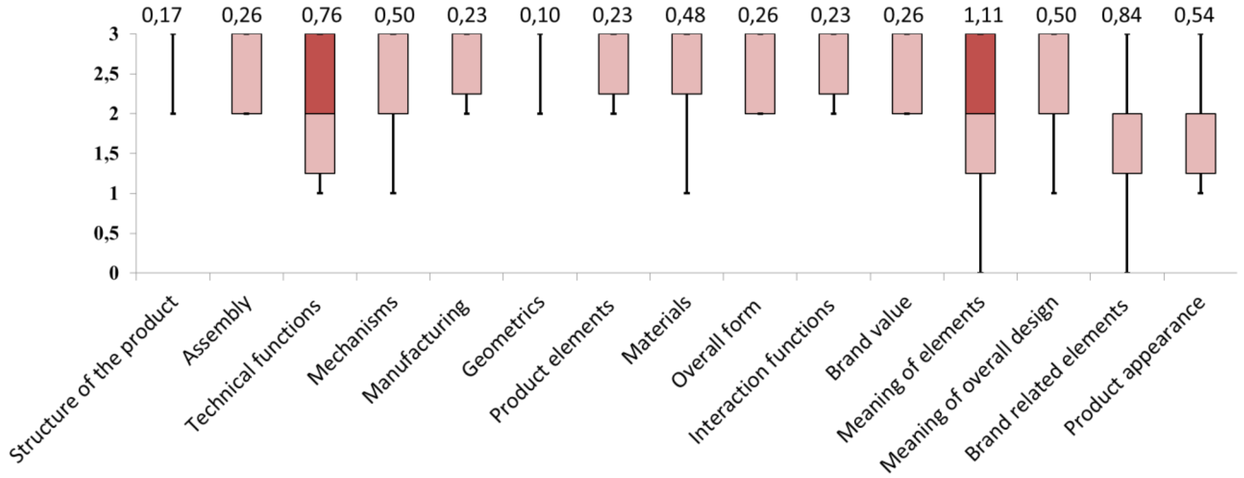



Figure 4-12: **Distribution of data related to the awareness matrix for product designers**

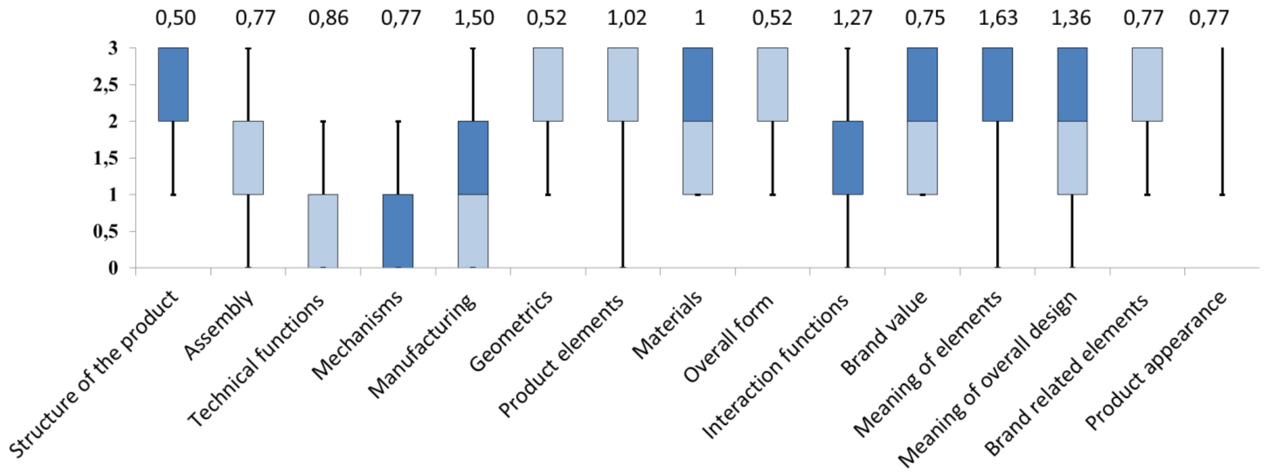



Figure 4-13: **Distribution of data related to the awareness matrix for engineering designers**

For product designers three higher variances are for “meaning of elements”, “brand related elements” and “technical functions”. The lower variances are for “geometrics”, “structure of the elements” and “interaction functions”.

For engineering designers three higher variances are for “meaning of elements”, “manufacturing” and “meaning of overall design”. The lower variances are for “structure of elements”, “geometrics” and “overall form”.

As the diagrams show, the highest variance occurred for “meaning of elements” for both groups. This indicates that the levels of importance given are relatively highly spread out from the average and from each other. The average of the importance level given to the communication of “meaning of elements” for both groups were medium (i.e. equal 2). From this we concluded that although the average importance level shows that they are rather aware of the importance on communicating the “meaning of elements” that is the Kansei, the opinions are diverse.

The same logic applies for communication of “brand related elements” (with the average of 2.5 and variance of 0.84) among product designers, and the “meaning of overall design” (with the average of 2 and variance of 1.36) among engineering designers. It cannot be concluded that they are not aware of the importance of this communication, but there is a considerable variety of opinions on the subject.

Figure 4-14 shows the average level of importance that the product designers and engineering designer gave to communication of each information type (the average responses from awareness matrix). For the majority of information the importance was more than medium.

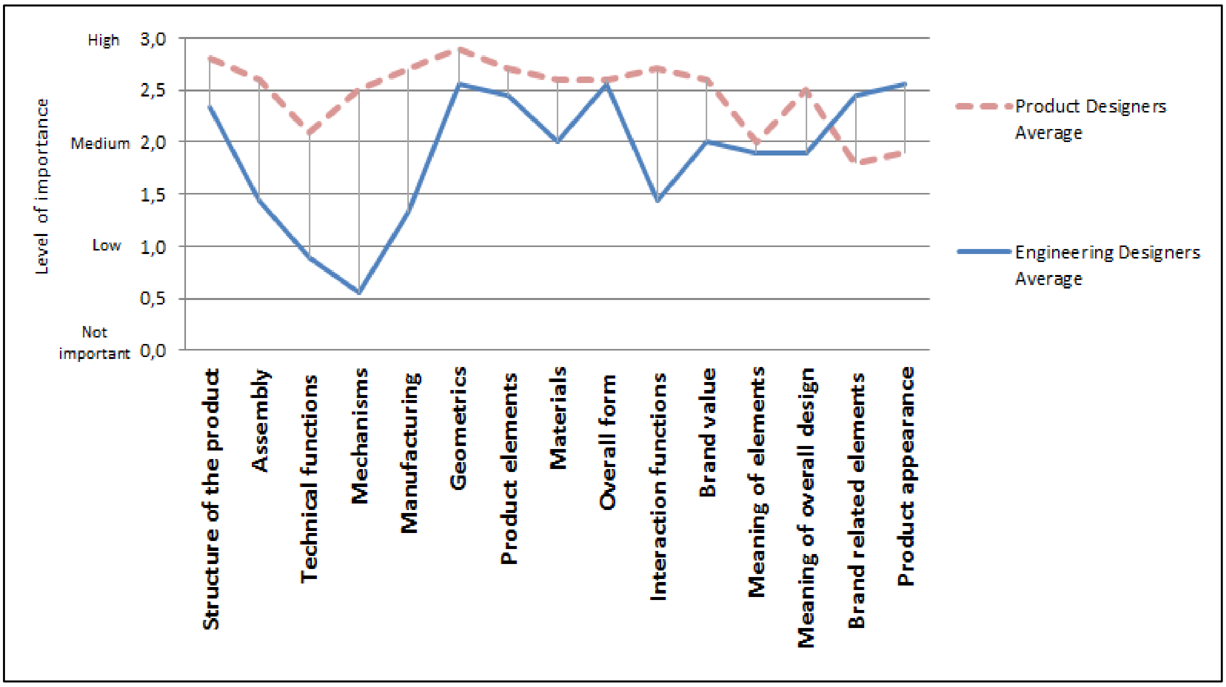



Figure 4-14: **Average level of importance accorded to each information to be exchanged**

As it is illustrated in Figure 4-14, the blue curve that is the average of engineering designers answers to the awareness matrix, is below the pink curve (average answers of product designers) for the engineering information (typically manufacturing, mechanisms, technical function and assembly).

We qualitatively interpret that the engineering designers gave less importance to the engineering information being communicated. In the audio records some of the engineering designers explained that they considered the engineering information as a part of the engineering job and that the product designers did not need to have such information. However product designers seemed to be interested in the engineering information as they gave relatively high importance to such information. Conversely, product designers gave less importance to the communication of information about the product appearance (how the product looks) and the brand related elements (the components and features that are used as a reference to the brand) while engineering designers gave this a more than medium score. A general comment from product designers was that communicating too much information causes confusion especially about subjective concepts. This could be a reason for why the communication of information about the "meaning of elements" was scored less important than the meaning of overall design.

From interviewing 20 product designers and engineering designers, our general understanding is that product designers and engineering designers that had collaborated for a long time in the company were used to each others' ways of working and seemed to have less communication problems. The company culture also was very important to make people communicate easily. For example for design agencies, where product designers were working on different projects and collaborated with different brand companies, the communication problems seemed to be more severe.

#### 4.7.2.2 Results of design representation matrix

The results of the "use of design representation for brand and Kansei communication" questions are summarized in Figure 4-15. For each of the questions related to "product appearance", "brand value", "meaning of elements", "brand related elements" and "meaning of overall design", the numbers in Figure 4-15, represent the average degree of effectiveness accorded by product designers and engineering designers to the product representation. The bar charts in the same Figure provide a better visualization of the numbers.

Based on the results shown in Figure 4-15, the opinion of engineering designers is that the 3D models (either physical or digital) are more efficient for communicating product appearance, brand value, meaning (Kansei) of elements, brand related elements and the meaning of overall design (Kansei of overall design).

Product designers considers that sketches, drawing or 3D models can communicate information about product appearance, but they have the tendency to employ other solutions in addition to product representations for the communication of brand value, brand related elements, meaning of elements and the overall meaning. The other solutions they mentioned are mainly verbal explanations and PowerPoint presentations. They also mentioned the use of mood boards, material and texture samples and in some cases descriptive documents and informal exchanges during the meeting and after the meeting by means of emails or phone calls.

During the interviews the respondents often commented on the use of each product representation according to the stage of the design process (sketches and drawing are used earlier in the design process and as the process progress, 3D models and prototypes appear). According to engineering designers the 3D models were the most efficient way of communicating the product appearance (e.g. looking modern, looking feminine). But this still remains subjective and interpretable in many ways. All respondents argued that the 3D models appear later in the design process and if the model is not meeting the design intention, this results in iterations.

Another point that we noticed during the interviews from the respondents' general comments, was that while the current product representations communicate the design concept, they do not communicate the relations between the initial intent (in terms of Kansei concepts or brand values) and the physical properties (shape, color, material).

Product designers add verbal explanations to the product representation, but they are not always available for oral description (e.g. when communication happens via intermediaries and not product designers themselves). Even when the product designers are available for explanations, some of the information could be lost if it is not formalized.

| | | Sketches | Drawings | 3D Models | Prototypes | Other solutions |
|---|---|---|---|---|---|---|
| Product appearance | Designer | 1,9 | 2,0 | 1,7 | 1,0 | 0,7 |
| | Engineer | 2,1 | 1,2 | 2,8 | 0,7 | 0,0 |
| Brand value | Designer | 1,3 | 1,6 | 1,3 | 1,0 | 1,7 |
| | Engineer | 0,4 | 0,6 | 1,8 | 0,2 | 1,0 |
| Meaning of elements | Designer | 0,8 | 0,8 | 1,6 | 1,2 | 2,0 |
| | Engineer | 1,0 | 0,8 | 1,7 | 0,8 | 0,7 |
| Brand related elements | Designer | 1,4 | 1,6 | 0,6 | 0,7 | 2,0 |
| | Engineer | 0,6 | 0,6 | 1,4 | 0,3 | 0,4 |
| Meaning of overall design | Designer | 1,1 | 1,1 | 1,0 | 0,3 | 1,3 |
| | Engineer | 1,2 | 0,4 | 1,2 | 0,2 | 0,3 |

Figure 4-15: **Use and efficiency of product representations for the communication**

#### 4.7.2.3 Summary of problem evaluation results

In answer to the question of whether product designers and engineering designers are aware of the importance of communicating information related to brand and Kansei concepts to each other, from the results it seems that they are relatively aware although they have diverse opinions.

On the other hand product designers use verbal explanation or other solutions that do not enable the formalization and keeping a trace the information related to brand and Kansei aspect of the product.

The results of the problem evaluation interviews confirm our initial finding from the in-depth interviews (in two French companies) that the actual product representations that are exchanged between product designers and engineering designers do not support the communication of brand values and Kansei concepts and there is a need for a tool that assists this communication by formalizing what is communicated in an informal way. In the following section we explain the requirements for such a support tool, following by proposition of three optional tools.

## 4.8 Requirements for support tools

From our study, the first requirement is that a support tool should permit the communication of brand values and Kansei concepts through expressing this information explicitly. Links between brand values and the Kansei concepts and the product properties needs to be visualized.

In previous Chapters (Chapter 3 and 1) we explained that some product elements (and their physical properties) have an important impact on the global image (and intended emotional responses) of the product. Therefore some physical properties are more important than others because they are specified to embody the Kansei concepts or brand values that are more important to be communicated to consumers than other Kansei or brand concepts. To communicate the design rationale behind the choices and the level of importance, the tool should be able to communicate the priorities of some brand and Kansei concepts over others. This includes prioritizing properties of product elements and the Brand or Kansei concepts related to these elements.

The tool should also communicate whether a design element is flexible and could be changed or should be kept untouched and therefore is inflexible to engineering changes. So the tool should indicate the degree of flexibility to technical changes.

The tool should also permit to visualize if a property of an element (i.e. texture, colour, material) is going to be changed, which emotional perception would be touched, i.e. trace the effect of a change in a design element and property on the meaning and appearance of the product.

As a summary the tool should permit:

- Explicit expression of brand value and Kansei concepts
- Linking between Kansei concepts or brand values and product elements
- Kansei-Kansei prioritizing
- Prioritizing properties of the elements
- Indicate the degree of flexibility
- Trace the effects of changes

Table 4-12 displays a summary of the requirements for a support tool and reports how the requirements would be helpful to reduce the difficulties related to brand and Kansei communication between product designers and engineering designers (that we have identified from the primary in-depth interviews).

| | | Requirement from support tool | | | | | |
|---|---|---|---|---|---|---|---|
| | | **Explicit brand value and Kansei** | **Kansei-Element linking** | **Kansei-Kansei prioritizing** | **Prioritizing properties of the element** | **Flexibility degree** | **Effect of changes** |
| Identified difficulties from interviews | Misunderstanding of design representation | Provides complementary information | Provides information about rational behind the choices , helps better understanding of representations | _ | _ | _ | _ |
| | Long loops of iteration | _ | _ | Creates better understanding and help the decision making about the tradeoffs _ | Creates better understanding and help the decision making about the tradeoffs | Creates better understanding and help the decision making about the tradeoffs | Facilitates understanding and helps to reduce the iterations |
| | No shared understanding of brand | Makes brand more accessible by providing information about Kansei aspect of brand | Provides information about rational behind the choices related to brand | Helps to understand which meaning or brand value is more important to be embedded | _ | _ | _ |
| | Expertise of intermediary | Prevents the information distortion as it is passed through intermediary people | Provides argument around the element from product designers' point of view | Helps to protect the prioritized Kansei concepts | Helps to protect the prioritized elements | _ | Provides information about rational behind the choices |
| | Engineering changes and choices of manufacturing process | _ | Provides information on the result of a change on the look of product | Gives more flexibility for the choice of process , permits the integration of engineering view point | Facilitate decision making related to process selection | Reduce undesired changes from the design point of view | Reduce undesired changes from the design point of view |

Table 4-12: **A summary of the requirements for a support tool to reduce the identified difficulties related to brand and Kansei communication between product designers and engineering designers**

## 4.9 Development of three potential tools

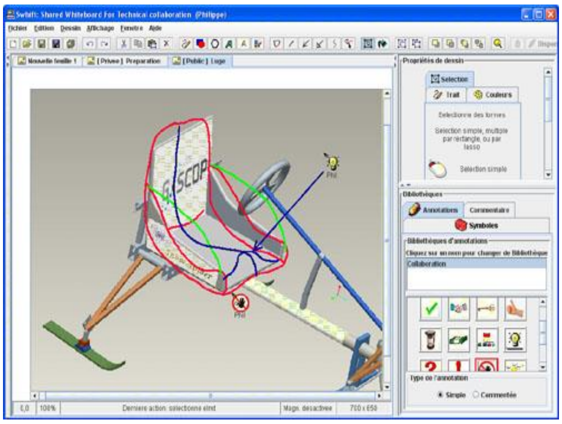
In order to find appropriate candidates, we conducted a literature review about tools that are used to communicate or formalize relationships between product elements description and information expressed in a literal format. According to the literature product linkage or connectivity models are good ways to highlight the relationship between elements (Keller et al., 2006b). Such a model captures the different interactions between characteristics and parts of the product. The relational data or graph structures that are the basis for the connectivity models can be represented in different ways. Most common are matrix-based and network-based visualisations (Keller et al., 2006b), which are isomorphic. Matrix-based approaches include diagrams such as QFD (quality function deployment) and MDM (Multiple Domain Matrix) that are popular in engineering design domain. Network-based diagrams include for example tree diagrams of product decomposition and FAST (functional analysis system technique) in engineering domain and social friend networks, transport station maps (e.g. RATP maps) and so on outside of the engineering domain. Because they seem to be more adapted to our issues, we decided to work on MDM (Multiple Domain Matrix) from the matrix-based approaches and word mapping (or concept mapping) from network-based approaches.

On the other hand annotation approach that has been the subject of research for long time in G-SCOP laboratory (see for example Boujut, 2003; Hisarciklilar & Boujut, 2009; Prudhomme, Marin, & Masclet, n.d., 2010) seem to be a promising way to support the communication of brand values and Kansei concepts. Designers are familiar with drawings and digital 3D models and might naturally use annotation as a way of showing some information about a particular part of the product. Engineering designers are more used to work with abstract representations than product designers.

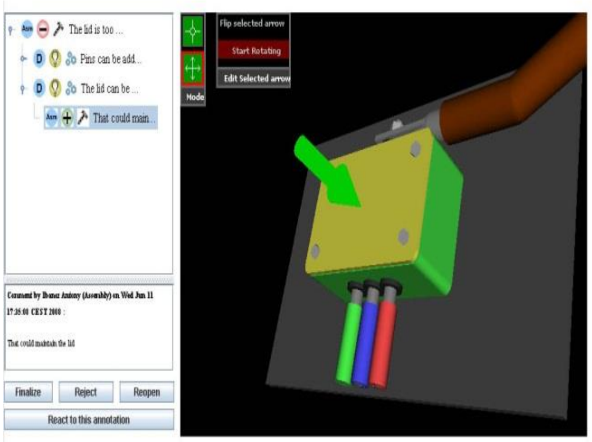
The following section includes a brief literature review on annotation, MDM and word mapping, which are our three selected candidates.

### 4.9.1 Annotation

Annotation is a natural way of adding information to a specific representation. It contains text information linked to a part of 2D or 3D representation by an anchor. In previous studies annotations have been identified as a good way of structuring informal information, facilitating negotiations in a design process, and creating shared references (J.-F. Boujut, 2003). Annotation is also an appropriate way to foster unambiguous asynchronous communication through graphical representations (Hisarciklilar & Boujut, 2009). In the conceptual design stage product designs are generally represented by sets of sketches in which the use of colors, shadows and curves to represent ideas. Annotations can be used to make the design intent that should be incorporated into final product concrete. The approach could be extended to later product development phases. After creating the 3D models or the drawings, the product designers can clarify the main information about the brand and Kansei aspect of the product by putting in annotations. Annotations will attract the attention of the engineering designers and act as a pointer that helps them to understand which properties must remain unchanged or can be modified. The engineering designers also can annotate the parts to exchange the information about manufacturing and engineering constraints with product designers. Therefore annotations are good candidates that allow the communication and negotiation of design and engineering constraints between product designers and engineering designers. Product designers and engineering designers can build these annotations collaboratively and keep the track of their common decisions for further activities in the design process. Tools like Swhift (Swhift Project, n.d.; Vu-Thi, Marin, & Noel, 2010 Prudhomme et al., 2010) and Annot'Action (AnnotAction, n.d.; Hisarciklilar & Boujut, 2009) that have been developed to facilitate the collaboration using annotation can be adapted according to the requirements and be used for the communication of brand and Kansei concepts between product designers and engineering designers.



(a)



(b)

Figure 4-16: **(a) Annotation made by Swhift tool, (b) Annotation made by Annot'Action tool**

### 4.9.2 Multiple-Domain Matrix (MDM)

MDM is one of the DSM (Design Structure Matrix / Design Structure Mapping) matrices (Maurer, 2007). The following mappings are used to analyze and manage complex systems, because they model, visualize and analyze the dependencies between entities (Browning, 2001):

- DSM (Design Structure Matrix) (Eppinger & Browning, 2012; Steward, 1981) is the basic matrix which is used to relate entities of the same kind to each other (e.g. tasks that make up a project or components of a product, see Figure 4-17(a)) and are therefore square.
- DMM (Domain Mapping Matrix) can be used to establish a mapping between two different kinds of elements of a system (e.g. tasks to persons or functions to the components, see Figure 4-17(b)).
- MDM (Multiple-Domain Matrix) (Maurer, 2007) combines multiple DSMs and DMMs into a complete system model (Figure 4-17 (c)) into a large aggregate DSM. Kortler et al. (2010) explain how the ongoing refinement of requirements and the design of the properties of the future product can be tackled through an MDM.

| | Task 1 | Task 2 | Task 3 | Task 4 | Task 5 | Task 6 |
|---|---|---|---|---|---|---|
| Task 1 | | X | | | X | |
| Task 2 | | | X | X | | |
| Task 3 | X | | | X | | |
| Task 4 | | | | | | X |
| Task 5 | | | | X | | |
| Task 6 | | | | | | |

(a)

| | Task 1 | Task 2 | Task 3 | Task 4 | Task 5 | Task 6 |
|---|---|---|---|---|---|---|
| Person 1 | X | | | | X | |
| Person 2 | | X | | | | |
| Person 3 | | | X | | | X |

(b)

| | Task 1 | Task 2 | Task 3 | Task 4 | Task 5 | Task 6 | Person1 | Person 2 | Person 3 |
|---|---|---|---|---|---|---|---|---|---|
| Task 1 | | X | | | X | | | | |
| Task 2 | | | X | X | | | | | |
| Task 3 | X | | | X | | | | | |
| Task 4 | | | | | | X | | | |
| Task 5 | | | | X | | | | | |
| Task 6 | | | | | | | | | |
| Person 1 | X | | | | X | | | X | X |
| Person 2 | | X | | | | | | | |
| Person 3 | | | X | | | X | | | |

(c)

Figure 4-17: **(a) Design Structure Matrix (DSM), (b) Domain Mapping Matrix, (c) Multiple Domain Matrix**

The crosses in the matrix mean that there is a link between an entity in the column of the matrix and an entity in the row. However, the directional influence is not inherent in the matrix. How it should be read and the definition of the link varies among different research communities. It could be read from row to column or vice versa from column to row. Typically elements in such a matrix can be ordered is some particular way, for instance alphabetical order. The ordering makes particular relations salient or at least immediately understandable to the users (Keller et al., 2006a).

Tools like DSMs could be used to map links between Kansei concepts and product elements from the product designers' point of view, and between the product elements and engineering parameters (e.g. technical solution, manufacturing process) from engineering designers' point of view. The links could be made collaboratively by product designers and engineering designers. In this way the impact of changes to product elements can be visualized trough traceable links, and clusters and mutual influences can be identified (Clarkson et al., 2004). MDM can be built using the CAM (Cambridge Advanced Modeller, see (CAM, n.d.) shown in Figure 4-18 or (Loomeo, n.d.) to map the Kansei and brand domains to the product and process domains.

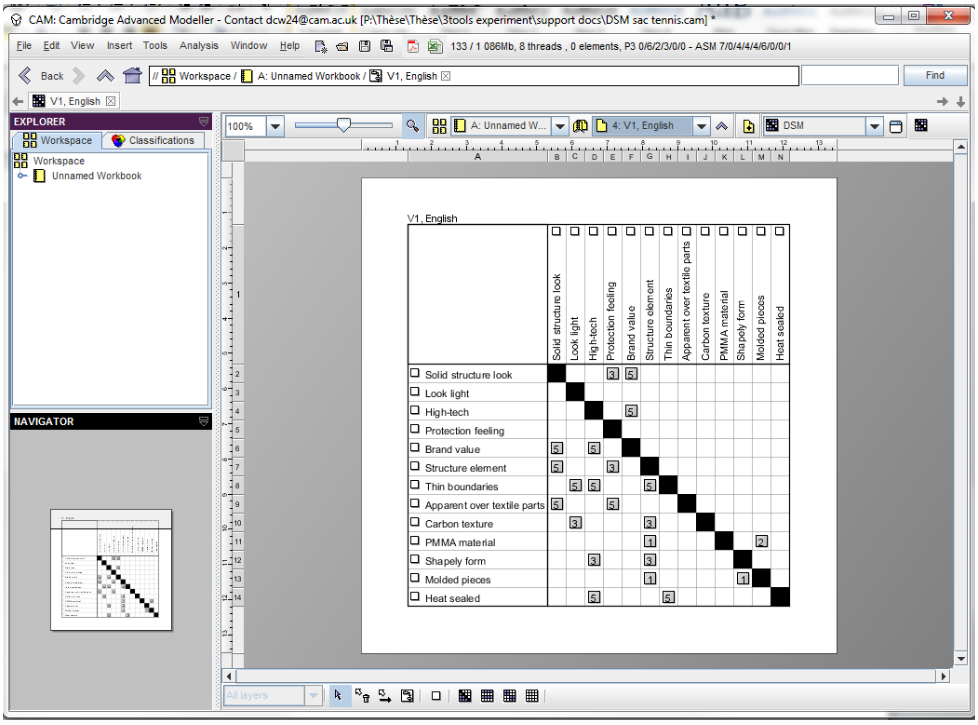



Figure 4-18: **Screenshot of CAM tool, building MDM diagram**

Such matrix needs improvements to meet the requirements and to be used in the design process as means to enable communication between product designers and engineering designers.

### 4.9.3 Word mapping

Word mapping is a diagram used to visualize ideas, definitions or actions around a central topic or concept. It helps to organize information in ways that highlight interrelationships between key entities. Graphs (Herman et al., 2000), Networks (Keller et al., 2006a) , Node-link or Node-edge (Keller et al., 2006b), Concept maps (Novak & Cañas, 2006) are all referring to the same concept as word mapping.

Concept mapping have been addressed by the works of Novak since 1970 in the studies about children's conceptual understanding  (Novak & Cañas, 2006). According to Novak concept maps could help students learn how to learn, but also in other contexts concept maps help to capture explicit knowledge held by experts, assist in design of complex systems and facilitate creative work and idea generation (Novak, 2010).

Word mapping essentially is comprised of nodes and arcs (or arrows). Each node represents a concept that is labeled by a word. Therefore word mapping is a graphical display of structural semantic interrelations that encode simplified sentences.

Word mapping diagrams help to summarize understanding and makes the relationships between concepts clear. Product designers and engineering designers can work together using word mapping diagrams to “brainstorm” problems and ideas. Relation between Kansei and brand concepts, between Kansei and product elements and between two product elements can be easily established to share a clear articulation of the design in a word mapping diagram.

Tools such as CmapTools, Mind Maps and X Mind are useful in the creation of word mapping diagrams. Figure 4-19 shows an example of word mapping diagram by CmapTools software (Novak, 2010). To act as a communication tool in the design process, word mapping can be supplemented by sketches, 3D models or drawing.

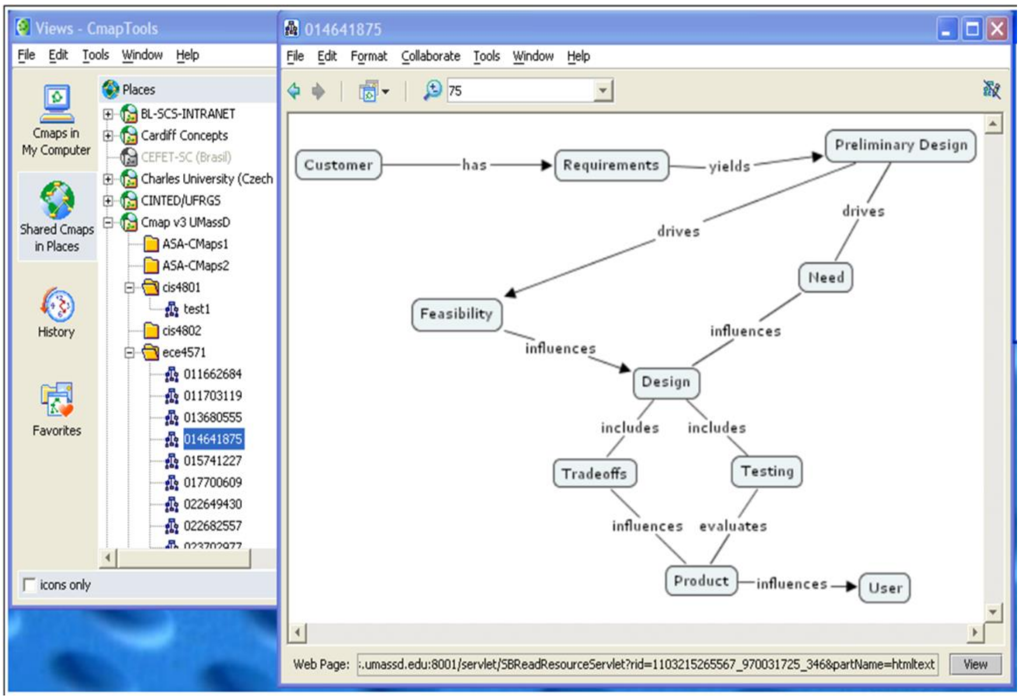



Figure 4-19: **CmapTools screenshot, retrieved from: http://datalab.cs.pdx.edu/sidewalk/pub/survey.of.concept.maps/**

## 4.10 Proposition and adaptation

We propose the use of annotation, MDM and word mapping diagrams as tools to formalize the communication of brand values and Kansei concepts between product designers and engineering designers during the design process. Each of the three tools can enable the explicit expression of Kansei concepts and brand values through the words (the first specified requirement) and can communicate relationships between Kansei concepts, brand values and product elements effectively (second requirement).

The main difference lies on the visualization of information and links. In order to adapt these tools to the specified requirements, and to assure that the same information is represented in each of the diagrams, three main adaptations were proposed:

1) Distinction of the type of information
Three types of information are represented in the diagrams; emotive information including brand values and Kansei concepts (for the purpose of tools we put Kansei and brand values in the same category), information about the product properties, information about industrial process (see Table 4-13). The distinction among these three types of information has the objective of making the exploration easier.

| | |
|---|---|
| Kansei & Brand | Information about the brand , brand value, meaning of elements , product's perception and look , feeling |
| Product | Structure, material, texture , product elements , mechanisms , functions |
| Process | Assembly process, manufacturing process |

Table 4-13: **Information related to Kansei & brand, Product, Process categories**

2) Distinction of the orientation of the links
Considering the orientation helps to better understand the relationships between two concepts. Whether a concept affects other concepts or is affected by other concepts can be assessed by distinction of the orientation of the links.

3) Highlighting the level of importance
Considering a level of importance for the relationships provides an understanding of the priorities between Kansei concepts (third requirement), or product elements (fourth requirement) and the degree of flexibility to technical changes in the product (fifth requirement).

The last requirement (trace the effects of changes) can be met through the whole links.

Table 4-14 summarizes how these three adaptations are fulfilled for each visualisation. In each diagram colours are used to distinguish different types of information (Blue: Information related to perception, emotions and brand, Green: Information related to the product properties, Orange: Information related to manufacturing processes). The use of numbers helps to determine the level of flexibility and susceptibility to engineering modifications, from 1 (least important) to 5 (most important).

| Adaptations | Annotation | MDM | Word Mapping |
|---|---|---|---|
| 1. Distinction of the information type | Use of different colors for the words related to each information type | Use of a color bar and ordering information (First Kansei, second product, third process) | Use of different colors for the words related to each information type |
| 2. Distinction of the orientation of the links | Use of a sentence to explain the orientation of the link | The matrix reading cross the lines or cross the columns | The orientation of the arrow |
| 3. Highlighting the level of importance | Use of numbers on the linking lines | Use of numbers in the matrix | Use of numbers on the arrows |

Table 4-14: **A summary of the adaptation of annotation, MDM and word mapping**

Annotation provides direct linking between the information and the concerned element on a graphical representation of a product. Word mapping and MDM provide rather an abstract and less concrete information compared to annotation. We propose to combine the use of a graphical representation of the product (sketches or drawing) to the word mapping and MDM, even if the direct linking to the representation would still be missed. Figure 4-20 shows, the application of the annotation, word mapping and MDM on the example of the tennis bag. The application is explained in next section.

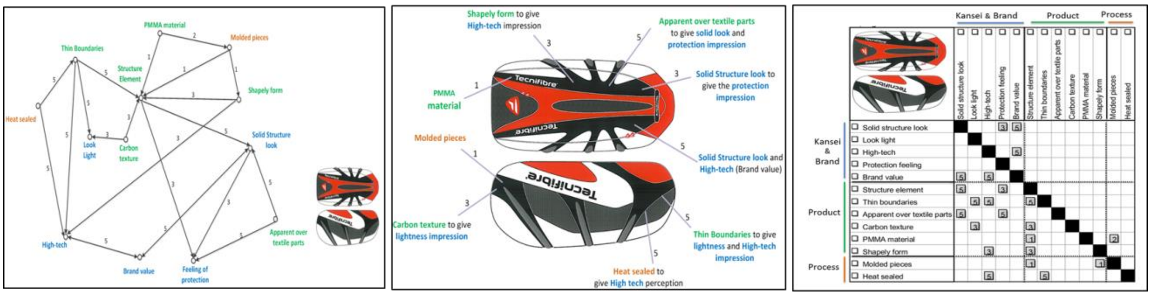



Figure 4-20: **Examples of Word mapping (left), Annotation (middle) and Multiple-Domain Matrix (right)**

## 4.11 Application

To apply annotation, MDM and word mapping diagrams for the example of the tennis bag, we used the audio records of the primary in-depth interviews in Diedre Design. We based our work on the verbal comments of the product designers and the project manager on the bag prototype, the emotive intentions and their links to the physical properties and the reasons the prototype failed to elicit the intended emotion. For example one of the product designer referred to the thickness of the boundaries for the structure element and said “it looks heavy, we wanted something light” and later he said “like they took a plastic sheet and cut the edges, everybody [other competitors] can do that, it doesn’t look high-tech at all … it was supposed to be heat sealed”. From the comments we concluded that thin boundaries were specified to give lightness and high-tech impression and the intention of choosing heat sealed process was to give high-tech perception. We categorized “high-tech and lightness impressions” as brand and Kansei information, “thin boundaries” as product properties information, and “heat sealing” as process information.

To define the level of importance for the relationships, based on our general understanding of the verbal comments and the emphasis of product designers or the project manager on some of the concepts, for each relation we accorded an importance level from 1 to 5. Because of the non-availability of the design team members in industry, we could not confirm the relationships and the accorded importance levels with the designers. However the application of annotation, word mapping and MDM on the tennis bag based on this information (even if not validated) shows the feasibility of building such representations.

Figure 4-21 shows the annotation diagram for the tennis bag designed for Tecnifibre. The PMMA material of the structure element is more flexible to be changed to another material (level 1) than the carbon texture of the panels (level 3). The annotation presented in this thesis is relatively simple and is created using Visio software. The arcs show the reference point and the orientation of links is implicit in the text. For example carbon texture is the root element that contributes to lightness impression and this is implicit in “Carbon texture to give lightness impression”.

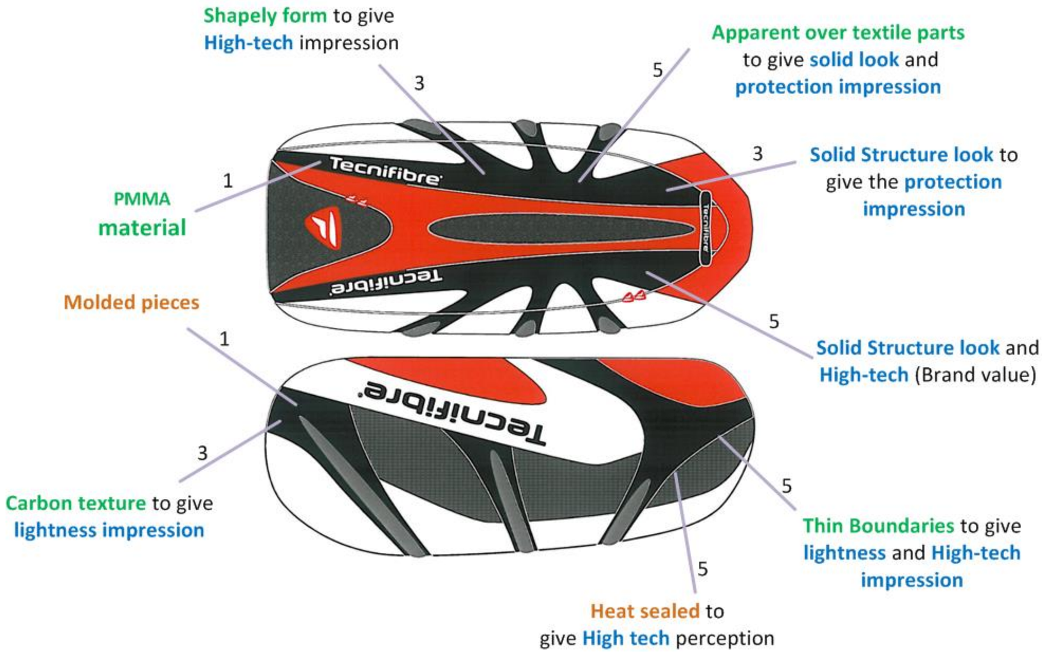



Figure 4-21: **Annotation diagram for example of the tennis bag**

The MDM diagram built for the example of the tennis bag is shown in Figure 4-22. The matrix is built using the CAM software. Reading across a row, the entity of the row contributes to realize entities of columns (Figure 4-22). For example, the solid structure look contributes to realize "feeling of protection" and "brand value". Reading across a column, the entity is realized through other entities. For example the solid structure look is realized because of the "structure element" and also because the structure element is "apparent outside and over textile parts" of the bag. These kinds of matrices can provide complementary information to other representations and result in better communication between product designers and engineering designers.

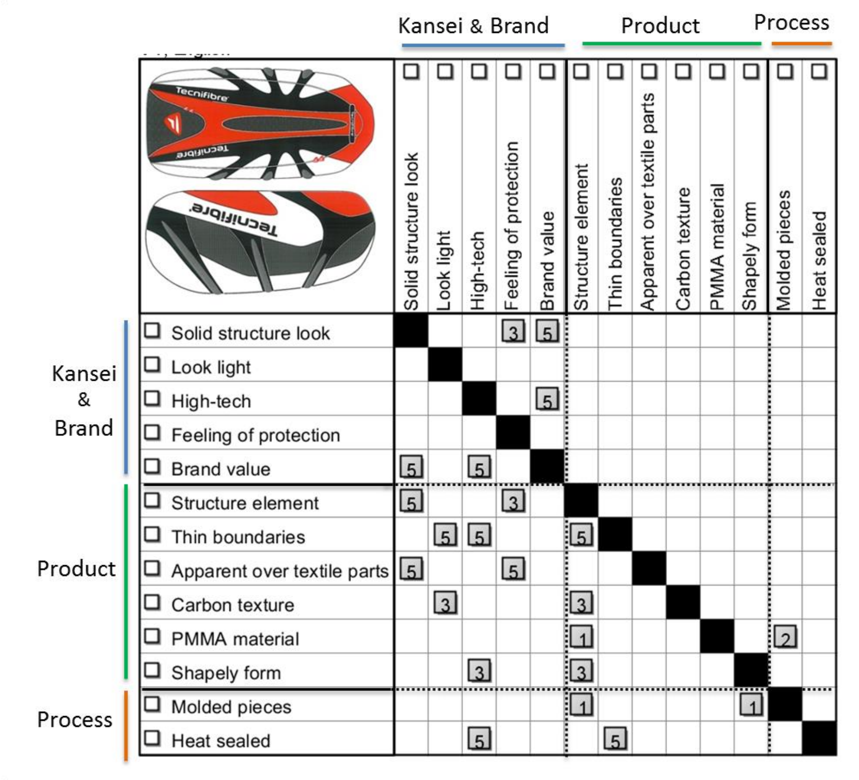



Figure 4-22: **MDM diagram used to map Kansei and brand domain to product and process domain, for the example of the structure element in the tennis bag**

The word mapping diagram is shown in Figure 4-23. The direction of the arrows means that the initial element contributes to achieve the target element (for example: "the solid structure look" contributes to the "feeling of protection").The diagram was also created using Visio software.

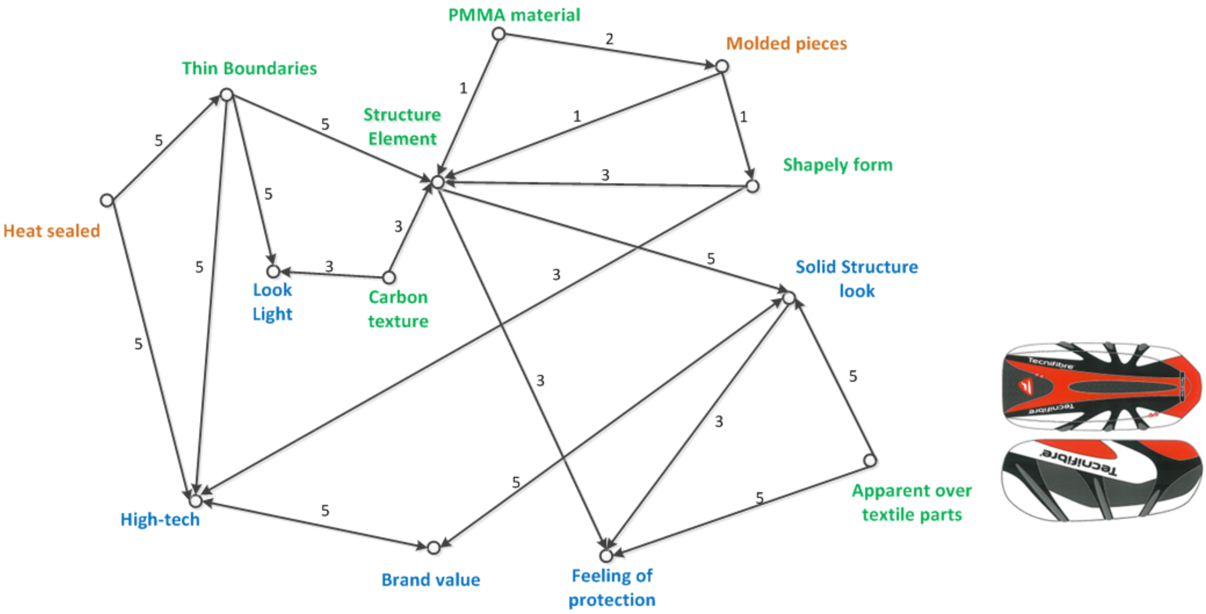



Figure 4-23: **Word mapping diagram for the example of the structure element in the tennis bag**

## 4.12 Relative merits and limitations

Matrix-based approaches (especially MDM) are more popular in the engineering community, where it has various applications such as process modeling or change prediction. Word Mapping (named also as node-link diagrams or networks) is a more generic approach with several applications outside of the design and engineering community. Each of the potential approaches has some advantages and limitations. Each of them makes different aspects of the same data set salient. Annotation is a good way to highlight a small number of points, but if there is too much information it gets confusing and overpowering. For word mapping the number of possible layouts is very large. An extensive collection of layout algorithms for graphs can be found in (Battista et al., 1994). The large variety of different layouts allows the viewer to focus on different aspects of the information and the graph could be personalized according to user's preferences. However the large number of layouts can give room for ambiguity (Keller et al., 2006b). Furthermore the problem of crossing-edges and overlapping nodes can be very severe especially for large graphs with many nodes (Keller et al., 2006a). Matrices and graphs are isomorphic that means containing the same information, a MDM matrix can be easily transformed to a word mapping graph and vice versa. Several studies have already been carried out in order to reveal differences between word mapping and matrix based representations in terms of readability (Ghoniem et al., 2005; Keller et al., 2006a). Considering matrix and word mapping as two different representations of the same underlying graph, word mapping diagrams are better suited for reading information from small and spars graphs. For most of the tasks on large and dense graphs, participants were faster and more accurate using the matrix representation rather than word mapping. The results were the same for both semantic (Keller et al., 2006a) and non-semantic comparison (Ghoniem et al., 2005). Keller et al. (2006b) concluded that depending on the model and even on personal preference, either matrix-based or network based representation can be advantageous.

To study the acceptability of annotation, word mapping and MDM among product designers, engineering designers and academics we conducted a series of tool evaluation interviews.

## 4.13 Tool evaluation interviews

The second part of the evaluation interviews consisted of evaluation of annotation, MDM and word mapping by the same respondent (who participated in problem evaluation interviews). In addition to that we asked 10 academics to participate in the tool evaluation interviews. The structure of the tool evaluation interview is illustrated in Figure 4-24.

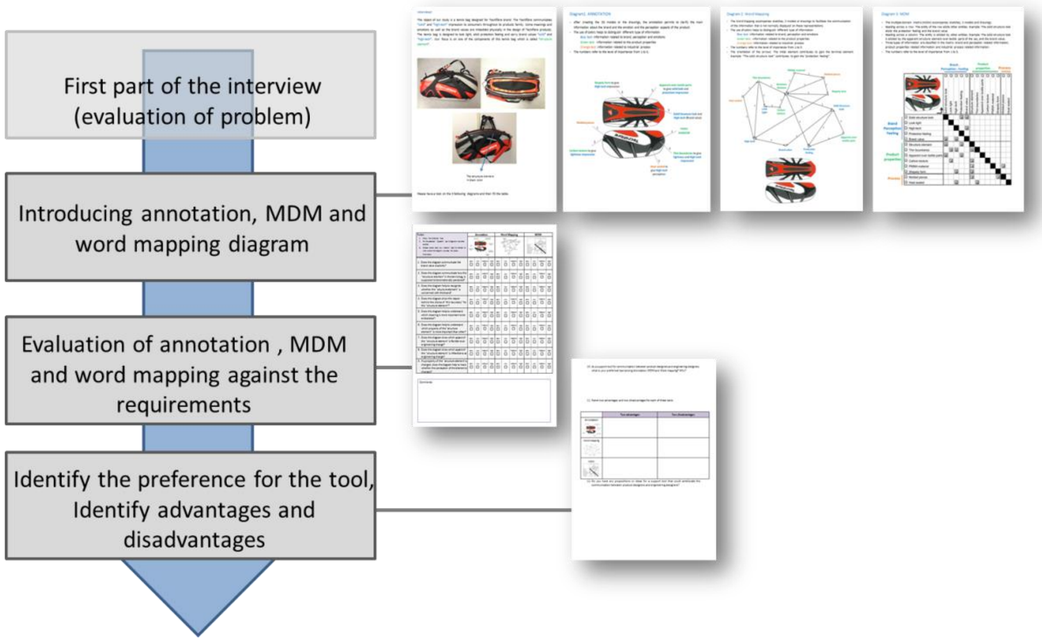



Figure 4-24: **The structure of evaluation interviews, second part; evaluation of the three tools**

In the primary pages the example of the tennis bag as well as the three diagrams were introduced to the interviewees. Then the interviewees answered 9 questions (Figure 4-25) to evaluate annotation, MDM and word mapping against the identified requirements (see requirements for a support tool section). For each diagram they assigned a level of suitability (zero, low, medium, high). The Table 4-15 shows the related questions for each identified requirement.

| Requirement | Related question |
|---|---|
| Explicit brand value | Q1. Does the diagram communicate the brand value explicitly? |
| Explicit Kansei concepts | Q2. Does the diagram communicate how the “structure element” in the tennis bag, is supposed to be emotionally perceived? |
| Brand-Element linking | Q3. Does the diagram help to recognize whether the "structure element" is concerned with the brand? |
| Kansei-Element linking | Q4. Does the diagram show the reason behind the choice of “thin boundary" for the "structure element”? |
| Kansei-Kansei prioritizing | Q5. Does the diagram help to understand which meaning is more important to be embedded? |
| Prioritizing properties of the element | Q6. Does the diagram help to understand which property of the "structure element" is more important than other? |
| Flexibility degree | Q7. Does the diagram show which aspect of the "structure element" is flexible to an engineering change? |
| | Q8. Does the diagram show which aspect of the "structure element" is inflexible to an engineering change? |
| Trace the effect of changes | Q9. If a property of the "structure element" is changed, does the diagram help to trace whether the perception of the element is changed? |

Table 4-15: **Related questions for each identified requirement**

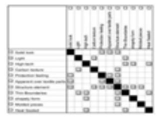
| Rules:<br>1. Follow the horizontal lines.<br>2. For the selected "Question" use 3 diagrams one after another<br>3. Choose a level (zero, low, medium, high) to indicate to what extend the diagram provides the asked information. | Annotation<br> | | | | Word Mapping<br> | | | | MDM<br> | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Does the diagram communicate the brand value explicitly? | zero ☐ | Low ☐ | Medium ☐ | High ☐ | zero ☐ | Low ☐ | Medium ☐ | High ☐ | zero ☐ | Low ☐ | Medium ☐ | High ☐ |
| 2. Does the diagram communicate how the "structure element" in the tennis bag, is supposed to be emotionally perceived? | zero ☐ | Low ☐ | Medium ☐ | High ☐ | zero ☐ | Low ☐ | Medium ☐ | High ☐ | zero ☐ | Low ☐ | Medium ☐ | High ☐ |
| 3. Does the diagram help to recognize whether the "structure element" is concerned with the brand? | zero ☐ | Low ☐ | Medium ☐ | High ☐ | zero ☐ | Low ☐ | Medium ☐ | High ☐ | zero ☐ | Low ☐ | Medium ☐ | High ☐ |
| 4. Does the diagram show the reason behind the choice of "thin boundary" for the "structure element"? | zero ☐ | Low ☐ | Medium ☐ | High ☐ | zero ☐ | Low ☐ | Medium ☐ | High ☐ | zero ☐ | Low ☐ | Medium ☐ | High ☐ |
| 5. Does the diagram help to understand which meaning is more important to be embedded? | zero ☐ | Low ☐ | Medium ☐ | High ☐ | zero ☐ | Low ☐ | Medium ☐ | High ☐ | zero ☐ | Low ☐ | Medium ☐ | High ☐ |
| 6. Does the diagram help to understand which property of the "structure element" is more important than other? | zero ☐ | Low ☐ | Medium ☐ | High ☐ | zero ☐ | Low ☐ | Medium ☐ | High ☐ | zero ☐ | Low ☐ | Medium ☐ | High ☐ |
| 7. Does the diagram show which aspect of the "structure element" is flexible to an engineering change? | zero ☐ | Low ☐ | Medium ☐ | High ☐ | zero ☐ | Low ☐ | Medium ☐ | High ☐ | zero ☐ | Low ☐ | Medium ☐ | High ☐ |
| 8. Does the diagram show which aspect of the "structure element" is inflexible to an engineering change? | zero ☐ | Low ☐ | Medium ☐ | High ☐ | zero ☐ | Low ☐ | Medium ☐ | High ☐ | zero ☐ | Low ☐ | Medium ☐ | High ☐ |
| 9. If a property of the "structure element" is changed, does the diagram help to trace whether the perception of the element is changed? | zero ☐ | Low ☐ | Medium ☐ | High ☐ | zero ☐ | Low ☐ | Medium ☐ | High ☐ | zero ☐ | Low ☐ | Medium ☐ | High ☐ |

Figure 4-25: **Questions for the evaluation of the three tools**

On the last page the respondent précised the diagram they preferred the most with an explanation of reasons. Then they were asked to write down two advantages and disadvantages for each of the diagrams, and finally make other propositions for support tool.

### 4.13.1 Results of tool evaluation

A total of 30 people (10 product designers, 10 engineering designers and 10 academics) evaluated annotation, MDM and word mapping against the identified requirement for a support tool. Table 4-16 shows the collected data for product designers. Likewise two other Tables for engineering designers and academics are established (that are excluded from this report). The results of the interviews for product designers, engineering designers and academics are shown in bar charts (Figure 4-26 and 4-27) for visual comparisons.

| | | Product Designers | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **PD1** | **PD2** | **PD3** | **PD4** | **PD5** | **PD6** | **PD7** | **PD8** | **PD9** | **PD10** | **Avr** |
| Explicit brand value | Annotation | 3,00 | 1,00 | 3,00 | 3,00 | 2,00 | 2,00 | 3,00 | 3,00 | 3,00 | 3,00 | 2,60 |
| | Word Mapping | 1,00 | 1,00 | 1,00 | 3,00 | 2,00 | 1,00 | 0,00 | 1,00 | 1,00 | 1,00 | 1,20 |
| | MDM | 3,00 | 0,00 | 2,00 | 1,00 | 0,00 | 3,00 | 1,00 | 1,00 | 0,00 | 2,00 | 1,30 |
| Explicit Kansei concepts | Annotation | 3,00 | 2,00 | 3,00 | 3,00 | 2,00 | 3,00 | 3,00 | 3,00 | 3,00 | 3,00 | 2,80 |
| | Word map | 0,00 | 1,00 | 1,00 | 1,00 | 1,00 | 1,00 | 0,00 | 1,00 | 1,00 | 1,00 | 0,80 |
| | MDM | 1,00 | 0,00 | 2,00 | 1,00 | 1,00 | 2,00 | 0,00 | 2,00 | 0,00 | 2,00 | 1,10 |
| Kansei-Element & Brand-Element linking | Annotation | 1,00 | 2,50 | 2,50 | 3,00 | 3,00 | 2,50 | 1,50 | 2,50 | 2,00 | 3,00 | 2,35 |
| | Word Mapping | 0,50 | 1,00 | 2,00 | 2,50 | 1,50 | 1,00 | 0,00 | 0,50 | 1,00 | 1,50 | 1,15 |
| | MDM | 3,00 | 0,00 | 2,50 | 2,00 | 1,00 | 1,50 | 0,00 | 1,50 | 0,00 | 2,00 | 1,35 |
| Kansei-Kansei prioritizing | Annotation | 0,00 | 2,00 | 2,00 | 2,00 | 1,00 | 2,00 | 3,00 | 3,00 | 2,00 | 2,00 | 1,90 |
| | Word Mapping | 2,00 | 1,00 | 3,00 | 2,00 | 0,00 | 1,00 | 0,00 | 1,00 | 1,00 | 2,00 | 1,30 |
| | MDM | 0,00 | 2,00 | 3,00 | 2,00 | 0,00 | 3,00 | 3,00 | 1,00 | 0,00 | 3,00 | 1,70 |
| Prioritizing properties of the element | Annotation | 0,00 | 1,00 | 3,00 | 1,00 | 2,00 | 1,00 | 2,00 | 3,00 | 2,00 | 2,00 | 1,70 |
| | Word Mapping | 3,00 | 0,00 | 2,00 | 1,00 | 1,00 | 1,00 | 2,00 | 1,00 | 1,00 | 2,00 | 1,40 |
| | MDM | 2,00 | 3,00 | 3,00 | 3,00 | 1,00 | 2,00 | 1,00 | 2,00 | 0,00 | 3,00 | 2,00 |
| Flexibility degree | Annotation | 0,50 | 0,00 | 3,00 | 2,50 | 1,00 | 1,00 | 1,00 | 2,00 | 1,00 | 3,00 | 1,50 |
| | Word Mapping | 2,50 | 2,00 | 1,00 | 1,50 | 2,00 | 1,00 | 2,00 | 1,00 | 1,00 | 2,00 | 1,60 |
| | MDM | 3,00 | 1,00 | 3,00 | 2,00 | 2,00 | 2,00 | 2,00 | 1,00 | 3,00 | 3,00 | 2,20 |
| Trace the effect of a change | Annotation | 1,00 | 0,00 | 3,00 | 2,00 | 1,00 | 1,00 | 0,00 | 2,00 | 3,00 | 2,00 | 1,50 |
| | Word Mapping | 2,00 | 1,00 | 2,00 | 2,00 | 1,00 | 1,00 | 1,00 | 1,00 | 1,00 | 2,00 | 1,40 |
| | MDM | 3,00 | 1,00 | 3,00 | 1,00 | 2,00 | 1,00 | 1,00 | 1,00 | 1,00 | 3,00 | 1,70 |

Table 4-16: **The data collected for 10 product designers**

Figure 4-26 (a) shows the results of the evaluation of annotation (red), word mapping (blue) and MDM (green) by product designers and engineering designers, and academics (b). The vertical axis shows the requirements (from Table 4-15), the horizontal axis shows the level of suitability of the diagrams from 0 to 3 (0 = zero, 1= low, 2= medium, 3= high). The extent of the bars shows the average value associated to each diagram.

The results show that for communicating the brand values and the Kansei concepts and the relation between brand values and Kansei to the product elements, annotation is seen as most efficient by the product designers, engineering designers and academics (see in Figure 4-26 (a) and (b) the suitability accorded to the "Explicit brand value", "Explicit Kansei concepts" and "Kansei-element and brand-element linking"). On the other hand the MDM matrix was seen by all groups as more efficient for communicating information about priorities, the degree of flexibility and for tracing a change in one product property to others (see in Figure 4-26 (a) and (b) the suitability accorded to "Kansei-Kansei prioritizing", "Prioritizing properties of the element", "Flexibility degree" and "Trace the effect of changes").

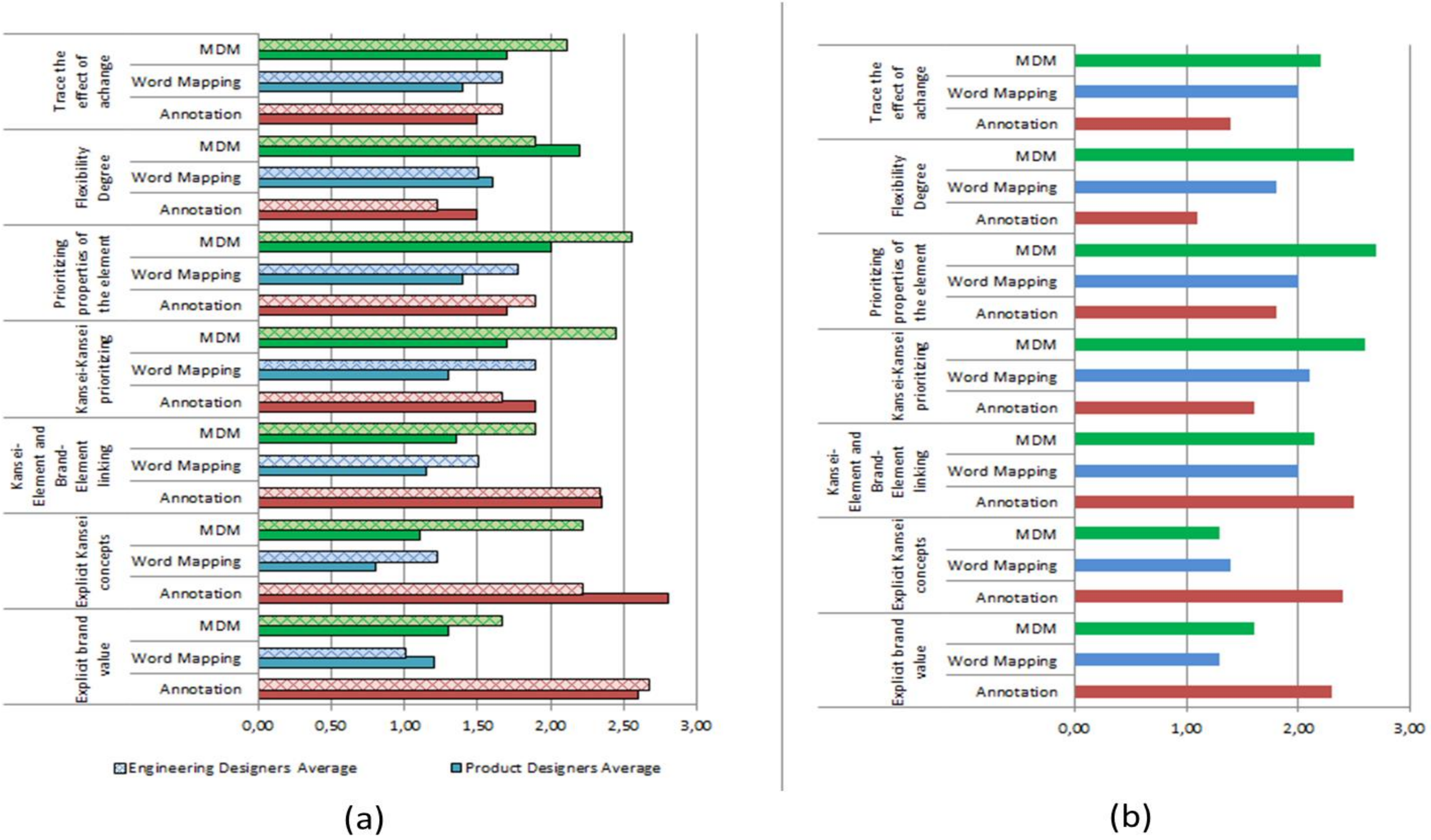



Figure 4-26**: Evaluation of annotation (red), word mapping (blue) and MDM (green) against the requirements by product designers and engineering designers (a) and academics (b)**

Figure 4-27 shows a visual comparison of the average of suitability level (zero, low=1, medium=2 and high=3, on the vertical axis) that each group associated to annotation, MDM, word mapping.

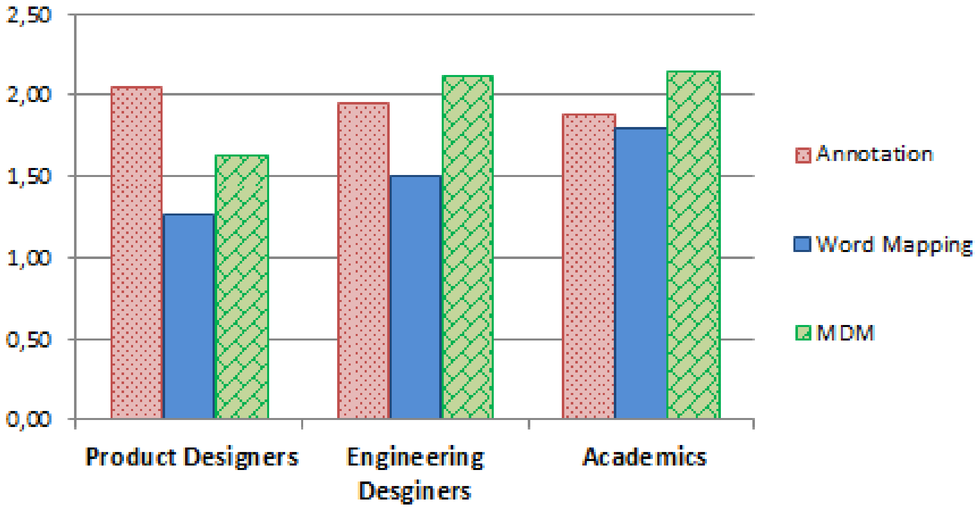



Figure 4-27: **Average evaluation of annotation, word mapping and MDM by each group**

According to this diagram (Figure 4-27), it seems that the product designers found annotation more efficient than MDM and word mapping for the communication of brand values and Kansei concepts (the red column is higher than the blue and green columns for product designers). To verify whether the difference is significant an ANOVA (analyse of variance) test was carried out. ANOVA is a method to determine whether there are any significant differences between means of three or more independent (unrelated) groups. To apply ANOVA test for product designers we used the following Table that shows the average evaluation (average of suitability levels accorded to questions in Figure 4-25) for each respondent (Table 4-17).

| | PD1 | PD2 | PD3 | PD4 | PD5 | PD6 | PD7 | PD8 | PD9 | PD10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Annotation | 1,21 | 1,21 | 2,79 | 2,36 | 1,71 | 1,79 | 1,93 | 2,64 | 2,29 | 2,57 |
| Word mapping | 1,57 | 1,00 | 1,71 | 1,86 | 1,21 | 1,00 | 0,71 | 0,93 | 1,00 | 1,64 |
| MDM | 2,14 | 1,00 | 2,64 | 1,71 | 1,00 | 2,07 | 1,14 | 1,36 | 0,57 | 2,57 |

Table 4-17: **Average of suitability levels accorded to annotation, word mapping and MDM by product designers**

The null hypothesis of "there is no difference in efficiency of annotation, MDM and word mapping for product designers" falls in the rejection area with F=4.68 and alpha= 0.05 (Figure 4-28). According to the results of the ANOVA method there is a significant difference of the efficiency among the three tools. However, from the results of ANOVA test it is not clear which specific approach is different from others.

| *Efficiency of three tools for product designers* | Sum of Squares | DF | Mean Square | F |
|---|---|---|---|---|
| Between approaches | 3.10 | 2 | 1,55 | 4,68 |
| Error (within approaches) | 8,9301 | 27 | 0,33 | |
| Total | 12,03 | 29 | | |

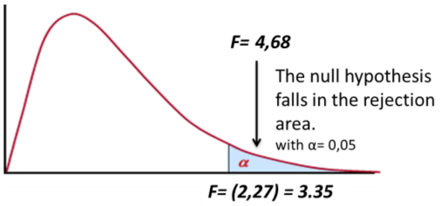



Figure 4-28: **Results of ANOVA test for comparison of the efficiency of three approaches among product designers**

To identify where the difference lies, we applied t-Test for pair comparisons between approaches. Based on the results of the paired sample t-Test, there is a statistically significant difference in the efficiency of annotation compared to word mapping (because the value of the t Stat is greater than t Critical two-tail and the probability that the null hypothesis is true (0.002) is smaller than alpha (0.05) see Figure 4-29 (a)). On the other hand there is no significant difference for word mapping compared to MDM and for MDM compared to annotation (because the value of the t Stat is not greater than t Critical two-tail and the probability that the null hypothesis is true is greater than alpha (0.05) see Figure 4-29 (b) and (c)).

Therefore, for product designers annotation is more efficient representation than word mapping. However there is no significant difference between word mapping and MDM and between MDM and annotation for product designers.

| | *Annotation* | *Word map* |
|---|---|---|
| Mean | 2,05 | 1,264285714 |
| Variance | 0,323185941 | 0,157653061 |
| Observations | 10 | 10 |
| Pearson Correlation | 0,279021741 | |
| Hypothesized Mean Difference | 0 | |
| df | 9 | |
| t Stat | 4,170871148 | |
| P(T<=t) one-tail | 0,00120425 | |
| t Critical one-tail | 1,833112933 | |
| P(T<=t) two-tail | 0,002408501 | |
| t Critical two-tail | 2,262157163 | |

(a)

| | *Annotation* | *MDM* |
|---|---|---|
| t Stat | 1,765045216 | |
| P(T<=t) one-tail | 0,055686623 | |
| t Critical one-tail | 1,833112933 | |
| P(T<=t) two-tail | 0,111373246 | |
| t Critical two-tail | 2,262157163 | |

(b)

| | *MDM* | *Word map* |
|---|---|---|
| t Stat | 2,125575755 | |
| P(T<=t) one-tail | 0,031234531 | |
| t Critical one-tail | 1,833112933 | |
| P(T<=t) two-tail | 0,062469062 | |
| t Critical two-tail | 2,262157163 | |

(c)

Figure 4-29: **Results of t-Test for pair comparisons of three approaches among product designers**

The ANOVA approach was also applied for engineering designers. The null hypothesis of "there is no difference in efficiency of annotation, MDM and word mapping for engineering designers" falls in the rejection area (with F=3.76 and alpha= 0.05) that means there is a significant difference of the efficiency among the three tools (Figure 4-30) and the t-Test should be applied for pair comparisons between tools (Figure 4-31).

| Efficiency of three tools for engineering designers | Sum of Squares | DF | Mean Square | F |
|---|---|---|---|---|
| Between approaches | 1,76 | 2 | 0,8798 | 3,76 |
| Error (within approaches) | 6,31 | 27 | 0,2338 | |
| Total | 8,07 | 29 | | |

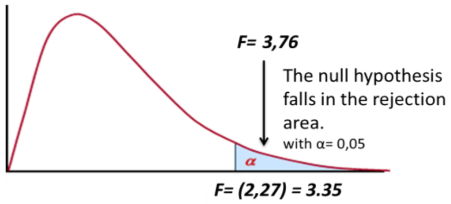



Figure 4-30: **Results of ANOVA test for comparison of the efficiency of three approaches among engineering designers**

According to the results of the t-Test, for engineering designers there is a significant efficiency for MDM compared to word mapping (because the value of the t Stat is greater than t Critical two-tail and the probability that the null hypothesis is true (0.02) is smaller than alpha (0.05) see Figure 4-31 (a)). However there is no such a difference for word mapping compared to annotation and MDM compared to annotation (because the value of the t Stat is smaller than t Critical two-tail and the probability that the null hypothesis is true is greater than alpha, see Figure 4-31 (b) and (c)).

Therefore, for engineering designers MDM is more efficient representation than word mapping. However there is no significant difference between word mapping and annotation and between MDM and annotation for engineering designers.

| | *MDM* | *Word map* |
|---|---|---|
| Mean | 2,111111111 | 1,507936508 |
| Variance | 0,22845805 | 0,47888322 |
| Observations | 10 | 10 |
| Pearson Correlation | 0,369129426 | |
| Hypothesized Mean Difference | 0 | |
| df | 9 | |
| t Stat | 2,658903428 | |
| P(T<=t) one-tail | 0,014427255 | |
| t Critical one-tail | 1,859548038 | |
| P(T<=t) two-tail | 0,028854511 | |
| t Critical two-tail | 2,306004135 | |

(a)

| | *MDM* | *Annotation* |
|---|---|---|
| t Stat | 0,897348328 | |
| P(T<=t) one-tail | 0,197867276 | |
| t Critical one-tail | 1,859548038 | |
| P(T<=t) two-tail | 0,395734552 | |
| t Critical two-tail | 2,306004135 | |

(b)

| | *Annotation* | *Word map* |
|---|---|---|
| t Stat | 1,857913803 | |
| P(T<=t) one-tail | 0,050125642 | |
| t Critical one-tail | 1,859548038 | |
| P(T<=t) two-tail | 0,100251284 | |
| t Critical two-tail | 2,306004135 | |

(c)

Figure 4-31: **Results of t-Test for pair comparisons of three approaches among engineering designers**

For the academics, according to the results of ANOVA method the null hypothesis of "there is no difference in efficiency of annotation, MDM and word mapping" is accepted (with F= 2.27 and alpha= 0.05). This is shown in Figure 4-32.

Therefore for academics, annotation, word mapping and MDM have similar efficiency.

| Efficiency of three tools for academics | Sum of Squares | DF | Mean Square | F |
|---|---|---|---|---|
| Between approaches | 0,68 | 2 | 0,34 | 2,27 |
| Error (within approaches) | 4,6 | 27 | 0,15 | |
| Total | 8,07 | 29 | | |

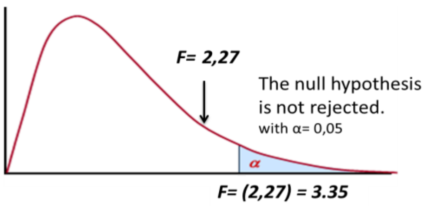



Figure 4-32: **Results of ANOVA test for comparison of the efficiency of three approaches among academics**

Another point is that, as the results show (Figure 4-27), word mapping is seen as most promising by academics compared to product designers and engineering designers.

Despite the evaluation against the requirements, when we asked the interviewees to choose their general preferred option, from the 30 respondents, 67% preferred the annotation over word mapping and MDM. 27% opted for MDM and 6% selected word mapping as their preferred communication tool.

### 4.13.2 Discussion on the results of tool evaluation

The results of the evaluation interviews provide insights from three different groups (product designers, engineering designers and academics) on the efficiency of using tools to support the communication and formalization of brand values and Kansei concepts. To investigate the development of new tools the preference of users should be considered.

One of the important variables in tool evaluation is the respondent's familiarity with the tool. For example, product designers are more familiar with annotations and they use them as a natural way to communicate information. Although we have structured and adapted the annotation to support the communication of Kansei and brand, product designers didn't have to put too much effort into understanding how to use the tool.

The other important variable is the amount of information the three diagrams provided. By adding more information and creating therefore bigger diagrams the evaluation of the tools would be different. It is also important to keep in mind that the evaluation of tools could be different if they were used in the design practice (i.e. during a design project).

The following general comments were made by the participants:

- Annotation is more intuitive, visual and useful to provide a holistic overview of the information. It helps to see the reference by pointing directly to a part of product. However, it is relatively difficult to understand the relationships between different types of information since the texts are not interconnected (this was mentioned by D1, D5, D7, E5, E7, A1). A product designer (D3) stated "it takes a long time to read all the texts to find the information". This was again picked up by E4 and some of the academics. "Too much information would disturb the focus" was mentioned by D2, D9, A3 and E7.

- Word Mapping centralizes information and is helpful to show the relationships and interconnections as it is easy to follow the paths (D2, A5, E1, E2, E3 and E7). However, it is less intuitive and doesn't give a global overview (mentioned by seven persons). A product designer (D2) stated that word mapping doesn't explicitly show the relation of the words to the references since the words are not directly connected to the product parts. This issue was again picked up by D2, D6, D8, D9, A1 and E7. Several interviewees also mentioned that word mapping could easily get unreadable and confusing by adding more information (bigger size).

- MDM gives a more compact, structured and systematic view of the information. It helps to follow the crossing rows and columns and understand the interrelations and the eventual impacts of a change. It is especially useful to analyze the product (E4, E6, E9, D1, D9, A1, A5, A6, and A9). However it is not intuitive and needs prior training (mentioned by all the interviewees). It is not pictorial and doesn't show the relations to the references (product parts), mentioned by D1, D2, D4, D8 and D10, also by A2, A10, E4 and E1.

The interviewees also commented on how they saw the role of annotation, word mapping and MDM diagrams in the design process. The respondents were free to add comments in the end of the interviews and interestingly most of them referred to annotation as a communicating tool to be used during the conceptual and embodiment design phases. The MDM was most seen as a tool to analyse and structure information later in the design process. Word mapping was more referred to be used in idea generation phase to centre the discussion on one particular topic.

## 4.14 Summary

This Chapter used the findings of an empirical study to illustrate how the factors identified from literature review on branding, Kansei Engineering and collaboration in design are coming together to contribute to the challenges of implementation of Kansei and brand concepts in a product. From the literature review and the primary and complementary interviews, this study identified the sources of difficulties related to design process of branded product. The core of the problem was identified as the brand value and Kansei concept getting lost during the design process because of their inefficient communication between product designers and engineering designers. We also pointed out that the current product representations do not support the communication and formalization of Kansei concepts and brand values. Tools like annotation, word mapping and MDM are good ways of visualizing the relationships between design elements and brand and Kansei concepts. Although several advantages and limitations, annotation is seen as the more efficient for communicating the brand value and the Kansei concepts and the relation between brand value and Kansei to the product elements. MDM matrix was seen as more efficient for communicating information about priorities, the degree of flexibility and to trace change in one property of product on the others. Word mapping was better for visualization of pathways compared to annotation (in which some of the pathways are implicit) and to MDM (in which finding the pathways is not easy). The three tools can be modified and improved to support more requirements. The tools could be combined into one tool or be used complementary to other product representations.

# Chapter 5 : Integration Support

In the previous Chapters we explained that the brand values and Kansei concepts are important in the product designers' rationale behind their design choices. The loss of the emotive aspect (brand and Kansei) on the appearance and the look of the product, due to the choices of manufacturing processes and technical constraints, leads to additional long and costly iteration loops during the design process. Chapter 4 described the current problems that companies are having related to the communication breakdown of the emotive aspects of the design between product designers and engineering designers. The use of three potential tools was proposed to support and improve the communication and formalization of the brand values and Kansei concepts. The ultimate goal was to make brand values and Kansei concepts and their relations to the design choices (of product's physical properties) more accessible and understandable to engineering designers.

This Chapter deals with the question of how to integrating engineering designers' view point into early design phases of branded products. We propose an integration approach and describe the application of the approach in the context of the SKIPPI project.

## 5.1 Proposition of integration approach

The question that we address in this Chapter is how to integrate the engineering view point into early design phases of branded products. The integration of engineering view point in early design phases, in the idea generation and definition of design specification and decisions, has the benefits of obtaining a more improved product in terms of technology advance and a better compromise between technical and emotive aspects of the design. In previous chapters we characterized the object world of product designers concerning brand values, Kansei concepts and consumers' emotional responses. In this Chapter we characterize the engineering object world and then we propose an approach to integrate the engineering view point into early design phases. The approach consists of three main steps of modeling, transforming and integrating (Figure 5-1).

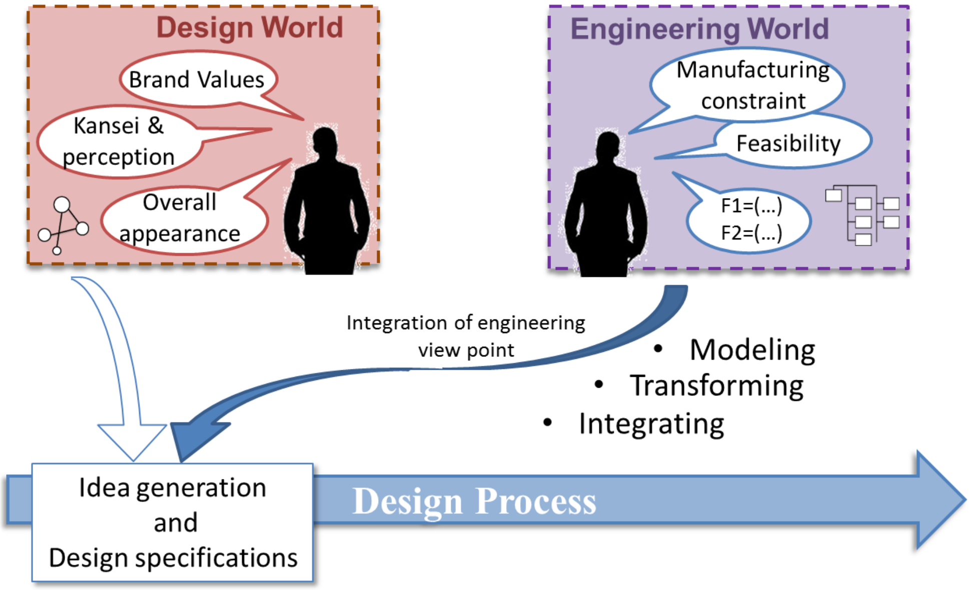



Figure 5-1: **Integration of engineering view point**

To answer the question of "how to integrate engineering view point?" the research method that we followed is summarized in Figure 5-2. The research method begins with the problem identification that is the characterization of the engineering view point, the early design stage and the product designers' view point. Since the characteristics of early design stage and the product designers' view point is explained previously, here we will explain the characterization of the engineering view point.

The next step is the proposition of solution that is an integration approach. Then the approach is applied on some product examples in a specific context and contributed to the SKIPPI project. The evaluation step in our research approach is not about the evaluation of the proposed integration approach but on the evaluation of the tool developed in the SKIPPI project using the integration approach.

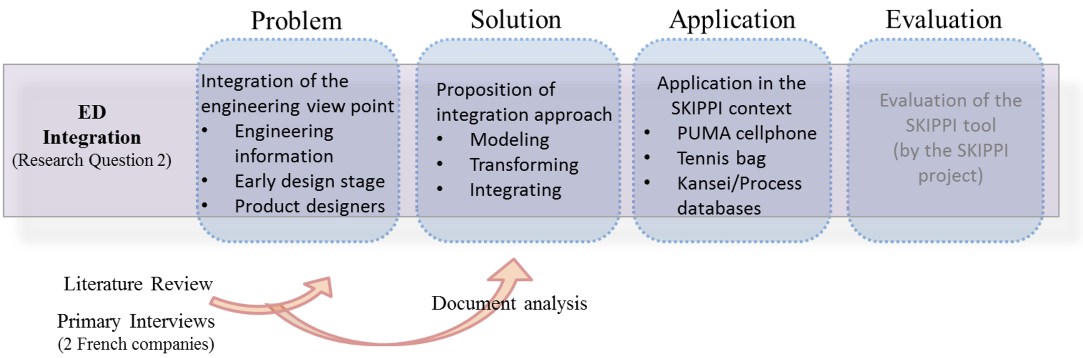



Figure 5-2: **Research method applied to the second research question**

In the following paragraphs we explain the main concepts and considerations of engineering activity and then we propose an approach to make use of and integrate the concepts earlier in the design process.

### 5.1.1 Engineering preoccupation

As it was described in Chapter1, engineering activities involves the study of proposed design concepts and evaluating them regarding the expected performances from the individual components as well as the global performance of the product.

The study of the individual components and their physical properties, their spatial configurations, the connections between different components, the technical functions supported by individual components or a combination of connected components, and the selection of appropriate manufacturing and assembly processes to obtain the global product in regard to the difficulty of the processes and cost, is a part of engineering designers' preoccupation.

The selection of appropriate processes for the manufacture of a particular part is based upon a matching of the required properties of the component and the various process capabilities. Once the overall function of the component is determined, a list of the essential geometrical features, material properties and required properties of the component can be formulated (Boothroyd et al., 1994)

Some of the processes give form to materials. The choice of these processes depends on the material, on the shape, on the required size, precision and surface finish and the associated cost depends most critically on the number of components to be made (the batch size) (Ashby & Johson, 2010). Some of the processes are economic even with a small batch size. Some become economic only when a large number is made.

Most component parts are not produced by a single process, but require a sequence of different processes to achieve all of the required properties of the final component. This is particularly the case when forming or shaping processes are used as the initial process and then material removal and finishing processes are used to produce some or all of the final features (Boothroyd et al., 1994)

Although the combination of many processes are used because application of a single process cannot in general result in all of the finished properties, it is the most economical to make the best use of the capabilities of the initial manufacturing process in order to provide as many of the required attributes of a part as possible (Boothroyd et al., 1994).

A more economical assembly can be achieved through minimizing the number of components and to enable ease of assembly as well as selecting the assembly processes that best suits the materials, joint geometry and the required performances of the joint during its life (Ashby & Johson, 2010). Many processes can join only components made of the same material (e.g. steel to steel) whereas others can bond dissimilar materials (e.g. metal to glass).

Most of the components of a product have some sort of surface process applied to them. Surface processes enhance the thermal, fatigue, friction, wear, corrosion or aesthetic qualities of the surface without changing other properties of the component (Ashby & Johson, 2010) . The choice of a surface process depends on the material to which it will be applied and the function it has to perform (e.g. the processes used to etch the surface of glass differ in obvious ways from those used to texture polymers).

As it was explained in Chapter1, the engineering activity can be extended to the concerns related to other steps in the product life cycle such as transport, logistics and environmental considerations and so on. But here our focus is rather on the activities related to the product and processes in terms of the study of technical solutions and technical functions, and the selection of manufacturing and assembly processes.

To make use of the engineering view point about product and process we propose an approach containing three main steps (Figure 5-2). First the engineering information requires to be classified and structured (modeling step). Then the representation of the model requires adaptation to meet the characteristics of early design stages and also to become more accessible for product designers (transforming step). Although providing the product designers with the engineering information early in the design process can be beneficial for the development of creative products, the engineering information still requires to be properly linked to design information including brand values and Kansei concepts (integrating step).

Following sections provide more details on the different steps of modeling, transforming and integration.

### 5.1.2 Modeling engineering view point

A promising way of modeling the engineering information is using product models. A literature review on the product models is provided in Chapter 1. After a review of the product models including MOKA, CPM, PPO and Multi-View product models we decided to base our work on Multi-View product model because of its' research history in G-SCOP lab.

The Multi-View model was initially intended to support the integration of design actors and their collaboration during the design process of mechanical products. However since our objective was to model the engineering information that can be integrated into early design phases of branded products, our use of the multi-view model is limited to an inspiration from its main concepts.

We established the product process model (ProP model) that is a simplified and lightly modified version of the original multi-view model (see Figure 5-3). The ProP model aims to formalize information about the existing manufactured products rather than supporting the collaboration during their design process. The ProP model consists of four views on the product: structure, function, assembly and manufacturing. For each view in ProP model we define the concepts of components, characteristics and relations according to our objectives. Characteristic is the term we use instead of "link" in the original multi-view model.

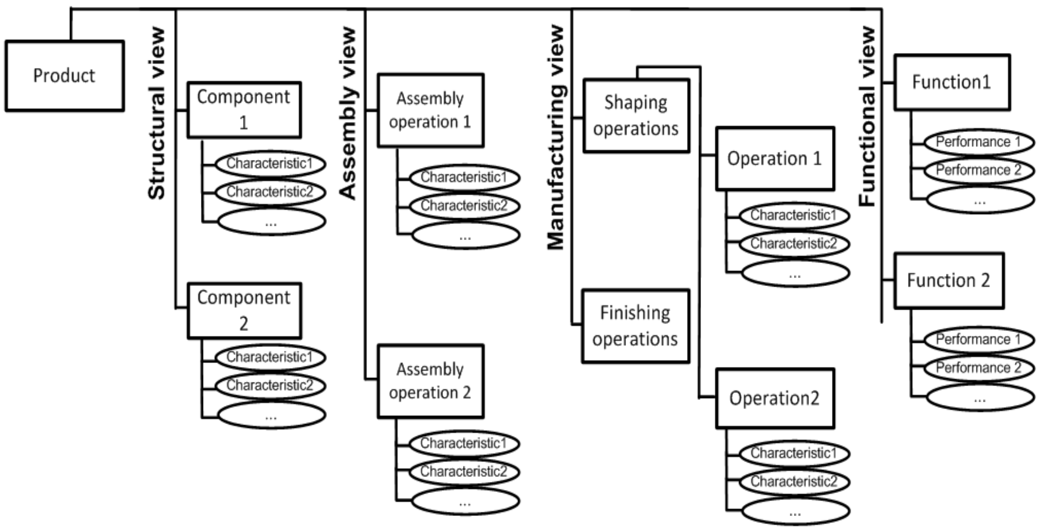



Figure 5-3: **The product and process model (ProP model)**

### Structure View

The structure view provides an understanding of the structure of the product and the way the sub-assembly components and parts are positioned. The structure view contains components and the characteristics of the components. Characteristic refers to properties of the component such as its color, shape, dimension, material and weight. In previous Chapters we employed the term "physical properties" that for us has the same meaning as the term characteristics we use here. The value of each characteristic can be either digital or lexical (e.g. 0.5 gram, blue color). Documents such as bill of materials (BOM) that usually contain the list of individual components or the assembly tree can be used to build the structure view. The structure view takes part in the description of the characteristics of the components required to meet the product intended functions.

### Assembly View

The assembly view contains the information about the assembly operations and their characteristics. Examples of assembly operation include soldering, glue fixing, screwing and son on. The characteristics refer to specification of assembly operations such as the time of assembly, dimension of joint surfaces, and allowable materials. The characteristics can be seen as the process constraints or the assembly rules that designers need to respect, to avoid the later issues or unusually costs. The design for assembly (DFA) method was our inspiration source to define the characteristics for each assembly operation in the assembly view.

### Manufacturing View

The manufacturing view contains two types of operations: shaping materials operations (e.g. molding, casting) and finishing operations (e.g. printing, polishing). Characteristics for each type of operations are defined based on Design for Manufacturing (DFM) method. The characteristics of shaping material operation include allowable weight range, minimum thickness, shape complexity and allowable material (Table 2 provides more details on manufacturing operations).The characteristics of finishing operations include surface hardness, coating thickness and curved surface coverage. The values of these characteristics refer to the normal capabilities of the manufacturing process that design team need to avoid exceeding when they define the product specifications.

### Function View

The function view provides an overview of the services functions provided by the product (including interaction and adaptation functions) and how each service function is performed by a set of subfunctions (or technical functions) (AFNOR, 1995). Tools like FAST (Functional Analysis System Technique) can be used as support for the functional decomposition. The characteristics of functions are defined as performance criteria, such as durability or the quality.

The following table summarizes the entities and the characteristics of the four views in the ProP model (Table 5-1).

| | Structure View | Assembly View | Manufacturign View | Function View |
|---|---|---|---|---|
| Entity | Components and sub-components | Assembly operations | Raw material shaping, finishing operations | Service and technical functions |
| Characteristics | Physical properties of the component | Specifications of assembly operations | Specifications of manufacturing operations | Performance criteria |

Table 5-1: **Summary of entities and characteristics in the ProP model**

We collected generic process operations and their characteristics and values. Table 5-2 shows an extract of the table for manufacturing processes (See Annex 3 for complete manufacturing table). The information in the Table including the values of the characteristics are collected based on literature review (Ashby & Johson, 2010; Boothroyd et al., 1994) and DFMA software.

We identified a number of characteristics for process operations, but to simplify the amount of information, we limited our work to a selection of the characteristics. Table 5-2 contains the name of manufacturing process and seven characteristics. The characteristics include the weight range that can be manipulated by the process (kg), the minimum thickness that can be produced by the process (mm), the shape complexity that can be produced (low, medium, high), the roughness or smoothness of the surface (µm), the economic number of components to be made or the economic batch size, the precision of dimension or allowable tolerance (mm) and the range of material for which the process can be applied. Other characteristics that we excluded from the table were: the need for complementary process, operation time, process temperature, depression (the ability to form recesses or grooves in the surface) and uniform wall (the ability to produce uniform thickness).

| | | Characteristics of manufacturing processes and their values | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Weight range (kg) | Minimum thickness (mm) | Shape complexity | Surface roughness (µm) | Economic batch size | Allowable tolerance (mm) | Material |
| Manufacturing processes | Injection molding | 0,01-25 | 0,3-10 | high | 0,2-1,6 | 10k-1000k | 0,05-1 | thermoplastic, thermosets, elastomer |
| | Rotation molding | 0,1-50 | 2,5-6 | low | 0,5-2 | 100-10k | 0,4-1 | thermoplastic, thermosets |
| | Blow molding | 0,001-0,3 | 0,4-3 | low | 0,2-1,6 | 1k-10,000k | 0,25-1 | thermoplastics, limited levels of reinforcement for composite materials |
| | Expanded foam molding | 0,01-10 | 5-100 | low/med | 50-500 | 2k-1000k | 0,5-2 | thermoplastics, polystyrene |
| | Compression molding | 0,2-20 | 1,5-25 | low/med | 0,2-2 | 2k-200k | 0,1-1 | thermoplastics |
| | Resin transfer Molding | 0,2-20 | 1,5-13 | med/high | 0,2-1,6 | 10k-100k | 0,25-1 | polyester, epoxies, vinyl esters, phenolic |
| | Die-casting 1) Cold Chamber 2) Hot Chamber | 0,05-20 | 1-8 | med/high | 0,5-1,6 | 5k-1,000k | 0,15-0,5 | aluminum, magnesium, zinc alloy |
| | Sand-casting | 0,3-1000 | 5-100 | med/high | 12-25 | 1-1000k | 1-3 | aluminum alloy, copper alloys, cast irons, steel |
| | Investment Casting | 0,001-20 | 1-30 | med/high | 1,6-3,2 | 1-50k | 0,1-0,4 | silver, copper, gold, bronze, pewter, lead, nickel, cobalt, iron based alloys |
| | Polymer Casting | 0,1-700 | 2-100 | high | 0,5-1,6 | 10-1000 | 0,8-2 | resins, thermosets |
| | Shape Rolling and Die forging | 0,1-100 | 2-100 | low | 3,2-12,5 | 10k-1000k | 0,3-2 | metals, copper alloys, steel |
| | Extrusion | 1-1000 | 0,1-900 | low | 0,5-12,5 | 1k-1000k | 0,2-2 | Aluminum, magnesium, copper |
| | Press forming , Rolling forming and spinning | 0,01-30 | 0,2-5 | med | 0,5-12,5 | 25k-250k | 0,1-0,8 | metals, steel, aluminum, copper, nickel, zinc, magnesium, titanium |
| | Thermoforming | 0,003-50 | 0,25-6 | low | 0,3-1,6 | 10-100k | 0,5-1 | thermoplastic, ABS, PA, PC,PS, PP, PVC |
| | Powder methods | 0,01-5 | 1,5-8 | low/med | 1,6-6,3 | 1k-1000k | 0,1-1 | brass, bronze, iron-based alloys, stainless steel, cobalt, titanium, tungsten, beryllium, metal, ceramic |
| | Laser Prototyping | 0,1-20 | 0,5-100 | high | 100-125 | 1-100 | 0,2-2 | ABS, Nylon |
| | Deposition Prototyping | 0,1-10 | 1,2-100 | high | 75-100 | 1-100 | 0,3-2 | ABS, Nylon |

Table 5-2: **Manufacturing process, their characteristics and values**

We proceeded in the same way to define equivalent Tables for assembly and finishing processes. See the Annex 3 for these assembly and finishing Tables.

According to the multi-view product model, the entities in the views can be related to each other through their links (Tichkiewitch & Véron, 1997). Likewise in the ProP model, the relations between the entities of the same view (two components in structure view) or the entities of different views (a component in structure view and a manufacturing process in manufacturing view) can be established through their characteristics. The relations become more concrete when the model is applied on a product example.

### 5.1.3 Transforming

The ProP model represents the engineering information about product and process in a hierarchical structure. But in the beginning of the design process the inputs are vague, unstructured and based on words. To meet the characteristics of early design phases and to make the engineering information more accessible for product designers, we propose the transformation step in which the representation of engineering information in ProP model become more similar to a graph representation.

Graph representation seems to be promising because as we explained in Chapter 4, based on the results of the evaluation interviews, the word mapping graphs was referred to be suitable for idea generation phase. We call the graph representation lexical model in this Chapter because it is slightly different and doesn't contain orientation and importance level for links (Figure 5-4).

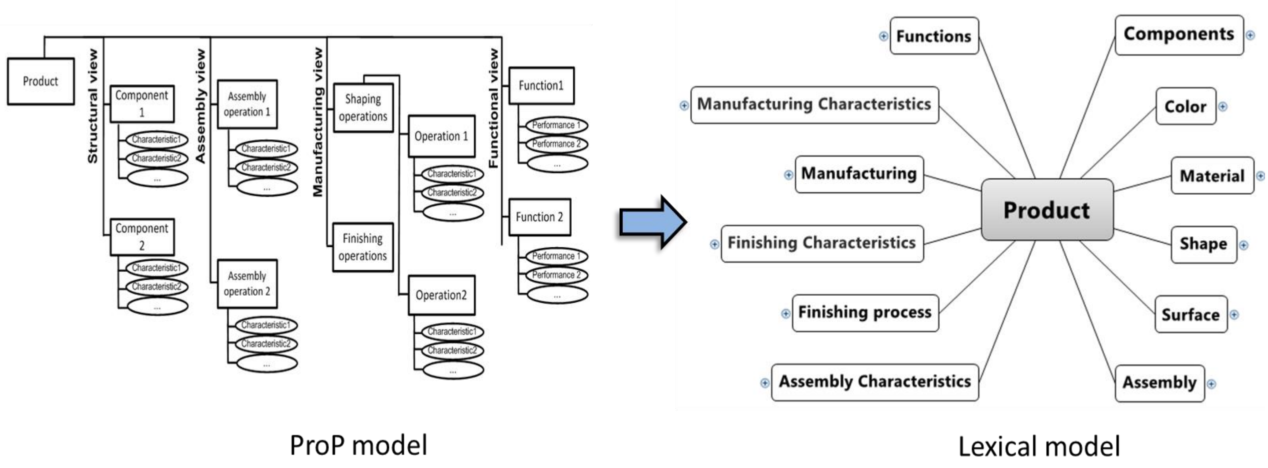



Figure 5-4: **Transformation of ProP model (left) to Lexical model (right)**

In the transformation step, all the entities and characteristics of entities in each view in ProP model gain the same level of hierarchy in the lexical model. For example color, shape and material which are among the characteristics of components in the structure view (ProP model), become entities of the same level as components in the lexical model. We call that the first level entities. Likewise the characteristics of the assembly, manufacturing and finishing operations become the first level entities in lexical model. We used the X Mind software to construct the lexical model (Figure 5-5).

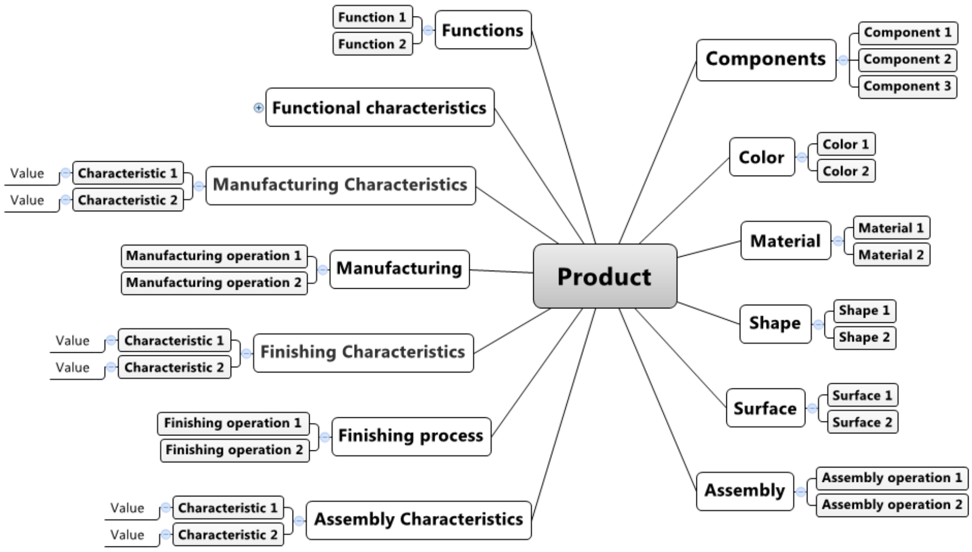



Figure 5-5: **First, second and third level entities in the lexical model**

The characteristics (in first level entities) contain a second level information including the name of the characteristics and third level information including the values associated to the characteristics (Figure 5-5). As it was summarized in Table 5-2, many of the characteristics have digital values (and are quantitative data).

Among the characteristics presented in Table 5-2, lexical values were already defined for the shape complexity (low, medium and high). To achieve a fully lexical model, all the other values should be expressed in words. We applied the following approach to convert the quantitative values to lexical descriptions.

To convert the quantitive values to qualitative values we considered the data provided in Table 5-2. In this table for each characteritics an interval of data is defined. For example for weight range of matrials that can be manipulated using the injection modling process, the data inerval is from 10 grams to 25 kilograms.

To classify the data in qualitative categories , first we considered the distance between the minimum and the maximum data related to a specific characteristic for all the processes.

For example the weight range related to all the manufacturing processes includes a large distance between the minimum and the maximum data (0.001and 1000). To cover this large distance , we decided to define five qualitative catergories for the weight of materials namely : very light, light, medium, heavy and very heavy (Figure 5-6).

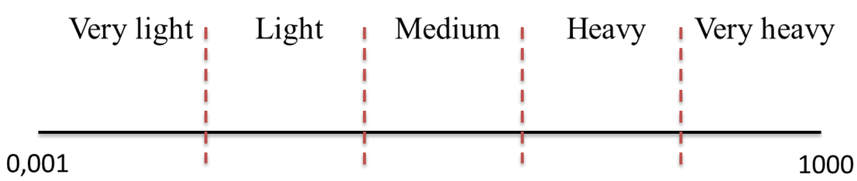



Figure 5-6: **Consideration of five qualitative categories for the weight range**

To associate the qualitative categories to the data, instead considering five equal devisions, we proceeded to find out whether there are rules in data intervals related to different manufacturing processes (see Table 5-2 , the first culumn). We draw bar chart diagram to visualize the data ranges using logaritmic skale because of the huge distance between the minimum and the maximum data (Figure 5-7).

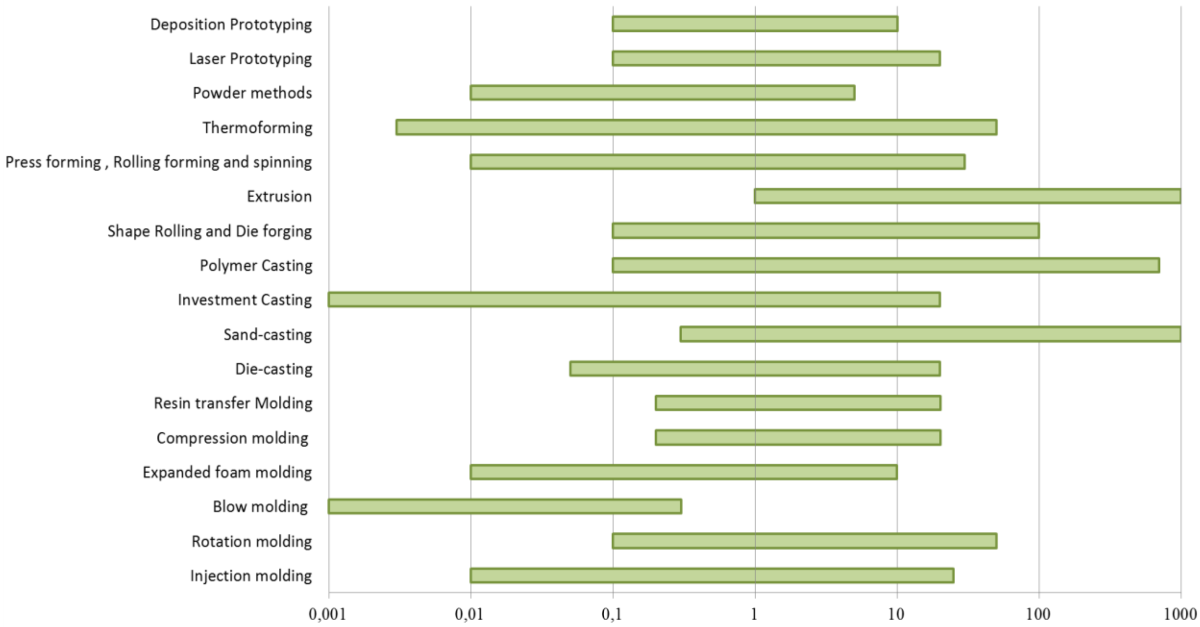



Figure 5-7: **Data intervals related to weight range, for different manufacturing processes**

The vertical axis in Figure 5-7 represents the manufacturing processes and the green horizental bars represent the data intervals related to each manufacturing process.

As it can be seen in Figure 5-7 , for some of the processes the begining of the data intervals are the same (e.g. rotation molding , polymer casting, , shape rolling and die forging, laser prototyping and deposition prototyping). Likewise the end of data intervals for some processes are the same (e.g. compression molding, resin transfer molding, die-casting, investment casting, laser prototyping).

Based on the occurrence of the beginig points and the ending points in intervales , we proposed an association of qualitative categories to the data as it is shown in Figure 5-8.

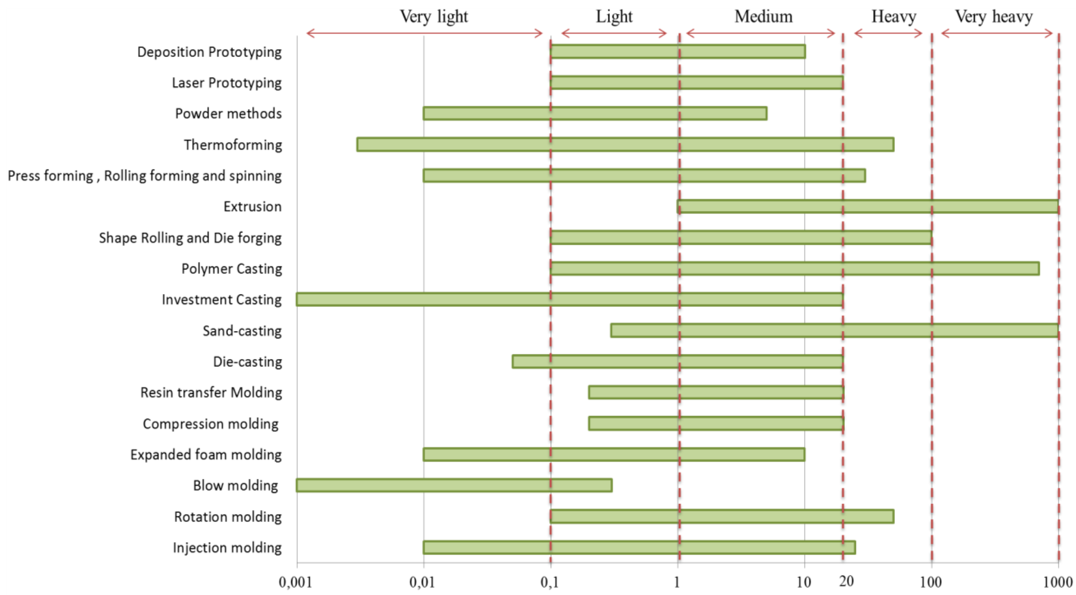



Figure 5-8: **Associating qualitative categories to quantitative intervals**

We applied the same approach for other characteristics of manufacturing processes (presented in Table 5-2) and also for assembly and finishing processes. The diagrams are provided in Annex 3.

We gathered the results in the Table 5-3. This table can serve as a reference to convert digital data to words for the manufacturing, assembly and finishing processes.

| Characteristics | Category 1 | Category 2 | Category 3 | Category 4 | Category 5 |
|---|---|---|---|---|---|
| Weight range (kg) | 0.001-0.1 | 0.1-1 | 1-20 | 20-100 | 100-1000 |
| | very light | light | medium | heavy | very heavy |
| Minimum thickness (mm) | 0.1-1 | 1-5 | 5-30 | 30-100 | 100-900 |
| | very thin | thin | medium | thick | very thick |
| Surface roughness (mm) | 0.1-1.6 | 1.6-12.5 | 12.5-25 | 25-75 | 75-500 |
| | very smooth | smooth | medium | rough | Very rough |
| Economic batch size | 1-1000 | 1000-10k | 10k-100k | 100k-1000k | 1000k-10000k |
| | small batch size | medium | large batch size | | |
| Allowable tolerance (mm) | 0.05-0.1 | 0.1-0.5 | 0.5-1 | 1-2 | 2-3 |
| | very low tolerance | low tolerance | medium | high tolerance | |
| Surface hardness (vickers) | 5-10 | 10-40 | 40-600 | 600-1100 | 1100-10k |
| | very soft | soft | medium | hard | very hard |
| Coating thickness (mm) | 1-10 | 10-100 | 100-1000 | 1000-2000 | - |
| | thin | medium | thick | Very thick | - |
| Maximum thickness of assembled parts (mm) | 0.01-1 | 1-10 | 10-50 | 50-200 | - |
| | thin | medium | thick | very thick | - |

Table 5-3: **Converting quantitative data to qualitative data**

We used the proposed converting table for the manufacturing processes (presented in Table 5-2). The Table 5-4 shows an extract of the manufacturing process, the characteristics and their lexical values.

| | Characteristics of manufacturing processes and their values | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Weight range (kg) | | | | | Minimum thickness (mm) | | | | | Shape complexity | | | Surface roughness (µm) | | | | | Economic batch size | | | Allowable tolerance (mm) | | | |
| | very light | light | medium | heavy | very heavy | very thin | thin | medium | thick | very thick | low | medium | high | very smooth | smooth | medium | rough | very rough | small | medium | large | very low | low | medium | high |
| Injection molding | x | x | x | | | x | x | | | | | | x | x | | | | | | | x | x | x | x | |
| Rotation molding | x | x | x | | | | x | | | | x | | | x | x | | | | | x | | | x | x | |
| Blow molding | | x | | | | x | x | | | | x | | | x | | | | | | x | | | x | x | |
| Expanded foam molding | x | x | | | | | x | x | x | | x | x | | | | | x | x | | x | x | | | x | x |
| Compression molding | x | x | x | | | | x | x | | | x | x | | x | x | | | | | x | x | | x | x | |
| Resin transfer Molding | x | x | x | | | | x | | | | | x | x | x | | | | | | | x | | x | x | |
| Die-casting 1)Cold Chamber 2) Hot Chamber | x | x | x | | | | x | | | | | x | x | x | | | | | | x | x | | x | | |
| Sand-casting | x | x | x | x | x | | x | x | x | | | x | x | | | x | | | x | x | x | | | | x |
| Investment Casting | x | x | x | | | | x | x | | | | x | x | | x | | | | x | x | x | | x | | |
| Polymer Casting | x | x | x | x | x | | x | x | x | | | | x | x | | | | | x | | | | | x | x |
| Shape Rolling and Die forging | x | x | x | x | | | x | x | x | | x | | | | x | | | | | | x | | x | x | x |

Table 5-4: **Manufacturing process, characteristics and lexical values**

### 5.1.4 Integrating

In the integration step, the engineering information represented in the Lexical model would be linked to product designers view point. As we explained previously in this dissertation, the product designers view point can be characterized by brand values and Kansei concepts as their reasoning behind the design choices. From the product designer's point of view, the link between product properties and brand values and/or Kansei concepts is made through the product designer's rationale and consumers study (thin boundaries to give lightness feeling to tennis bag). From the engineering designer's point of view, the link between product properties and industrial processes is made through the engineering rationale based on matching the characteristics (properties) of the product and the compatibility of processes. Therefore to integrated engineering and product design viewpoints, process and

Kansei/brand information should be linked. There are two ways for linking processes and Kansei/brand; through indirect and direct linking.

The indirect-linking occurs when an industrial process and the Kansei/brand concept are connected through the common product property. For example thin boundaries of the structure element in tennis bag give a high-tech perception of the bag. Thin boundaries can be achieved by heat sealing process. Here an indirect link can be built between heat sealing and high-tech. However this way of linking is not always reliable since the heat sealing process has other characteristics (e.g. surface roughness, range of allowable material) that can contradict the intended Kansei or brand values. Therefore for indirect links, we suggest considering the linking between that specific characteristics of the process and the intended Kansei or brand.

The direct-linking occurs when an industrial process and the Kansei/brand concept are directly connected. For example a direct link may connect a specific industrial process and rustic perception because the process is easy and doesn't apply advanced technologies. Likewise a direct linking may exist between the handmade processes and delicacy or one-of-a-kind perception (Figure 5-9).

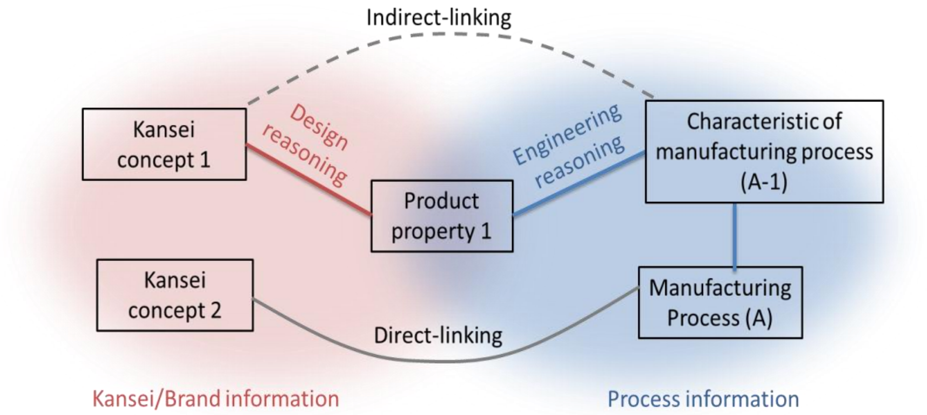



Figure 5-9: **Indirect and direct linking between process and Kansei/brand words**

Direct and indirect links between process and Kansei/brand information can be established based on data collection from consumer studies (see Chapter 1 for Kansei Engineering approach).

Figure 5-10 recapitulates the mains steps and the use of information representations (ProP model and lexical model) for the integration approach. The integration approach that we proposed is generic. In the following sections we describe the application of the integration approach in the context of the SKIPPI project.

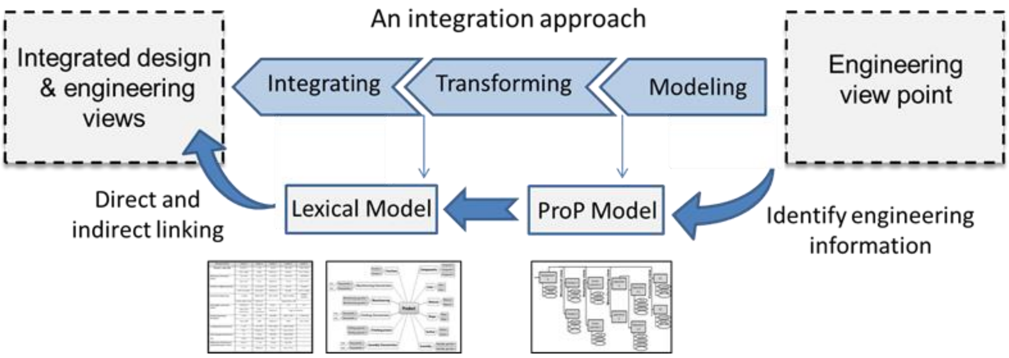



Figure 5-10: **The proposition of integration approach**

## 5.2 The context of the SKIPPI project

SKIPPI (System for Kansei Image Product Process Innovation) is a project financed by National Research Agency (ANR). The objective of the project is to develop a system to support idea generation and the decision-making in the upstream design phase. The SKIPPI tool aims to link semantic and emotional dimensions to the functional, material and engineering dimension (Figure 5-11). From a given Kansei/brand word, the tool is supposed to assist the ideas generation about using special material, or special shape, or special process or technology for the design of the product and vice versa, from a given process the tool is supposed to assist the estimation of how the product would be perceived.

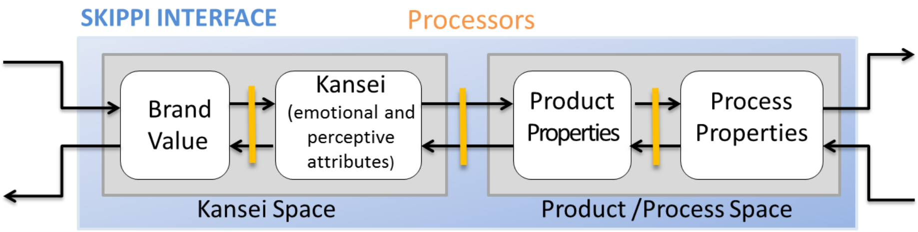



Figure 5-11: **The SKIPPI model from (SKIPPI Report, 2012)**

To develop the SKIPPI tool, the SKIPPI project gathered academic researchers from four research laboratories, as well as two industrial partners (Diedre Design and Option France). The LCPI laboratory that is also the leader of the project was more focused on the integration of product designers' view point and design information (in terms of brand values, Kansei and aesthetics) into the SKIPPI tool. The G-SCOP laboratory was in charge of identifying the engineering information and engineering designers' viewpoint to be integrated into the SKIPPI tool. The linkage between design and engineering viewpoints was conducted through the collaboration of LCPI and G-SCOP laboratories. The interface design, the information visualization and the further tool evaluations were conducted through the collaboration between LCPI, LIP6 and PYCLE laboratories.

To meet the characteristics of early design stage, the SKIPPI tool aimed to use three lexical databases containing Kansei, product and process information and the SKIPPI graph to visualize the linkages among the words. The Kansei database was provided with categories of information about Kansei concepts and brand with the word collection conducted by the LCPI lab. Our mission in the SKIPPI project was to integrate the engineering view point to the construction of the SKIPPI graph by:

- Providing the product and the process databases with proper words and relations
- Participate in linking process database to Kansei database

The product database was the overlapping part because it was built considering both engineering and product design viewpoints. The definition of word categories for product database was tackled collectively by LCPI and GSCOP laboratories. Figure 5-12 illustrates the frontiers of our mission in the project. Next we will explain the application of our approach to integrate the engineering view point in early design phases and its contribution into the SKIPPI project.

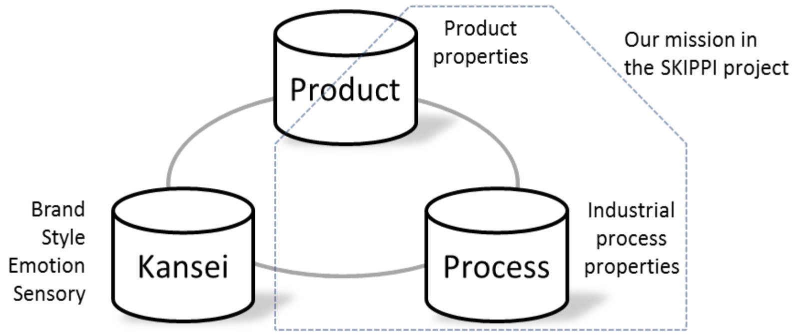



Figure 5-12: **SKIPPI databases and the frontiers of our mission in the project**

Further information about the project including the approach to collect words and relations for Kansei and product databases (by LCPI laboratory), the tool devolvement process, the functionalities of the tool, its interface and the information about the algorithms (to search words and select short pathways among words) are all described in the project technical reports (SKIPPI Report, 2012),(SKIPPI Project, 2010) and are out of the scope of this dissertation.

## 5.3 Application of the integration approach in SKIPPI

To identify the engineering information, we conducted in-depth interviews in two companies (Diedre Design and Option France) and gathered data related to design projects of the Tecnifibre tennis bag and the PUMA cellphone (explained in Chapter 4).

### 5.3.1 Modeling

Based on the analysis of the collected documents, and product samples, and the process characteristics tables we built the ProP models for the tennis bag and the cellphone. An extract of the application of the ProP model for PUMA cellphone is illustrated in Figure 5-13. We extracted the name of the component based on the collected documents from Option France. The Front Logo is a part of Upper Housing which it-self is a part of the main Body. Some characteristics of Front Logo include its plastic material and its silver color. The Front Logo is assembled to Housing by soldering operation. The component is obtained by Injection molding and then through the NCVM (Non Conductive Vacuum Metallization) operation a thin nonconductive metal film is placed on the molded plastic surface. The relations are excluded from Figure 5-13 for a better readability but are shown in Figure 5-14. The complete version of the ProP model for PUMA cellphone is illustrated in Annex 4.

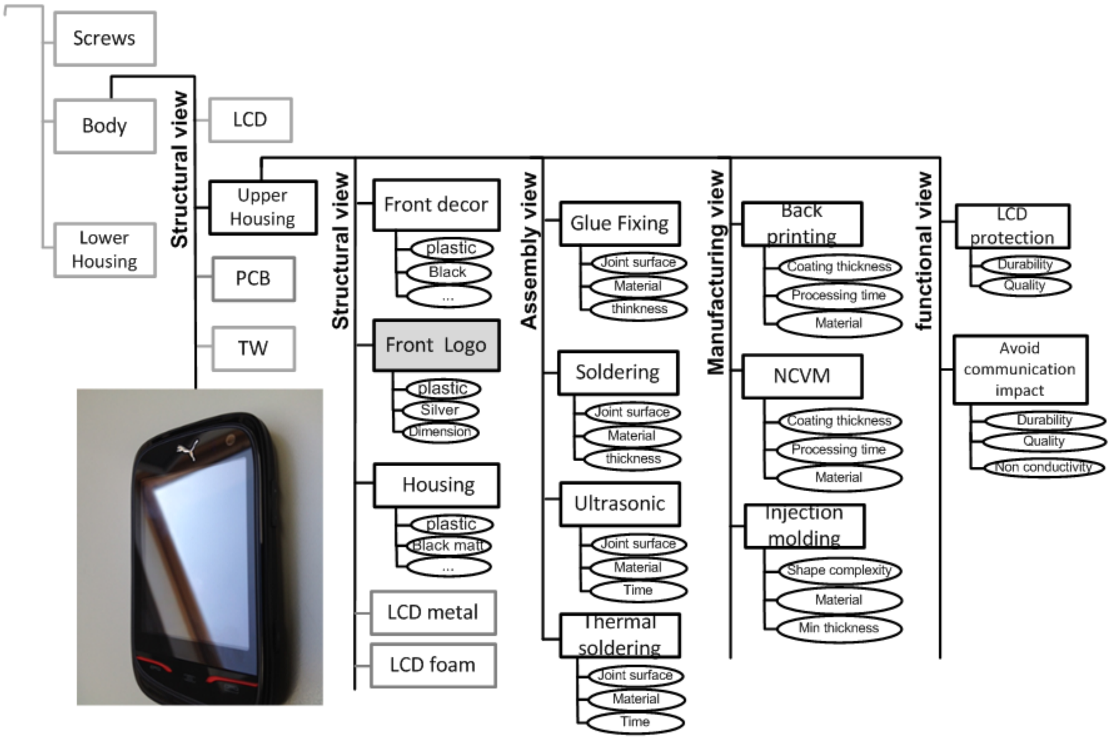



Figure 5-13: **Selected part of ProP model for Front logo component in the PUMA cellphone**

The relations play an important role in identifying the effects of changing a component on the other components or on the whole product structure. Building relations between characteristics is supposed to be done by experts such as engineering designers or manufacturing engineers during the design process as a result of expert knowledge reasoning. However for this example we built the relations using the collected documents from Option France and also based on our factual reasoning. For the Front Logo, some of the relations are shown in Figure 5-14. There is a relation between the plastic material of this component, and the possible material ranges for molding operation (R1). Also the shape of Logo is compatible with the range of shape complexity that could be produced by the molding operation (R2). The Soldering assembly of the Logo on the Housing is possible because the contact surface between the Logo and the Housing is compatible with the required joint surface of the soldering operation (R3). The Silver color of Logo is included in the color range supported by NCVM process (R4). The special metal film used in NCVM process, prevents radio interference and doesn't require any measures against electrostatics, therefore it meets "avoid communication impact" Function due to its non-conductivity performance (R5).

The relations can be classified as product-process relation if they are established between the characteristics of the entities in the structure or the function view and the characteristics of entities in manufacturing or assembly view. The relations can be classified also as product-product when they are established between two or more characteristics in the structure view, or between two or more characteristics in the function view, or between characteristics in the structure and the function views.

Likewise the relations are classified as process-process when they are established between/within characteristics of manufacturing and assembly views.

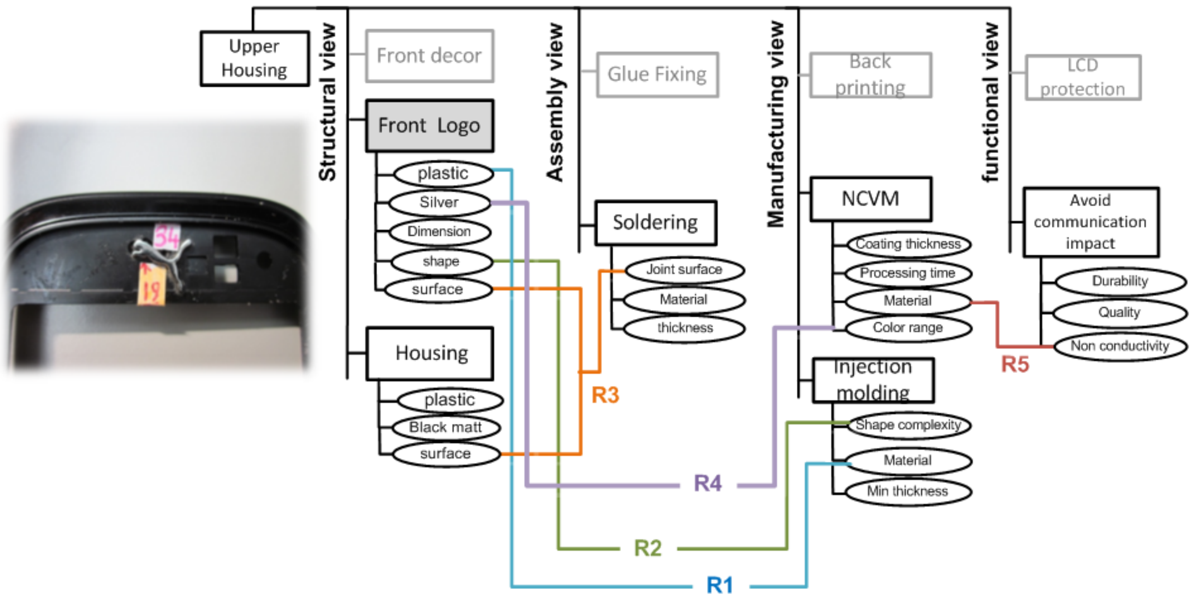



Figure 5-14: **Example of relations in the ProP model**

### 5.3.2 Transforming

Figure 5-15 shows the lexical model built for the example of cellphone, transformed from the ProP model illustrated in Figure 5-14. The lexical model of PUMA cellphone contains the same relations as in the ProP model (R1, R2, R3, R4, and R5), however because of the changes in the representation (from ProP model to lexical model), some relations that are implicit in the ProP model, appear in the lexical model. These relations are shown in gray dash lines. For example “plastic” that is the second level entity for “material” is connected to the “housing” component through a gray dash line in the lexical model, because the plastic material is a characteristic of the Housing component in ProP model and this relation is implicit in the ProP model.

As it is illustrated in Figure 5-15, the relations are established between second level entities (characteristics). The first level entities can be excluded from the lexical model and be used rather as labels for the categories of information. The lexical model therefore becomes more like Figure 5-16.

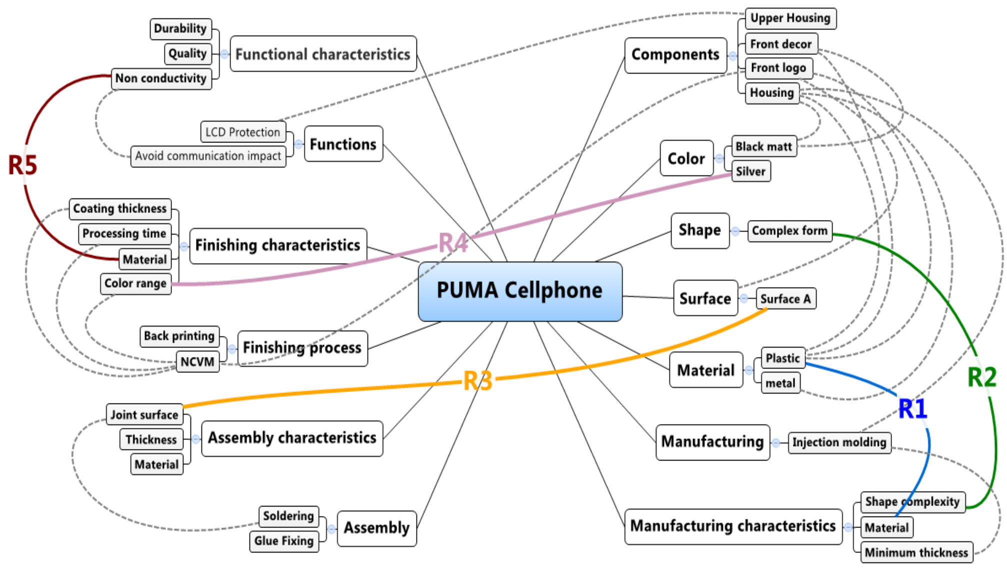



Figure 5-15: **A selected part of the lexical model of the PUMA cellphone**

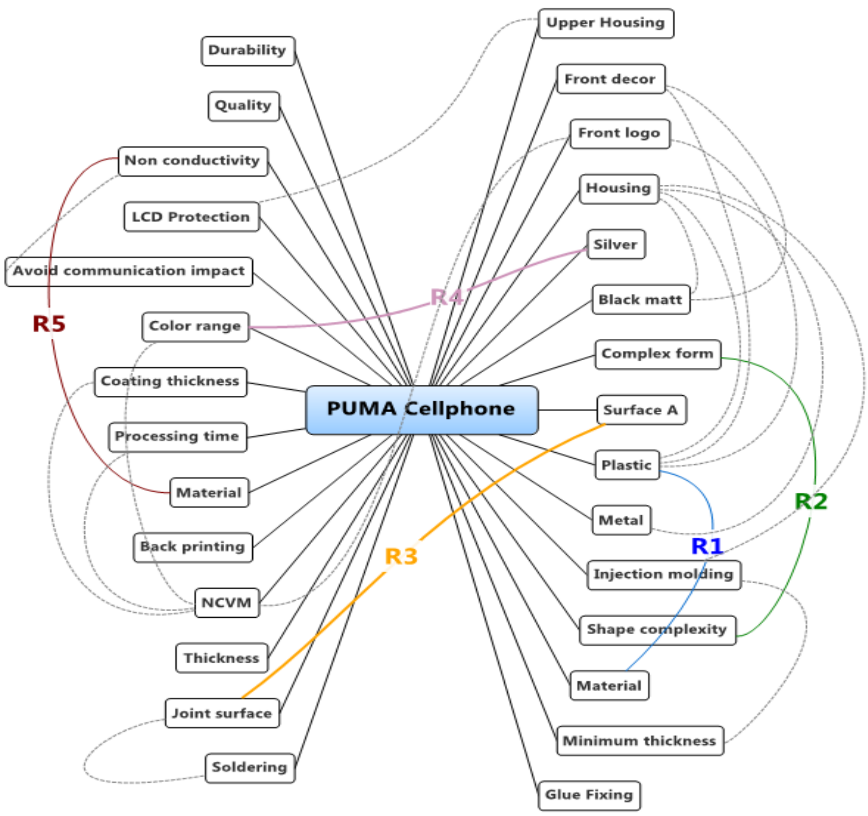



Figure 5-16: **Lexical model without the first level entities**

From the lexical model we identified different categories (labels) of information for the product and the process databases in the SKIPPI tool. For the product database we proposed components, shape, color, material, surface and functions. For the process database we proposed manufacturing, assembly, finishing and the characteristics of the manufacturing, assembly and finishing processes (Table 5-5).

| | | | |
|---|---|---|---|
| **Product** | • Components<br>• Shape | • Color<br>• Material | • Surface<br>• Function |
| **Process** | • Assembly<br>• Assembly characteristics | • Manufacturing<br>• Manufacturing characteristics | • Finishing<br>• Finishing characteristic |

Table 5-5: **Categories of information for the product and process databases**

To provide product-process relations for the SKIPPI graph, from the lexical model of PUMA cellphone (illustrated in Figure 5-16), product-process relations were extracted. We built the lexical model for Tecnifibre tennis bag and for another product (a staple remover: because of its simple structure it served as our pilot product in the transformation step) using the same approach. Likewise the product-process relations were extracted for the SKIPPI graph.

### 5.3.3 Integrating

In the integrating step, process and Kansei databases should be connected. The establishment of direct and indirect links between process and Kansei databases requires data collection and a large number of people to evaluate the processes using the Kansei/brand concepts. To link the process and the Kansei databases, an experiment took place by the participation of the industrial partners of the SKIPPI project (Diedre Design and Option France companies).The initial objectives of the experiment were to capture and analyze the recurrent relations between Kansei and process words to be used in the SKIPPI graph, and to capture a maximum amount of relations between Kansei and process databases for further development of the SKIPPI tool.

Considering the total amount of words in Kansei and process databases at that time (736 Kansei words and 176 process words) providing both recurrent and maximum amount of relations at the same time appeared to be opposed because of time constraint and availability limitation (of the industrial partners of the project).

Further development of the SKIPPI tool required a maximum amount of relations to be implemented for the evaluation of data processing time of the software and algorithms for searching and selecting pathway. The choice was made to obtain a maximum amount of links through the experimentation and leave the analysis of recurrent relations in the perspective and for future works.

To cover the totality of the words in Kansei and process databases for the establishment of relationships, and also to respect the readability of words, four experiment sheets were prepared in A1 format (841 x 594 mm) see Figure 5-17. Each sheet contains a total of 360 Kansei and process words, distributed in a random order in the sheet. Each sheet contained the same process words (176 words) and ¼ of the Kansei words (184 words). The numbers in Figure 5-18 is in purpose of making the analysis easier for researchers in data collection.

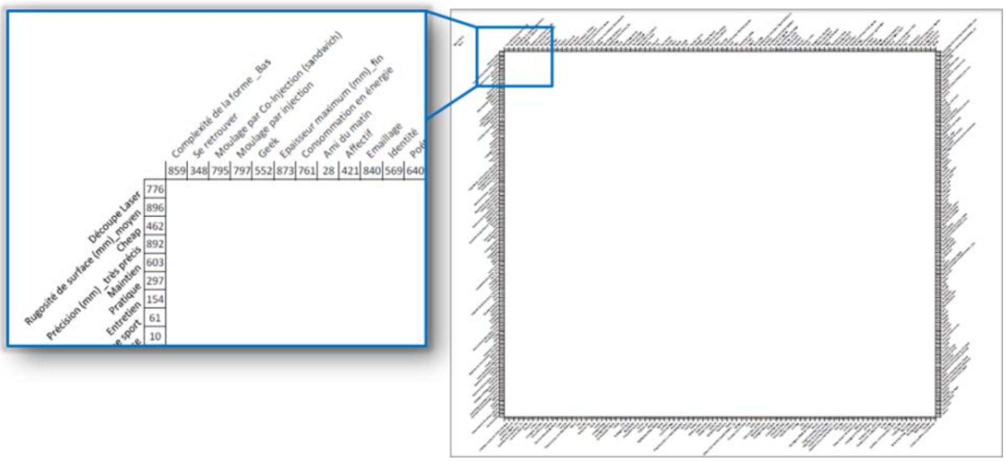



Figure 5-17: **The experimentation sheet**

The experiment was conducted by a master student from the G-SCOP laboratory who went to the Option France and Diedre Design companies with other researchers from the LCPI Laboratory. Eleven persons participated in the experiment individually (see Table 5-6). In the beginning of the experiment, the context of the project and the objective of the experiment were explained and the participants were asked to link the words in the sheet. The experiment took one hour. Table 6 shows the participants' profession, the company's name, the experiment sheet number and the experiment code (initial of the company's name, participant's number and the sheet number). As it is summarized in Table 5-6 the sheet number 3 was distributed 4 times, sheet number 4 was distributed 3 times, and the sheet number 1 and 2 were distributed 2 times.

| Participants | Company | Experiment sheet | Experiment code |
|---|---|---|---|
| Project manager (1) | Option France | 3 | Opt 1-3 |
| Product designer (2) | Option France | 1 | Opt 2-1 |
| Graphic designer (3) | Option France | 4 | Opt 3-4 |
| Product designer (4) | Option France | 3 | Opt 4-3 |
| Graphic designer (1) | Diedre Design | 4 | Die 1-4 |
| Product designer  (2) | Diedre Design | 4 | Die 2-4 |
| Product designer (3) | Diedre Design | 3 | Die 3-3 |
| Design student (Trainee) (4) | Diedre Design | 2 | Die 4-2 |
| Product designer  (5) | Diedre Design | 2 | Die 5-2 |
| Engineering designer (6) | Diedre Design | 3 | Die 6-3 |
| Project manager (7) | Diedre Design | 1 | Die 7-1 |

Table 5-6: **Summary of the participants for the Kansei-Process relation experiment**

After the experiment, the sheets were collected and the links were classified in Excel files. Figure 5-18 shows examples of the sheets. Table 5-7 shows an extract of the Excel file that contains the two related words in the first and second columns, the link code (labels for the links to facilitate the analysis), the experiment code and the type of the link (Kansei-Process , Kansei-Kansei, Process-Process). Since the experiment took place in French language, we keep the original words in the Table 5-7.

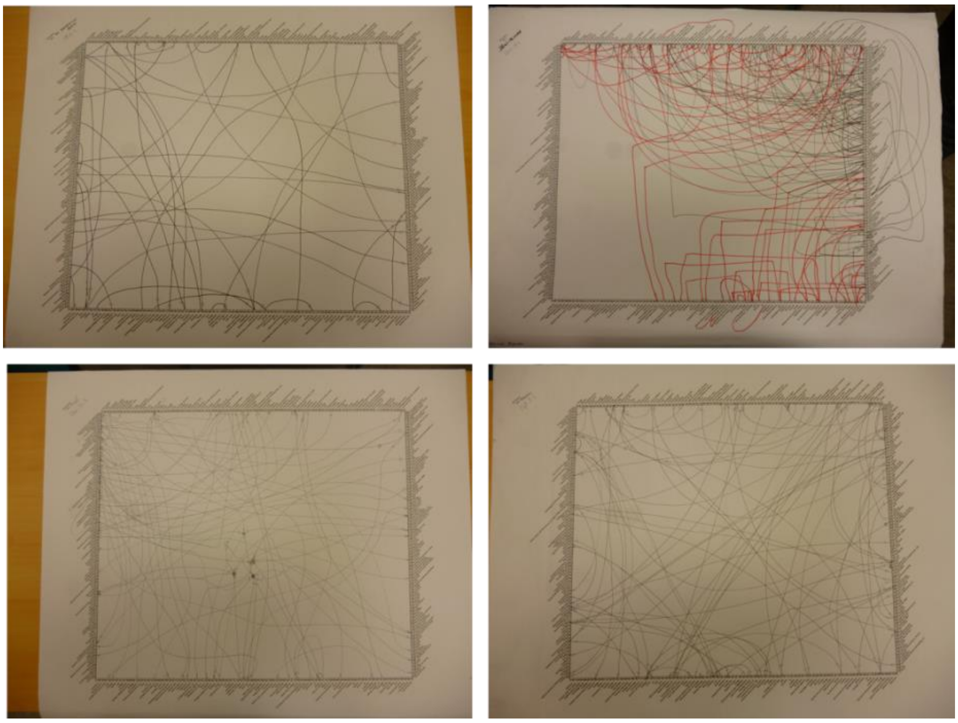


Figure 5-18: **Example of collected sheets after the experiment**

| First word | Second word | Link code | Experiment code | Link type |
|---|---|---|---|---|
| Valeur monétaire | Sculpter | 1 | Opt-1-3 | K - P |
| Valeur monétaire | Précision | 2 | Opt-1-3 | K - K |
| Valeur monétaire | Tabacco | 3 | Opt-1-3 | K - K |
| Valeur monétaire | A la main | 4 | Opt-1-3 | K - K |
| Style | Inspirer créativité | 5 | Opt-1-3 | K - K |
| Logo | Tissage | 6 | Opt-1-3 | K - P |
| Logo | Fashion victim | 7 | Opt-1-3 | K - K |
| Tôlerie | Poids (kg) _très lourd | 8 | Opt-1-3 | P - P |
| Poids (kg) _très lourd | Solidité | 9 | Opt-1-3 | K - P |
| Légalité | Produits de la marque | 10 | Opt-1-3 | K - K |
| Dureté de surface (Vickers)_très dur | Durabilité | 11 | Opt-1-3 | K - P |
| Bricolage | Prototypage Rapide | 12 | Opt-1-3 | K - P |
| Early adopter | Electro polissage | 13 | Opt-1-3 | K - P |
| Early adopter | Assemblage de PCB | 14 | Opt-1-3 | K - P |
| Humour anglais | Londonien | 15 | Opt-1-3 | K - K |
| Logo Vodafone | Faire la musique | 16 | Opt-1-3 | K - K |
| Défoncer | Reggae | 17 | Opt-1-3 | K - P |
| Matin | Lever du soleil | 18 | Opt-1-3 | K - K |
| Injection plastique | Poids (kg) _Très léger | 19 | Opt-1-3 | P - P |
| Butane gaz | Pollution de l'air | 20 | Opt-1-3 | K - P |
| Titiller le puma | Tout public | 21 | Opt-1-3 | K - K |
| Peinture électromagnétique | Innovation | 22 | Opt-1-3 | K - P |
| Nomadisme | Mobile | 23 | Opt-1-3 | K - K |
| Over-booké | Senior exécutive CEO | 24 | Opt-1-3 | K - K |
| Horoscope | Femme | 25 | Opt-1-3 | K - K |
| Web-radio | Sortir | 26 | Opt-1-3 | K - K |
| Durabilité | drop test | 27 | Opt-1-3 | K - P |
| Désirable | Polissage | 28 | Opt-1-3 | K - P |
| Chaussures de sport | Nike | 29 | Opt-1-3 | K - K |
| Athlète | Nike | 30 | Opt-1-3 | K - K |
| Sécurité | drop test | 31 | Opt-1-3 | K - P |
| Boire en s'activant | Life style | 32 | Opt-1-3 | K - K |
| Life style | Baladeur MP3 | 33 | Opt-1-3 | K - K |
| Innovation | Electro polissage | 34 | Opt-1-3 | K - P |
| Innovation | Visser | 35 | Opt-1-3 | K - P |
| Masculin | Vissage | 36 | Opt-1-3 | K - P |
| Tissage | Faire progresser art de vivre | 37 | Opt-1-3 | K - P |
| Tabacco | Toxicité | 38 | Opt-1-3 | K - P |

Table 5-7 : **Extract of the Excel tables for analysis of data**

From the eleven experiment sheets collected, we extracted a total of 971 links made by participants. The amount of links per sheet is summarized in Table 5-8. We conducted further analysis to find the occurrence of similar links over the experiment sheets. But since different sets of Kansei words were used in the four sheets to cover the totality of Kansei database, the number of similar links was limited. Table 5-9 summarizes the amount of similar links built by different participants.

| Company | Sheet | Experiment code (company + person + sheet number) | Number of links |
|---|---|---|---|
| Option France | 3 | Opt 1-3 | 46 |
| Option France | 1 | Opt 2-1 | 88 |
| Option France | 4 | Opt 3-4 | 60 |
| Option France | 3 | Opt 4-3 | 101 |
| Diedre Design | 4 | Die 1-4 | 41 |
| Diedre Design | 4 | Die 2-4 | 159 |
| Diedre Design | 3 | Die 3-3 | 216 |
| Diedre Design | 2 | Die 4-2 | 17 |
| Diedre Design | 2 | Die 5-2 | 53 |
| Diedre Design | 3 | Die 6-3 | 11 |
| Diedre Design | 1 | Die 7-1 | 179 |

Table 5-8 : **The amount of links between words per sheet**

| Experiment Sheet | Experiment code | Number of similar links | Similar link in other experiment sheet |
|---|---|---|---|
| 1 | Opt 2-1 | 2 | Die 7-1 |
| | Die 7-1 | - | - |
| 2 | Die 4-2 | - | - |
| | Die 5-2 | - | - |
| 3 | Opt 1-3 | 4 | Opt 4-3 |
| | | 2 | Die 3-3 |
| | Die 3-3 | 5 | Opt 4-3 |
| | | 1 | Die 6-3 |
| | | 1 | Die 7-1 |
| | Opt 4-3 | - | - |
| | Die 6-3 | 1 | Opt 4-3 |
| 4 | Die 1-4 | 1 | Opt 3-4 |
| | | 5 | Die 2-4 |
| | | 1 | Die 3-3 |
| | Die 2-4 | 4 | Opt 3-4 |
| | | 1 | Opt 4-3 |
| | | 1 | Die 7-1 |
| | | 1 | Die 3-3 |
| | | 2 | Die 6-3 |
| | Opt 3-4 | 1 | Opt 4-3 |
| | | 1 | Die 7-1 |

Table 5-9: **Amount of similar links established by different participants**

All the established links were used to connect the process and Kansei databases in the SKIPPI tool. The experiment also provided some unexpected links appearing between Kansei words (K-K), and between process words (P-P). Although the study of the link types and their recurrence can raise interesting insights and questions about the reliability of the links, the study was kept for future works.

## 5.4 General discussion on the approach and the results

This section provides a discussion on the proposed integration approach that we applied, the difficulties met, the limitations, and an overview of the results in the SKIPPI tool.

### 5.4.1 Discussion on the modeling step (ProP model)

We built the ProP model for the PUMA cellphone and the Tecnifibre tennis bag in the purpose of extracting relevant engineering descriptions of these products. One of the advantages of building the ProP model was primarily to understand the nature of relations between the characteristics of the entities (in the same view or across the views) in an engineering model. The relations were established based on logical and factual reasoning and are objective (compared to relation between Kansei concepts and product elements that are subjective, discussed in Chapter 3).

The ProP model can represent the product in different levels of abstraction and therefore provides different levels of details related to physical properties and manufacturing or assembly process. To define properly the entities of each view it is important to specify the intended level of abstraction because an assembly process in one level of abstraction can become a manufacturing process in another level. For example a pre-manufactured part such as PCB contains assembly operations for internal parts, but in an upper level the process would be considered as PBC manufacturing process. Sometimes it is difficult to distinguish between manufacturing and assembly process for example when two textile parts are sewed to make a lateral pocket, sewing can be considered either as manufacturing or assembly process.

Using the ProP model for two products from very different product classes (textile versus electro mechanics) showed the potential of the ProP model to be applied for a wide range of products. However some difficulties occurred. For example when dealing with the decomposition of the tennis bag for the structure view, definition of components and sub-components was less obvious than for the cellphone.

The application of some manufacturing or assembly processes requires adding extra elements to the products (e.g. screw, thread, glue, zip). The question then was whether to consider these additional elements as a component in the structure view or rather define them as characteristics of process (i.e. "need additional element"). This again depends on the aim of using ProP model. In our research we made a choice to consider the additional elements in the structure view, when they have external appearance on the product (for example decorative visualization) and consider them as the characteristics of the process when they do not appear on the final look of the product.

### 5.4.2 Discussion on the transforming step

We proposed a converting table to convert the quantitative values related to characteristics of the processes to qualitative values. Although the table helped us to achieve a fully lexical model, and was used in the SKIPPI project, it has some limitation.

Converting digital data to word description causes reduction of the precision level and can create ambiguity.

When associating the lexical categories to data intervals in Table 5-3, we did not consider particular product or product sector because the values of characteristics were independent of the product but rather related to the capabilities of the manufacturing machines. However, this association can be ambiguous for product designers when they consider different products. For example the meaning of "smooth" surface for a cellphone can be different from its meaning for a tennis bag.

Another limitation is the frontiers of lexical intervals. Although we proposed exact frontiers for the intervals based on the exact digital numbers, in reality the lexical frontiers are fuzzy. For example if 20 kilograms is considered as medium weight, by adding one more kilogram (= 21 kg) it falls in to the heavy category while there is not such different between 20 and 21kg , to make the second one be considered as heavy. Future works can address these issues and propose more adapted approaches to covert digital data to lexical descriptions.

### 5.4.3 Discussion on the integration step

The objective of our experiment was to collect as maximum as possible links between Kansei and process words for the SKIPPI database rather than trying to obtain the most reliable connections. Although we successfully achieved the objective, the method on connecting Kansei and process words needs more reflection. It is particular because the collection of links cannot be limited only to consumer studies as many of product consumers might not be familiar with the industrial processes. Product designers and engineering designers should also participate in building connections. What we obtained through the experiment, were rather direct links between process and Kansei words since the product information was excluded from the experiment sheets. As we discussed in previous chapters, Kansei concepts are context dependent. Building Kansei-process links without considering a context (i.e. particular product) may have negative effect on the reliability or recurrence of links. However in the SKIPPI tool, liking between words can be modified (added or removed), and be adapted for different projects.

The integration approach that we proposed helps to integrate the engineering viewpoint to design viewpoint, through the steps of modeling, transforming and integrating. Yet one other important step is missing to complete the loop back to engineering. This step deals with the question of how the information provided through the integrated design and engineering views, can be transformed backward according to engineering view point. In other words, the next step in the integration approach should address the way in which engineering designers can make use of the provided information and intervene in the proposition and development of solutions all along the design process (Figure 5-19).

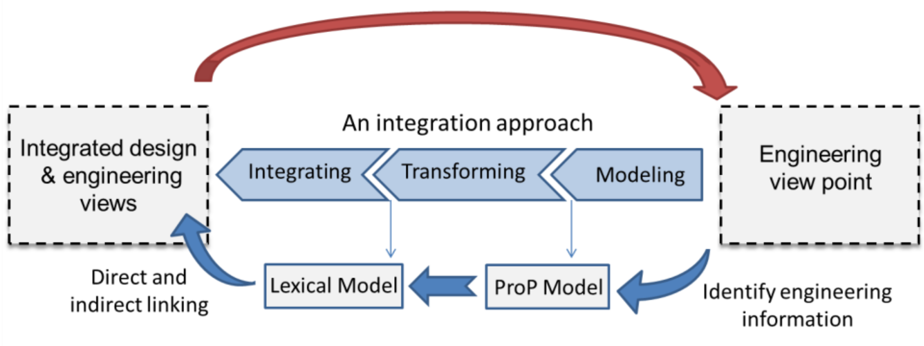



Figure 5-19: **Making use of the integrated design and engineering views, according to engineering view point**

Engineering designers can make use of the provided information when they set up the product specifications and refine the physical properties. For example in the material selection, the choices can be based not only on thermal, electrical and mechanical characteristics but also on the aesthetic and perceptual properties of the materials. Likewise in the selection of manufacturing and assembly processes, having the complementary information about the way the process affects the look of the product (Kansei-Process relations) would help the engineering designers to determine a combination of processes that best suits both technical and perceptual objectives.

### 5.4.4 Overview of the results in the SKIPPI tool

The SKIPPI tool aims to support the integration of both product designers and the engineering designers' viewpoints in idea generation and early design decisions phases. The SKIPPI tool is supposed to be used by the design actors who are involved in design process, specially product designers and engineering designers. Our research contributed to the SKIPPI project by providing an approach to integrate engineering designers view point and link it to product designers view point (Figure 5-20).

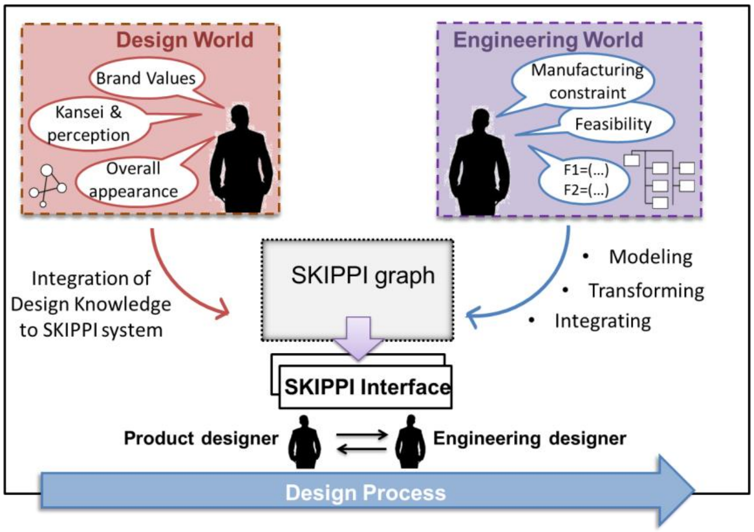



Figure 5-20: **Integration of Engineering and design view point into the SKIPPI tool**

We based our work on the ProP model to determine and classify engineering information. The ProP model represents information in a hierarchical and structured way. To make use of ProP model for the SKIPPI graph we proposed a transformation step to obtain a lexical model that is more relevant to a graph structure. From the lexical model we identified the categories of information to be used in the construction of the SKIPPI graph. The first level entities in the lexical model became the labels of subcategories in the SKIPPI tool and the second and third level entities became the words that are inside the subcategories and are the nodes in the SKIPPI graph. Figure 5-21 and 5-22 show screen shots of the SKIPPI tool.

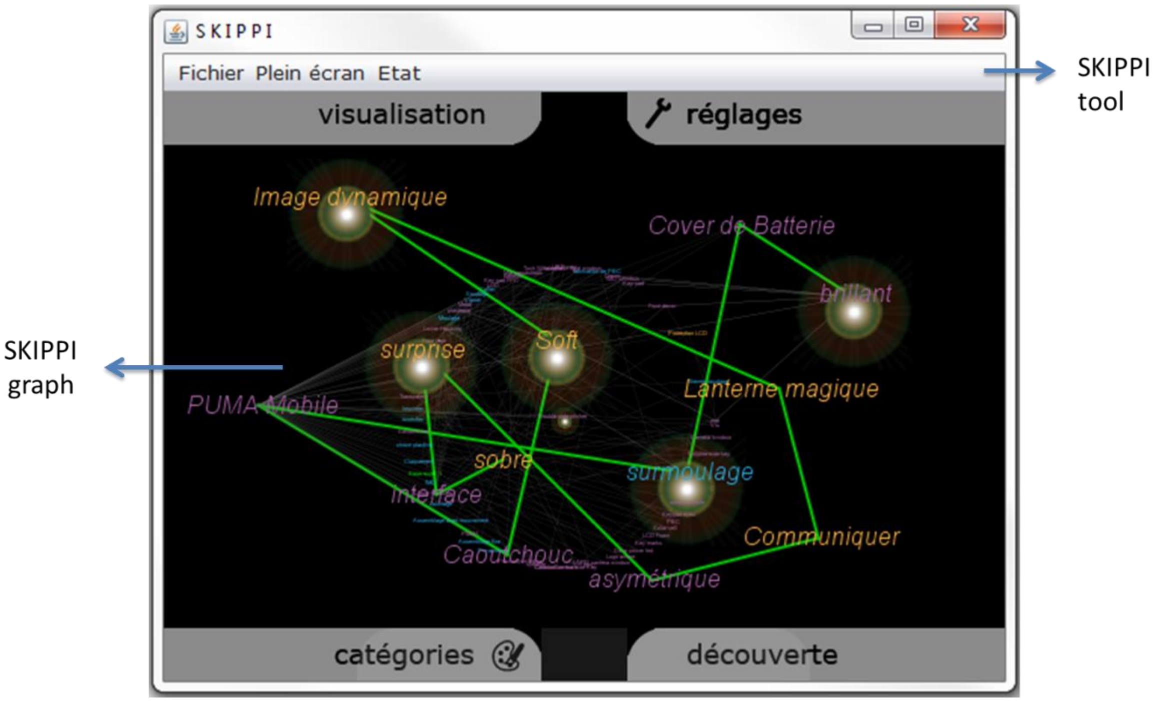



Figure 5-21: **Screen shot of the SKIPPI tool and SKIPPI graph**

By a click on the “catégories” icon on the left down corner of the screen, the information categories appear that is shown on the right side of the Figure 5-21. In the category menu there are three main categories and several subcategories. The middle and lower parts with cube and gear icons in the menu are the product and the process categories.

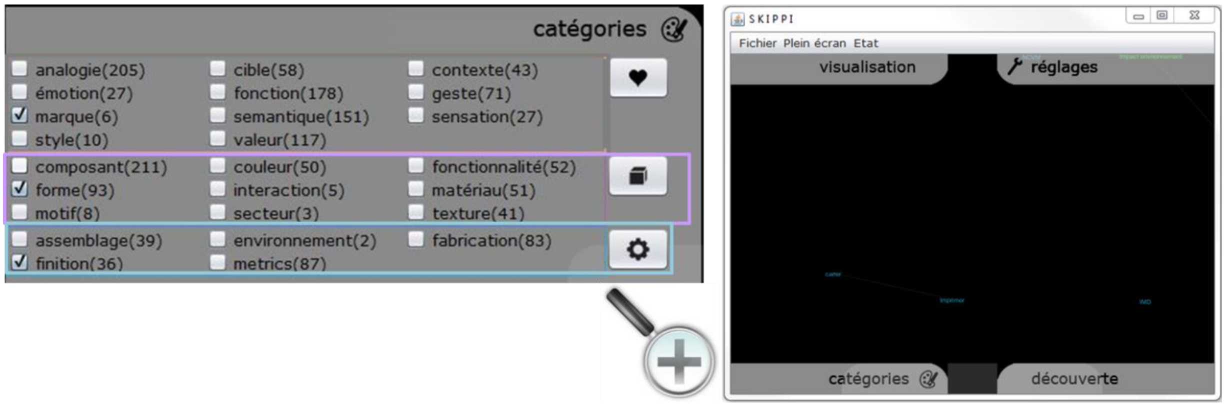



Figure 5-22: **Screen shot of categories menu of the SKIPPI tool**

In addition to the information we proposed to be include in the product category from the engineering view point, 4 more subcategories were added by other partners of the project to represent design view point. The added subcategories are texture, interaction, motif and sector. The surface subcategory was removed and the information related to surface was merged into the texture subcategory. The numbers between parentheses refer to the amount of words that subcategories contain. For example the material subcategory contains 51 words in the database.

The process category contains a total of 5 subcategories. The characteristics of the assembly, manufacturing and finishing operations are classified under the “metrics” subcategory in the menu. One of the subcategories that are in the process category is called “environment” that is still under development in the SKIPPI tool.

The upper part with a heart icon concerns Kansei and brand information category that is defined and developed by other partners of the SKIPPI project from the LCPI laboratory. The upper part includes 11 subcategories. Users of the software can select or unselect the subcategories to change the amount of words that are visualized in the SKIPPI graph. New words can be added to or deleted from the subcategories by the users of the tool. For example according to the technology progress, new manufacturing or assembly process and their characteristics can be added to update the database.

Algorithms are developed to support the exploration of links, through the analysis of pathways.

There are other experiments currently going on, to evaluate the usage of the SKIPPI tool in different design projects by product designers and engineering designers.

## 5.5 Summary

In this Chapter we proposed the integration approach that allows to couple engineering view point into design view point. We proposed the use of ProP model, lexical model and the conversion table. The application of the approach was explained and the limitations were highlighted.

Despite of the limitations, the approach contributed to the construction of a software called SKIPPI tool, to support idea generation for design of branded products.

# Chapter 6 : Conclusion

To recapitulate on what we have discussed in the manuscript, this Chapter reviews the main objectives of our research as well as the research questions. A summary of the contributions of the thesis is explained and the limitations are pointed out. Finally the opportunities that our research creates for further works are presented in this Chapter.

## 6.1 Reminder of the research context and the research questions

The objective of this research was to assist the collaboration between product designers and engineering designers during the design process of branded products. While their roles overlap, for most consumer products, product designers are responsible for the overall design and the specification of product form and usability including aesthetic, user interface, semantics and meanings, while engineering designers deal with the technical aspects such as mechanical, electrical and electronic analysis and calculation and consider criteria like cost, robustness, and available technologies when trying to find the technical solution to the design specification.

Kansei concepts (perceptual concepts and the semiotics to express feelings and perception), brand values and aesthetics construct an important part of the product designers' rationale behind their design choices. As the design process progresses, the link to original brand values appears to be gradually lost due to the choices of manufacturing process or the technical constraint. This causes long and costly iteration loops between the design agency and the manufacturers to finally obtain a product that is visually appealing and is technically feasible to manufacture.

We argued that communication of emotional or experiential aspects of the design intent between product designers and engineering designers affects the engineering designers' understanding of what exactly should be designed and what the appropriate technical and manufacturing choices are. However this communication is challenging and needs to be supported.

On the other hand the integration of engineering designers' and product designers' viewpoints from the beginning of the design process, in early design ideas and decisions, has the advantage of providing product designers by the proper information about what is happening at the forefront of technology (e.g. materials and manufacturing methods), and to make the brand values and Kansei concepts more accessible and understandable to engineers, who are not trained in brand design and aesthetics.

Based on this we formulated our research questions into the two following points:

1) How to support the communication of brand and emotional concepts between product designers and engineering designers during the design process of branded products?

2) How to integrate the engineering designers' viewpoint into early design phase of branded products?

These questions are addressed in Chapter 4 and 5 of the dissertation. The answers to the research questions are reminded in following section as a part of the contribution of this thesis.

## 6.2 Contribution

The research presented in this thesis reflects both theoretical and current situation and the issues related to collaboration between product designers and engineering designers. The key contributions derived from this research are as follow:

- In the emotional design literature, many studies aim to model the way in which users perceive or experience products and emotionally respond to them. Although these approaches are very useful to understand the factors contributing to the emotion elicitation, they do not provide a clear understanding of the relation between emotional responses to the brand and to the perception of the physical product. This thesis proposes a framework of "new branded product emotions" that contributes to an understanding about how consumers emotionally respond to a new branded product. According to this framework the consumers' emotional responses to a new branded product can be evoked by consumers' perception of the physical properties of that specific product (Kansei), by the associations to the brand and by the association to the product class. The framework points out the relation between brand and Kansei and provides the basis for future studies by raising interesting questions about how to identify and manage the compatibility and contradictory related to brand image and the product perception. This framework is presented in Chapter 3.

- Many of the studies on capturing the brand essence and user emotions for the design of a new product do not address the issues associated with communicating these among the actors during the design process. On the other hand, studies on collaboration and communication among design actors do not specifically address difficulties arising from the content of the communication being subjective and implicit information about the brand and emotive and perceptual aspect of the product. By bridging these bodies of literature, we contributed to an understanding about the different factors leading the communication breakdown between product designers and engineering designers related to brand values and Kansei concepts. We proposed the "communication challenges in design of branded products" framework. The framework helps to structure a theoretical view on the origins of the difficulties. According to this framework, the knowledge related to the brand (e.g. capturing the brand values, communicating the brand values through explicit and implicit elements) and the knowledge related to the Kansei concepts is challenging to communicate (for example due to the subjective and interpretable nature of the concepts). In addition, general factors contributing to the communication breakdown between product designers and engineering designers (e.g. different technical languages, different sets of principles) makes the communication of the brand values and Kansei concepts even more challenging. This framework provides basis for studies that aim to support the communication between product designers and engineering designers. This framework is presented in Chapter 3.

- To support the communication between product designers and engineering designers, in addition to a theoretical overview (based on literature review), an understanding of the current situation of the collaboration between product designers and engineering designers and the problem they are facing is required. Based on the results of empirical studies, we argued that the current product representations do not support the formalization and communication of Kansei and brand concepts and that product designers and engineering designers are not aware of the importance of this communication. Our research proposed and investigated the development, adaptation, application and evaluation of three fundamentally different approaches based on annotation diagrams, word mapping graphs and multiple-domain matrices (MDM) to support the communication of emotive aspects of design intent. Based on the results of our research, annotation-based tool is seen as the more efficient for communicating the brand values and the Kansei concepts and the relation between brand value and Kansei to the product elements. MDM matrix-based tool was seen as more efficient for communicating information about priorities, the degree of flexibility and to trace change in one property of product on the others. Word mapping-based tool was better for visualization of pathways compared to annotation (in which some of the pathways are implicit) and to MDM (in which finding the pathways is not easy).This contains the answer to our first research question and is presented in Chapter 4.

- To support the integration of engineering designers and product designers' view points earlier in the design process (that is the subject of our second research question), we proposed an integration approach. After identification of engineering information, the approach takes three main steps of classifying and structuring the engineering information (modeling), adapting the representation of the information become more accessible for product designers and to meet the characteristics of early design stages (transforming), and linking engineering information to design information in terms of Kansei concepts and brand values (integrating). The results of the application of this approach permits to reduce the gap between product design and engineering design by linking brand values and Kansei concepts to product and process parameters. The results of our study contributed to the construction of a software (SKIPPI tool) that aims to support the idea generation and design decisions in early design phases of branded products. Given a set of Kansei concepts, SKIPPI generates related product properties and the industrial process to produce them. Likewise given a set of industrial process properties, the SKIPPI tool is supposed to point out the product properties and the Kansei related to them. Our approach to provide data for the SKIPPI tool is described in Chapter 5.

## 6.3 Limitations

To tackle the objective of this thesis and to answer the research questions, we made several choices in terms of the methodology we applied and the theoretical and practical decisions related to the context of the research, and our research environment. Despite of the success in achievement of the research objective, there are some limitations that we pointed out:

- In this research our focus was rather on the consumers' emotion and perception related to visual aspects of the product. The non-visual aspects such as "soft" touch of the surface, or "click noise" of the buttons were outside of the scope. However the emotion responses coming from the consumers' interaction with products are also important to be considered and modeled. This topic is recently addressed in works of Bordegoni & Cugini (2013). Another point is that the consumers' emotional responses to a product may change during the product's lifetime (e.g. from the time they first bought the product, after the first week, first month and first year of usage). The analysis of the relation between physical properties of the product and consumers emotional response, within the context of daily use, is important in creation of products that maintain consumers' interest during the usage time (Yanagisawa et al. 2013). This aspect was excluded from our research.

- We argued that the results of analysis of consumers' perception of the product and the brand image provides input information for product designers and can help in developing a design brief about desired product properties. In our study on supporting the communication of brand and Kansei concepts between product designers and engineering designers, we used the product designers' rationale as input information rather than using directly the results of consumer survey. One of the limitations of doing so is that there might be a gap between what the product designers intend and what the consumers perceive and understand. Furthermore as authors in (Roschuni, Goodman, & Agogino, 2013) state, designers themselves are users of user research. Since Kansei and brand concepts are subjective and tacit, there is yet another communication step that needs to be supported to avoid misinterpretation of the results of consumer survey by product designers.

- We developed and adapted annotation diagrams, word mapping graphs and MDM matrixes and evaluated them by product designers, engineering designers and academics. The results that we provided and discussed in Chapter 4 are based on "a priori" evaluations, because we asked people to evaluate annotation, word mapping and MDM prior to an ongoing design project.The evaluation of tools could be different if they were used in the design practice. Further evaluations are required to study the use of approaches in supporting the communication during a design project. This would help to verify whether product designer and engineering designers face difficulties in constructing the diagrams and communicating information to each other. The effect of familiarity with approaches on the results of evaluation would be reduced if the approaches are evaluated in a design practice. Another limitation that is inherent in the three approaches is the amount of information they can represent without disturbing the readability. Managing the representation of bigger amount of information can be addressed in the development of tools that are based on the annotation, word mapping and MDM.

- The method we used to link engineering information to emotive and Kansei information was highly affected by the context of the SKIPPI project. For the purpose of the SKIPPI tool, we decided to provide a maximum amount of links between process and Kansei data bases. This was achieved through an experimentation in which a limited number of participants linked different parts of two databases to cover the whole data in the process and Kansei databases. To provide more reliable links between Kansei and process information, other techniques and methods can be applied including for example a larger amount of people to establish the links. In this way the occurrence of links can be analyzed.

## 6.4 Perspectives

We consider two main points as the perspectives of this research work:

- More research and experiments are needed on the development and the usage of the tools based on annotation, word mapping and MDM representation, during the design process to verify the efficiency of the tools in supporting the communication and formalizing the reasons behind the design choices.
- We proposed an approach to integrate the engineering viewpoint to design viewpoint, following the steps of modeling, transforming and integrating. The next step concerns the way in which the provided information (through the integrated design and engineering views), is transformed backward according to engineering view point to allow the engineering designers intervene in the proposition and development of solutions all along the design process. The proposed integration approach also contributed in the development of a tool based on word mapping representation (i.e. the SKIPPI tool). More research is required to study how engineering designers and product designers can make use of the information provided by the tool, and how the tool helps to ameliorate the information exchange and the shared understanding between product designers and engineering designers.

In addition, the thesis creates opportunities for further research and work by raising the following questions:

- How the emotional responses related to consumers' interaction with products (and not only the visual aspects) and also the long term feelings (during the usage phase) can be considered for the design of a new product? How the intentions related to these aspects can be communicated between product designers and engineering designers?

- How the communication of emotive aspects of product and brand values can be supported between product designers and other members of the design team who are interacting with product designers including marketing responsible and environmental expert?
- How to make use of current softwares to support the communication of brand and Kansei aspect of the design (for example Anno'Action, Swhift for Annotation, CAM for MDM)?
- What other approaches and tools can be suitable for formalizing and supporting the communication of brand values and Kansei concepts during the design project?
- What method should be applied to support the integration of other experts (for example environmental expert) to early design phases and how to link this information to emotive and brand information in the SKIPPI tool?
- How to adapt or develop further the SKIPPI tool to support following design phases coming after the generation of idea? This includes future work on the evaluation of the SKIPPI tool in design practice and projects and for the purpose of communication support. The construction of a complementary tool that can capture the results of the SKIPPI tool and then make use of the results for other design phases can also be investigated.

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# Résuméé en Francais

## 1) Introduction et questions de recherche

La conception de produits de marque implique la considération d'une part des aspects perceptuels liés à l'apparence du produit (issu de l'évaluation du produit et de l'émotion qu'il procure aux clients, mais aussi aux valeurs que ces clients attachent à la marque) et d'autre part des aspects techniques et d'ingénierie qui se traduisent par la faisabilité de la production, les performances du produit et son cout.

Pour une entreprise fabriquant des produits de marque, il est vital de communiquer son identité aux consommateurs au travers de tous les aspects liés à la marque tout autant qu'au travers du produit lui-même. Pour cela, le design du produit et son apparence peuvent bien sur agir comme un média pour reconnaitre la marque et pour rappeler ses valeurs au travers des propriétés du produit. Certaines approches cherchent uniquement à traduire les valeurs de la marque dans des propriétés physiques du produit. Ces approches s'appuient fortement sur l'expérience et ne peuvent être expliquées et formalisées que jusqu'à un certain degré. Communiquer avec succès les valeurs de la marque aux clients nécessite en premier lieu une compréhension de comment les clients perçoivent et interprètent les produits.

Le mot Kansei est Japonais. Il est difficile à traduire en Français. Il traite de l'émotion et de la perception qu'ont les clients d'un produit. L'approche de l'ingénierie Kansei prend en compte les sentiments et les émotions des clients au travers des mots Kansei. Elle aide ainsi le designer à comprendre ce que le produit en cours de conception devra ou ne devra pas inclure pour répondre aux attentes des clients. Bien que cette approche fournisse des informations utiles pour les phases amont de la conception, elle n'assiste pas le processus dans son entier et ne permet donc pas d'assurer l'implémentation des concepts Kansei dans les solutions proposées pour le produit.

Dans un contexte de conception multidisciplinaire, les designers et les ingénieurs de développement du produit se doivent de collaborer et communiquer pour concevoir avec succès un produit qui sera émotionnellement intéressant pour les clients, communiquant les valeurs de la marque, et techniquement performant, c'est-à-dire réalisant les fonctions attendues et fabricable facilement.

Dans cette thèse nous considérons que pour la plupart des produits, même si les rôles des designers et des ingénieurs parfois s'entrecroisent, ce sont les designers qui sont responsables du produit dans sa globalité, son apparence, ainsi que des spécifications des formes du produit. Ils sont ainsi responsables de l'esthétique, de l'attractivité du produit, de l'interface avec l'utilisateur, de la sémantique et du sens associés à tout ou partie de l'objet pour porter les valeurs de la marque et susciter les réponses émotionnelles attendues. Les ingénieurs traitent des aspects mécaniques, électriques et électroniques, et prennent en charge les coûts, la robustesse et la disponibilité des technologies (pour la fabrication, l'assemblage, la maintenance, …) quand ils cherchent les solutions techniques pour répondre aux spécifications techniques.

La collaboration entre les designers et les ingénieurs est souvent difficile notamment à cause de leur connaissances de base différentes (différents background), de leur façon de travailler qui n'est pas la même, et aussi de leurs responsabilités qui sont parfois contradictoires.

Dans la littérature scientifique qui a trait à la conception de produits, on trouve plusieurs méthodes et outils pour assister la communication entre les acteurs de la conception. L'une de ces approches, à laquelle les chercheurs du laboratoire G-SCOP ont largement contribué, est la conception intégrée.

Dans cette approche il s'agit de prendre en compte le point de vue de tous les acteurs de la conception, d'intégrer ces points de vue, et ce dès le début du processus. Ceci permet de réduire les coûts et les délais qui seraient dus à des changements émergeants dans des phases plus avales du processus.

En synthèse, on constate que d'une part les approches développées dans la littérature propre à l'ingénierie émotionnelle, telle que le Kansei, n'assistent pas le processus dans son entier et n'adressent pas les difficultés liées à l'implémentation simultanées des concepts Kansei et de valeurs de la marque dans un produit physique. Par ailleurs, les approches du domaine de l'ingénierie, qui assistent la communication et l'intégration des acteurs de la conception, ne ciblent pas particulièrement le sujet de la communication à propos des valeurs de la marque et des concepts Kansei entre les designers et les ingénieurs.

Cette recherche traite donc de la question de comment assister la communication entre les designers et les ingénieurs lors de la conception d'un produit, et de comment assister l'intégration du point de vue de l'ingénieur au plus tôt dans le processus de conception de produit de marque.

Les deux questions de recherche au centre de nos préoccupations sont donc :

1) **Comment assister la communication des concepts propres à la marque et aux émotions entre les designers et les ingénieurs au cours du processus de conception de produits de marque ?**
2) **Comment intégrer le point de vue des ingénieurs dans les phases amont de la conception de produits de marque ?**

## 2) Méthode de recherche

Pour approfondir notre problématique et traiter de nos questions de recherche, nous avons investigué deux visions complémentaires de la conception : la conception vue du côté des designers et vue du côté des ingénieurs. Nous avons suivi quatre étapes principales (figure 1) : l'identification du problème, la proposition de solutions, leur application, et enfin leur évaluation. Des revues de littérature, des interviews, des questionnaires et des analyses de documents ont été utilisés pour collecter de l'information à partir des institutions académiques et des industries.

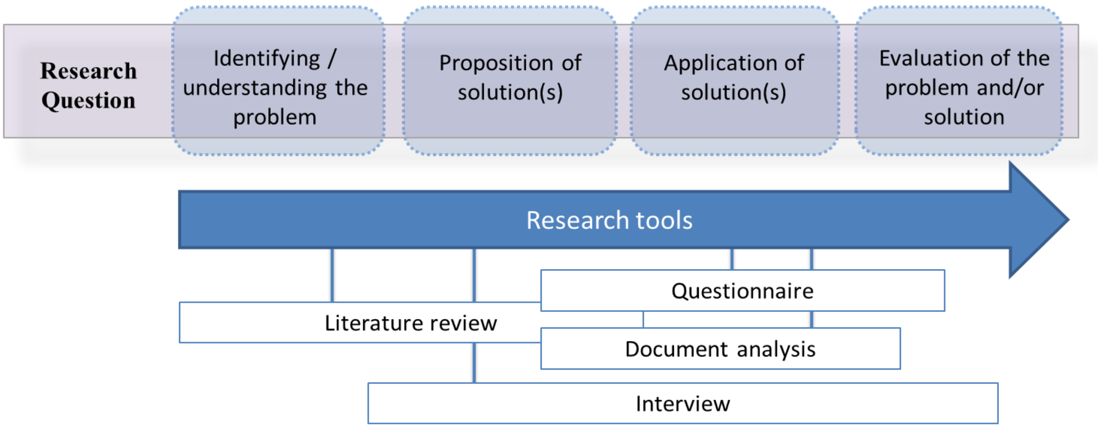



Figure 1: Les étapes de notre méthode de recherche

Cette thèse a été menée dans le contexte du projet SKIPPI ((System for Kansei Image Product Process Innovation) qui est un projet ANR. L'objectif du projet était de développer un logiciel pour assister le travail d'idéation initial et de prises de décisions lors de processus de conception de produits de marque. Des chercheurs de quatre laboratoires de recherche (LCPI, G-SCOP, LIP6, PSCYCLE) ainsi que des partenaires industriels (Dièdre Design et Option France) étaient réunis et ont collaboré dans le cadre du projet SKIPPI. La mission initiale du laboratoire G-SCOP était de modéliser, de caractériser et de proposer des informations relatives au produit et process (au sens des processus de production incluant les processus de fabrication, d'assemblage, …) à intégrer pour le développement du logiciel.

Bien que l'environnement académique offre un espace privilégié pour acquérir une vue théorique et scientifique sur les processus de conception, les problèmes et les défis qui peuvent être associés, observer le monde industriel aide à mettre en évidence certaines questions négligées. Au cours de cette thèse nous avons eu la possibilité d'interviewer des designers et des managers de projets de deux compagnies Françaises (Diedre Design et Option France), toutes les deux partenaires du projet Skippi. Nous avons ainsi constitué ce que nous avons appelé les premieres interviews en profondeur (in-depth interviews). Plus tard, nous avons interviewés des designers et des ingénieurs travaillant dans d'autres compagnies produisant des produits de marque pour avoir une vue plus large sur notre sujet de recherche. Ces secondes interviews constituent nos interviews d'évaluation (evaluation interviews).

La figure 2 montre une vue d'ensemble de la méthode de recherche que nous avons suivie, et les outils que nous avons utilisé pour répondre à nos questions de recherche. Nous reviendrons sur cette figure dans les chapitres 4 et 5.

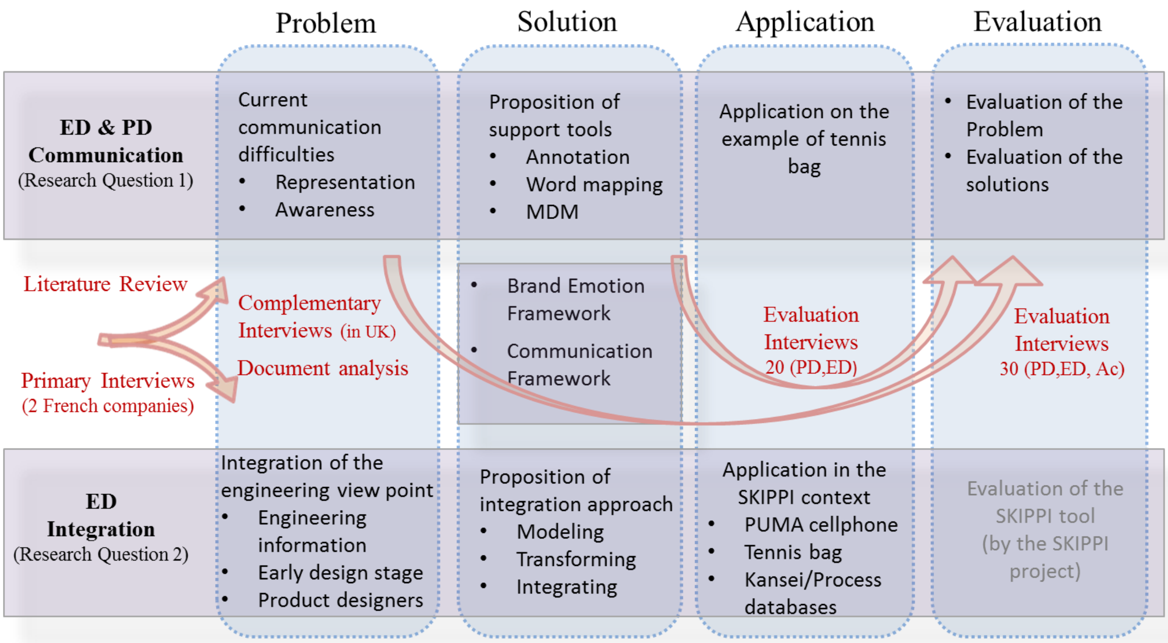



Figure 2 : Vue d'ensemble de notre méthode de recherche et des outils associés

## 3) Contribution théorique

Cette partie a pour but de fournir un moyen de comprendre comment les clients réagissent émotionnellement lorsqu'ils sont confrontés à un produit nouveau. Nous proposons pour cela tout d'abord un cadre dans lequel sont tracées et expliquées les relations entre les aspects Kansei et les valeurs de la marque. Puis les défis dans la communication des concepts Kansei et des valeurs de la marque tout au long d'un processus collaboratif de conception sont décrits, et les points clefs sont récapitulés dans un second cadre. Ce cadre a l'avantage de récapituler, de rassembler dans une représentation unique des facteurs qui n'avaient pas été mis en relation et qui sont la base pour notre étude sur les défis de la communication lors de la conception de produits de marque.

### a) Cadre d'études des émotions associées à un produit de marque

L'émotion s'appuie sur un ensemble de facteurs objectifs et subjectifs qui permettent de faire émerger des sentiments et conduisent à un comportement. Les réponses émotionnelles sont construites à partir de l'expérience et de l'articulation de ces émotions. Les concepts Kansei sont liés à la perception et supportent une sémantique qui permet l'expression de la façon dont nous percevons les produits.

Pour mieux comprendre la relation entre les aspects Kansei et marque, ce paragraphe présente un cadre (figure 3) que nous avons construit, inspiré par le modèle 'VPE' (Visual Product Expérience) de Warell (Warell 2008), par le modèle de 'Product Emotion' de Desmet (Desmet 2003, Desmet and Hekkert 2007) et par le modèle 'Semantic Transformation' de Karjaleinan (Karjaleinan 2004).

Selon ce cadre la réponse émotionnelle d'un client à un nouveau produit de marque se construit à partir de trois éléments : la perception qu'a ce client des propriétés physiques de ce produit spécifique, l'association du produit à la marque, l'appartenance du produit à une classe particulière de produit. De plus, en accord avec Crilly (Crilly et al., 2008), des facteurs tels que le background culturel du client, ses croyances, ses valeurs, sa personnalité, sont aussi importants à prendre en compte parce qu'ils affectent les réponses émotionnelles.

Dans ce modèle les concepts Kansei sont représentés par des mots incluant une sémantique pour décrire la perception qu'ont les clients des propriétés physiques des produits comme la forme, son poids, ses entités spécifiques, son emballage.

La classe de produits est un label pour tous les produits qui peuvent être classés dans une même catégorie de par leurs fonctionnalités (par exemple la classe des chaussures de sport, celle des téléphones mobiles).

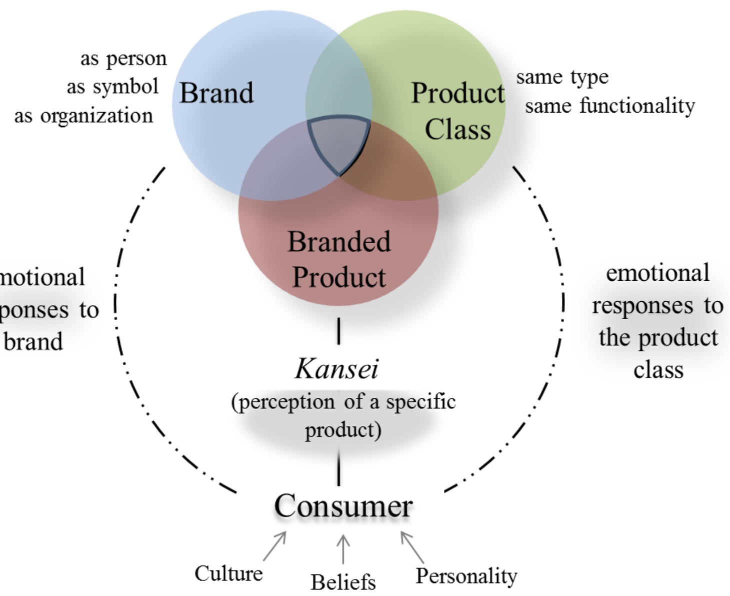



Figure 3: Cadre d'étude des émotions associées à un nouveau produit de marque

En résumé, le fait d'utiliser des formes particulières, des courbes, des couleurs spécifiques dans la conception d'un nouveau produit peut être relié à une intention de communiquer sur les valeurs de la marque, de rappeler l'image de la marque dans l'esprit des clients, de créer une reconnaissance. Ce peut être aussi dans l'intention de générer, à partir de perceptions, des émotions reliées à ce produit spécifique (concepts Kansei). Il est important que ces propriétés physiques ne génèrent pas des émotions contradictoires entre des aspects reliés Kansei ou marque. Par ailleurs, les réponses émotionnelles du client confronté à un nouveau produit de marque ne sont pas générées seulement par les propriétés physiques du produit. Elles sont aussi une conséquence d'une part de leur évaluation de la marque en elle-même et d'autre part de leur attrait ou non pour la classe de produit auquel ce nouveau produit appartient. Le background culturel du client, sa personnalité, ses croyances contribuent également à sa perception et à sa réponse émotionnelle face au produit.

### b) Cadre d'études des challenges associés à la communication

En posant un regard sur le processus de conception des produits de marque sous un angle de la communication, la compréhension des défis liés à la communication des concepts Kansei et des valeurs de la marque entre les designers et les ingénieurs rassemble trois pans de littérature scientifique reliés mais rarement connectés :

- La gestion de l'image de marque et de la marque
- La perception de l'utilisateur et le 'Kansei Engineering'
- La conception collaborative et multidisciplinaire

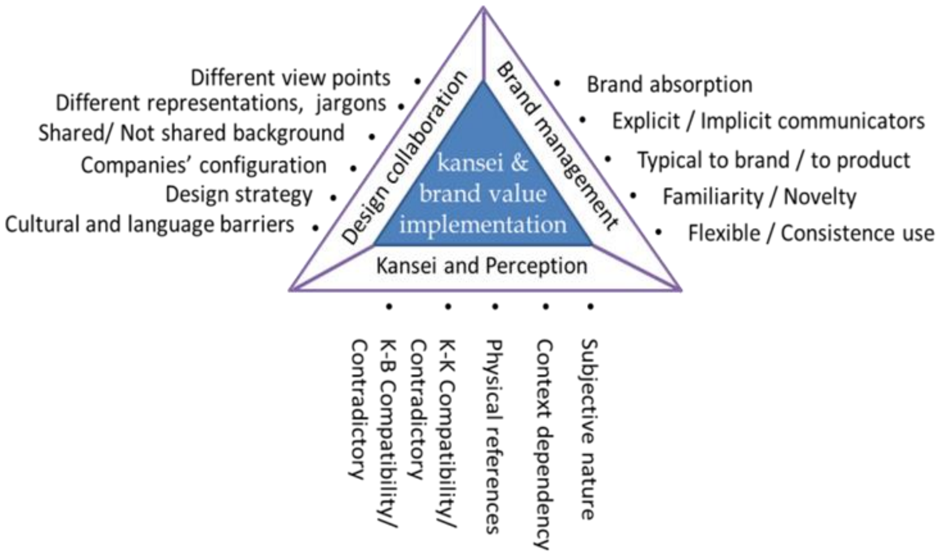



Figure 4: Cadre d'études des challenges lies à la communication au cours des processus de conception de produits de marque

Lors de la conception de produits de marque, les designers et les ingénieurs se doivent de collaborer et communiquer pour implémenter les concepts Kansei et les valeurs de la marque dans les nouveaux produits, et ce tout au long du processus de conception.

Du point de vue de l'image de marque, cela nécessite :

- de capturer et absorber les valeurs de la marque,
- de communiquer ces valeurs en s'appuyant sur des éléments explicites et implicites,

- d’identifier les éléments qui sont typiques de la marque et ceux qui sont typiques du produit
- d’équilibrer entre familiarité et nouveauté
- de prendre des décisions sur l’utilisation flexible ou cohérente des références à la marque, sur la famille de produits

Les points ci-dessus sont relatifs à des connaissances propres à la marque. Le fait d’appliquer cette connaissance lors de la conception de nouveaux produits est vu comme un processus plutôt intuitif. La communication de telles connaissances, souvent considérées comme tacites ou implicites, est donc très difficile.

De même, la connaissance associée à la perception des clients et les aspects Kansei est considérée comme implicite, voire tacite. Bien que l’approche Kansei puisse fournir des informations d’entrée, et jusqu’à un certain point puisse permettre l’explicitation de ces connaissances et la mise en lien des perceptions et émotions avec les propriétés physiques du produit, la mise en usage de telles connaissances au cours de la conception d’un nouveau produit n’est pas complètement évidente. En effet les concepts Kansei sont dépendants du contexte. Par exemple le sens du mot ‘doux’ change d’un produit à l’autre, et il est difficile de dire s’il existe un lien absolu entre ‘formes arrondies’ et une ‘impression de douceur’ qui serait valable pour tout type de produit. Par ailleurs il nous faut considérer les effets des éléments de produits locaux sur la perception de la vue globale que peut avoir le client sur le produit. Certains éléments locaux sont plus importants que d’autres car ils peuvent affecter la perception globale sur le produit (Chang & Wu, 2009). Par exemple le type de boutons digitaux d’un téléphone mobile peut influencer le jugement d’un client sur l’image globale de simplicité/complexité du produit (Chang & Wu, 2009). En cas de conflit entre le kansei lié à un élément spécifique du produit (par exemple les coins arrondis, ou un matériau utilisé pour une partie spécifique d’un produit) et le Kansei lié à l’apparence globale du produit, des décisions particulières et adaptées devront être prises.

La communication des concepts Kansei parmi les membres d’une équipe projet est difficile car les concepts associés sont subjectifs. Comme (Barnes et al) l’expriment ‘ … Soft could be expressed against the construction of the seat, the aesthetic appearance or the weak construction of the automobile’ (Barnes et al., 2008). Deux personnes peuvent utiliser le même mot pour signifier des choses différentes ou s’efforcer de trouver ensemble les mots qui décrivent le mieux ce qu’ils veulent exprimer. Dans la plupart des cas, utiliser une référence physique (des images ou des exemples de produits) est une voie prometteuse pour mieux comprendre le sens d’un concept kansei.

La nature subjective des concepts Kansei signifie que des personnes différentes peuvent avoir des interprétations différentes d’un même mot, laissant de la place à l’ambiguïté. La large interprétation de ces concepts dans la phase de génération d’idée de la conception peut contribuer à la créativité et à l’innovation (M. Kleinsmann & Valkenburg, 2008). Mais plus tard dans le processus de conception cette ambigüité peut conduire à des incompréhensions et interrompre des collaborations (Stacey & Eckert, 2003). Les personnes qui interagissent font usuellement l’hypothèse qu’ils partagent certains prémisses jusqu’à ce qu’ils notent, à partir de leurs interactions que ce n’est pas le cas (Karlgren and Ramberg 2012).

En résumé, les facteurs suivants constituent les fondements des challenges de la communication des concepts Kansei entre les acteurs de la conception :

- la nature subjective et interprétable des concepts Kansei,
- la dépendance de ces concepts Kansei au contexte

- le besoin de références physiques (images or échantillons de produit) pour les concepts Kansei pour permettre une meilleure compréhension du sens
- La compatibilité entre les concepts Kansei liés à des éléments spécifiques et ceux liés à l'apparence globale du produit
- la compatibilité des concepts Kansei liés au produit et à l'image de marque

En plus des challenges reliés à la communication des valeurs de la marque et des concepts Kansei, les facteurs contribuant à la rupture de la communication entre le designer et les ingénieurs est un autre axe de notre cadre d'études. Ces facteurs sont associés aux différentes expertises ayant à collaborer durant la conception :

- Différents ensembles de principes, objectifs, formations, soit différents points de vue sur la conception du produit
- Différentes représentations du produit en cours de conception, exprimant différents types d'informations
- Différents langages techniques (jargons)
- le degré de background partagé (par exemple des expériences de travail en commun lors de projets précédents)
- l'impact de l'organisation et de la configuration de l'entreprise (par exemple la localisation des départements de design et d'ingénierie, la définition des tâches de chaque département, l'ordre chronologique des activités, …)
- l'impact de l'approche de conception de l'entreprise (par exemple pilotée par le design ou par l'ingénierie)
- Le langage et les barrières culturelles

Le cadre d'études que nous avons introduit (et illustré en figure 4) nous aide à structurer la vue théorique sur les origines des difficultés auxquelles les designers et les ingénieurs sont confrontées pour l'implémentation des concepts Kansei et les valeurs de la marque lors de la concepion d'un nouveau produit. Ce cadre fournit les bases pour des études dont l'objectif est d'assister la communication entre les designers et ingénieurs. La proposition d'outils support nécessitant à la fois des apports théoriques et empiriques, la prochaine partie présente nos investigations empiriques et les résultats associés.

## 4) Outils support à la communication

Dans ce chapitre, nous adressons le problème de communication entre les designers et les ingénieurs. Nous nous appuyons sur les résultats de nos premieres interviews (in-depth interviews) dans deux entreprises Françaises et sur les interviews complémentaires conduits en Angleterre. A partir de ces interviews et de notre étude bibliographique, nous identifions les sources des difficultés liées au processus de conception des produits de marque. Le cœur du problème est dû à la perte des valeurs de la marque et des concepts Kansei durant le processus de conception à cause d'une communication inefficace entre designers et ingénieurs. Nous mettons aussi en évidence que les représentations actuelles du produit ne permettent pas la formalisation et la communication des concepts Kansei et des valeurs de la marque. Des outils comme l'annotation, les cartes de mots et le MDM (Multiple-Domain Matrix) sont des voies intéressantes pour visualiser les relations entre les éléments de solution et les concepts Kansei et valeurs de la marque.

## Développement de trois outils potentiels

Pour trouver des outils appropriés et candidats à supporter cette communication, nous avons étudié dans la littérature les outils utilisés pour exprimer des relations entre différentes natures d'informations relatives au produit. Des modèles de liens sur le produit ou de connectivité mettent en lumière les relations entre des éléments du produit. Ces modèles de type relations entre données ou graphe de structure peuvent être représentés par des visualisations basées sur des matrices ou des réseaux (Keller et al., 2006b). Les approches basées sur des matrices sont populaires en conception de produit. Elles incluent par exemple les approches QFD (Quality Function Deployment) et DSM (Design Structure Matrix) ou MDM (Multiple-Domain Matrix). Les diagrammes basés sur la notion de réseau incluent, dans le domaine de la conception de produit, les diagrammes de décomposition du produit de type arbre, les FAST (Functional Analysis System Technique).

Basé sur cette revue de littérature, les matrices Multiples Domaines (ou MDM) dans une approche basée sur les matrices, et le 'Word Mapping' ou 'concept mapping' dans une approche basée sur la notion de réseau ont été sélectionnées comme outils potentiels pour assister la communication entre les designers et les ingénieurs.

La sélection des approches a aussi été influencée par l'histoire de la recherche dans le laboratoire G-SCOP. La notion d'annotation, qui a été étudiée comme outil dans de multiples contextes pour la conception collaborative (voir par exemple Boujut, 2003; Hisarciklilar & Boujut, 2009; Prudhomme et al., 2010), nous a ainsi semblé être une voie prometteuse. En effet les concepteurs sont familiers avec les dessins et les représentations digitales 3D et annotent de manière assez naturelle ces représentations pour fournir des informations additionnelles à propos du produit. Ainsi, en plus des deux approches déjà mentionnées ci-dessus, nous avons choisi de nous intéresser également à l'annotation comme outil de communication en cours de processus de conception.

La figure 5 montre un exemple de chacune de ces trois approches appliquée à l'exemple d'un sac de sport. Plus de détails seront donnés pour la description de chacune de ces approches dans la suite du texte.

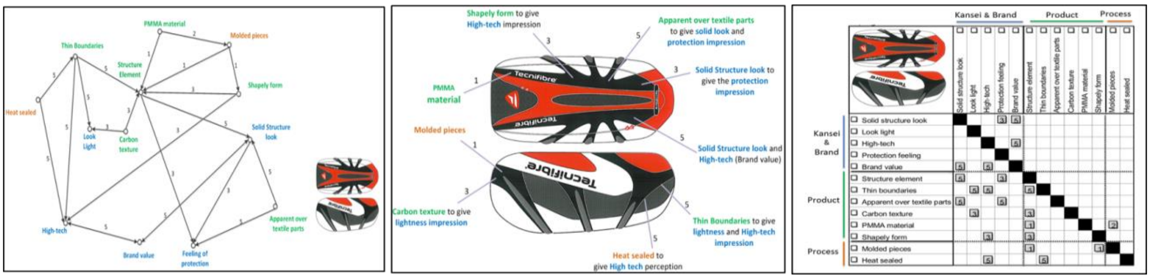


Figure 5: Exemples de Word mapping (gauche), Annotation (milieu) and Multiple-Domain Matrix (droite)

## Application

Nous avons appliqué ces trois approches : Annotation, MDM et Word Mapping à un exemple issu de nos premières interviews (in-depth interviews). Au cours de ces interviews initiaux, deux designers et leur manager de projet ont pris comme exemple un de leur précédent projet concernant un sac de tennis pour l'entreprise Technifibre. Technifibre est une marque de sport produisant notamment des raquettes de tennis. Le manager de projet et les designers ont explicité en détail l'histoire de la conception d'un sac de tennis qui a conduit à la réalisation d'un prototype non satisfaisant. Sa conception fut faite en France. Le prototype fut fabriqué en Chine et envoyé en retour aux concepteurs en France. Les intentions émotionnelles des concepteurs, leurs liens supposés avec les propriétés physiques du produit et les raisons pour lesquelles le prototype échoua à faire émerger ces émotions furent identifiées par l'analyse des commentaires des différents acteurs. Par exemple, un des designers, dit à propos de l'épaisseur des bords des éléments de structure : 'nous voulions quelque chose de léger, cela donne une impression de lourdeur… ils ont pris une feuille de plastique et ont coupé les bords. N'importe qui (les concurrents) peut faire cela… Cela ne donne pas du tout une impression de high-tech … C'était supposé être scellé à chaud'. De ces commentaires on peut conclure que les bordures fines étaient spécifiées pour donner une impression de légèreté et que le procédé de soudure à chaud devait donner une impression high-tech. Nous avons catégorisé les mots ou locutions : 'impression de high-tech' et 'légèreté' comme respectivement des informations de marque et de Kansei ; 'bordures fines' comme une information sur les propriétés du produit ; thermoscellage comme une information de processus de production. A partir des commentaires verbaux au cours de l'interview, nous avons associé à chacun de ces éléments un niveau d'importance.

La figure 6 montre le diagramme d'annotation construit par nos soins pour le sac de tennis. Les annotations présentées sur cette figure sont relativement simples et ont été créées en utilisant le logiciel Visio. Les lignes d'attache montrent le point de référence sur le produit et l'orientation du lien est implicite dans le texte. Par exemple la texture carbone est l'élément de base qui contribue à l'impression de légèreté, et ceci est inclut implicitement dans le texte 'texture carbone pour donner une impression de légèreté'. Le diagramme montre également qu'il est plus acceptable de discuter d'un changement du matériau PMMA (Polymethyl methacrylate) de l'élément de structure (niveau d'importance 1) que de discuter de la texture carbone du panneau latéral (niveau d'importance 3). Dans le diagramme : la couleur bleue concerne les informations liées à la perception, aux émotions et à la marque; la couleur verte concerne des informations liées à des propriétés du produit ; la couleur orange concerne des informations liées à des processus ou procédés de production.

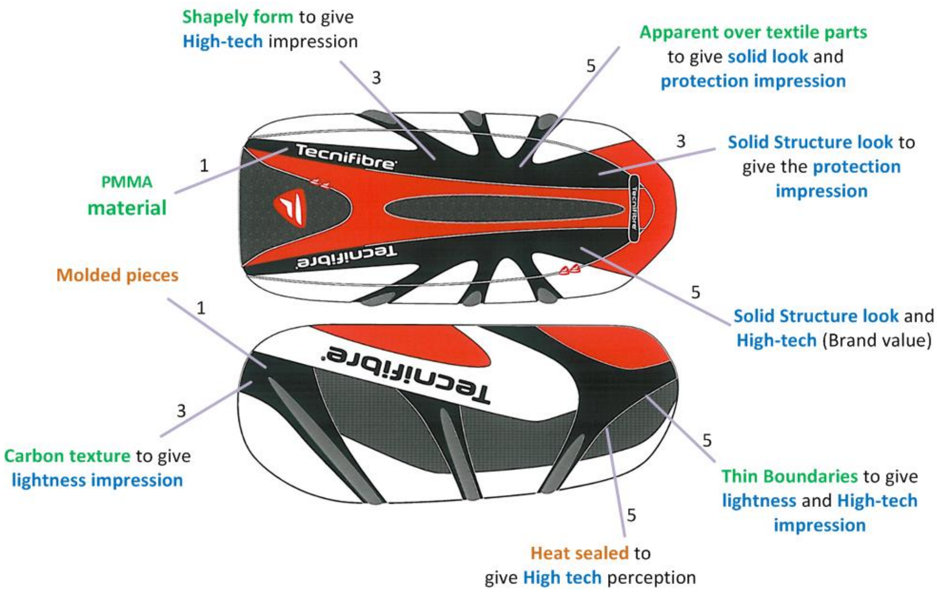



Figure 6: Diagramme d'annotation pour l'exemple du sac de tennis

La matrice multi-domaine (MDM) pour le sac de tennis est montrée sur la figure 7. Elle est construite en utilisant le logiciel CAM. Si on lit une ligne, l'entité de la ligne contribue à réaliser les entités inscrites dans les colonnes. Par exemple, 'l'impression de structure solide' contribue à créer d'une part un 'sentiment de protection' et d'autre part les 'valeurs de la marque'. Si on lit sur une colonne, l'entité est réalisée grâce aux autres entités. Par exemple, 'l'impression de structure solide' est réalisée d'une part grâce à la 'valeur associée à la marque' et d'autre part par 'l'élément de structure' qui est 'apparent sur les parties textiles' du sac.

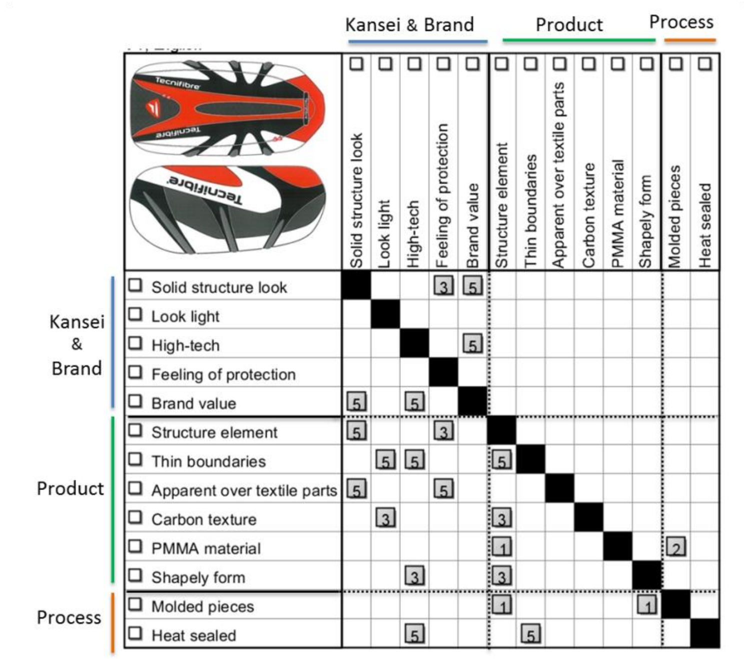



Figure 7: Diagramme MDM utilisé pour relier les domaines Kansei et brand aux domaines de produits et processus, appliqué à l'exemple du sac de tennis

Le graphe de Word Mapping est montré en figure 8. La direction de la flèche indique que l'élément à l'origine de la flèche contribue à atteindre l'élément cible associé à l'extrémité de la flèche. Par exemple, 'l'impression de structure solide' contribue au sentiment de protection et est lui-même une conséquence de 'l'élément de structure' et du fait qu'il est 'apparent sur les parties textiles'. Le graphe a été créé en utilisant le logiciel Visio.

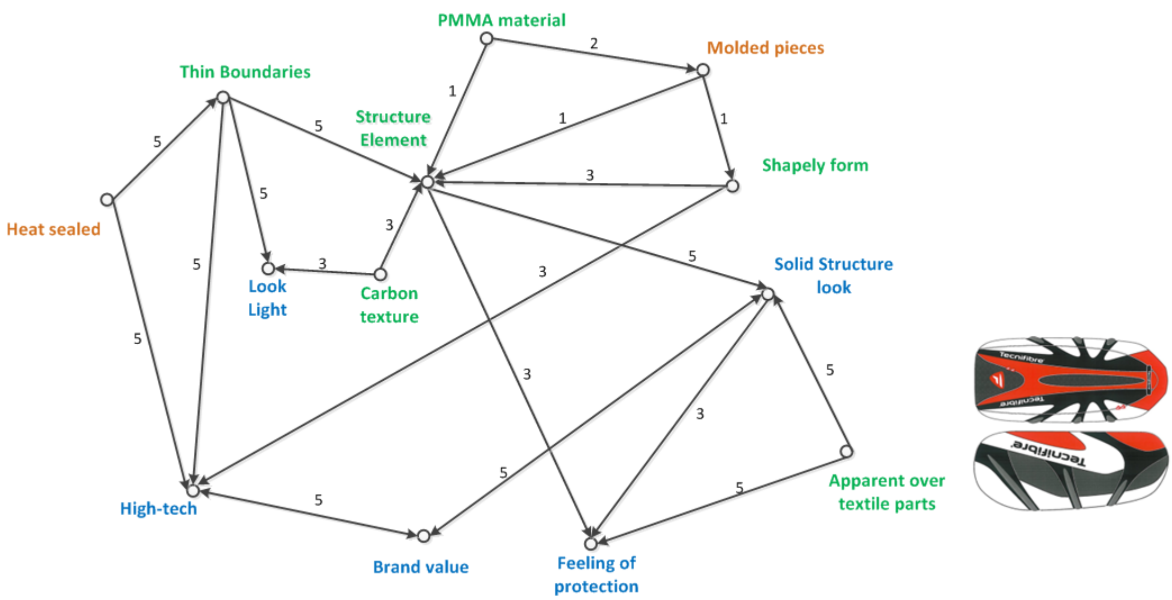



Figure 8: Diagramme Word mapping appliqué à l'exemple de l'élément de structure du sac de tennis

### Evaluation des outils

Pour évaluer les trois approches trente interviews ont été menées. Un total de vingt designers et ingénieurs travaillant dans différentes entreprises fabriquant des produits de marque ont participé à cette étude. De plus, dix académiques qui ont un background soit comme ingénieur soit comme designer, ont été questionné en raison de leur expérience dans des projets de recherche en collaboration avec des entreprises de marque ou leur expérience en tant qu'expert. Les interviews ont été enregistré (audio) et les questionnaires renseignés ont été archivés pour de futures analyses.

Le questionnaire a tout d'abord été préparé et donné aux participants au début de l'interview. Chaque participant a rempli le questionnaire individuellement. Il lui a été demandé d'expliquer ses réponses. Le temps moyen de chaque interview est de trente minutes. Sur la première page, il est demandé aux interviewés de renseigner : son background éducatif, son rôle et ses responsabilités dans l'entreprise, ses années d'expérience, le nombre de designers et d'ingénieurs travaillant dans l'entreprise, et quelques informations au sujet des situations de collaboration dans l'entreprise. Dans la seconde partie du questionnaire, les interviewés ont à répondre à neuf questions pour évaluer l'outil d'annotation, le MDM et le Word Mapping appliqué à l'exemple du sac de tennis. Pour chaque diagramme, et pour chaque item, les participants associent un niveau d'adéquation (zéro, faible, medium, haut). Sur la dernière page, les participants doivent choisir l'outil qui leur parait le plus adapté d'un point de vue global et expliquer les raisons de leur choix. Puis pour terminer, il leur est demandé d'écrire deux avantages et inconvénients pour chacun de ces diagrammes-outils.

### Résultats

La figure 9 ci-dessous permet de comparer visuellement la moyenne du niveau d'adéquation (zéro=0, faible=1, medium=2, haut=3) que chaque groupe associe à chaque outil : Annotation, MDM et Word Mapping.

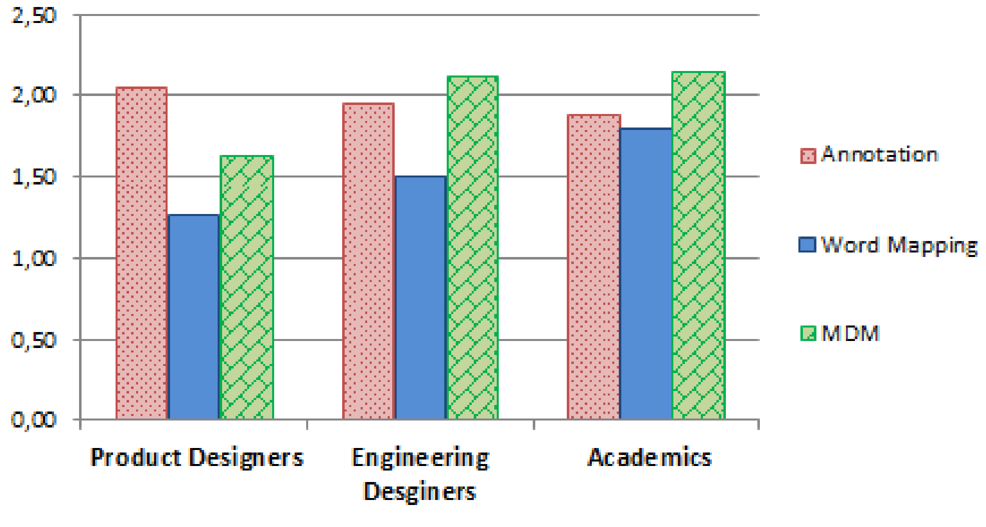



Figure 9: Evaluation moyenne des outils Annotation, Word Mapping, MDM par chaque groupe de participants

Selon cette figure 9, les designers trouvent l'annotation plus efficiente que le MDM et le Word Mapping pour communiquer les concepts relatifs au Kansei et aux valeurs de la marque. Pour vérifier si cette différence est significative, un test ANOVA (ANalyse Of VAriance) a été conduit. L'hypothèse de nullité 'Il n'y a pas de différence dans l'efficience des outils d'Annotation, de MDM et de Word Mapping pour les designers' est rejetée avec des coefficients F=4,68 et alpha=0,05. Selon les résultats de la méthode ANOVA, il y a une différence significative de l'efficience des trois outils. Pour identifier où se situe la différence, nous avons appliqué un t-Test pour des comparaisons par paires entre outils. A partir des résultats de ces t-Test par paires, il est constaté qu'il y a une différence significative dans l'efficience de l'outil d'Annotation comparé à l'outil MDM (la probabilité de l'hypothèse de nullité vraie (0,001) est plus petite qu'alpha (0,05)). Par ailleurs, il n'y a pas de différence significative pour le Word Mapping comparé au MDM et pour le MDM comparé à l'Annotation.

Le même travail a été réalisé pour les ingénieurs et les académiques. Pour les ingénieurs, il y a une différence significative pour le MDM comparé au Word Mapping. Mais il n'y a pas de différence significative ni pour le Word Mapping comparé à l'Annotation, ni pour le MDM comparé à l'Annotation.

Pour les académiques, selon les résultats de la méthode ANOVA l'hypothèse de nullité 'Il n'y a pas de différence dans l'efficience des outils d'Annotation, MDM et Word Mapping' est accepté (avec F=2,27 et alpha=0,05). Les outils d'Annotation, Word Mapping et MDM ont une efficience similaire. Cependant les résultats de la figure 9 montrent que le Word Mapping est vu comme plus prometteur par les académiques que par les designers et les ingénieurs.

En dépit de cette évaluation critériée faite au regard des attentes pour un outil de communication entre designers et ingénieurs, quand on demande aux participants de choisir globalement leur outil préféré, 67% préfèrent l'Annotation, 27% optent pour le MDM et seulement 6% sélectionnent le Word Mapping comme leur outil de communication préféré.

Malgré quelques inconvénients et limitations, l'Annotation est vu comme l'outil le plus efficient pour communiquer les valeurs de la marque et les concepts Kansei, tout comme les relations entre les valeurs de la marque et le Kansei vers les éléments constituants le produit. La matrice MDM est vue comme plus efficiente pour communiquer les informations de priorité ou de hiérarchie, le degré de flexibilité, et aussi pour tracer les changements dans les propriétés du produit. Word Mapping est considéré comme meilleur pour la visualisation des liens comparativement l'outil d'Annotation (pour lequel certain lien restent implicites) ou à l'outil MDM (pour lequel la recherche des liens n'est pas facile). Ces trois outils peuvent être modifiés et améliorés pour mieux répondre aux exigences. Ils peuvent aussi être utilisés de manière complémentaire tout au long du processus de conception.

## 5) Intégration support

Ce chapitre traite de la deuxième question de recherche : Comment intégrer le point de vue des ingénieurs dans les phases amont de la conception de produits de marque ? Nous proposons une approche d'intégration et décrivons l'application de cette approche dans le contexte du projet SKIPPI. Cette approche est faite de trois étapes principales de modélisation, transformation et intégration. La figure 10 récapitule ces étapes et l'utilisation des outils de représentation de l'information (modèle ProP et modèle lexical) utilisés pour construire cette intégration.

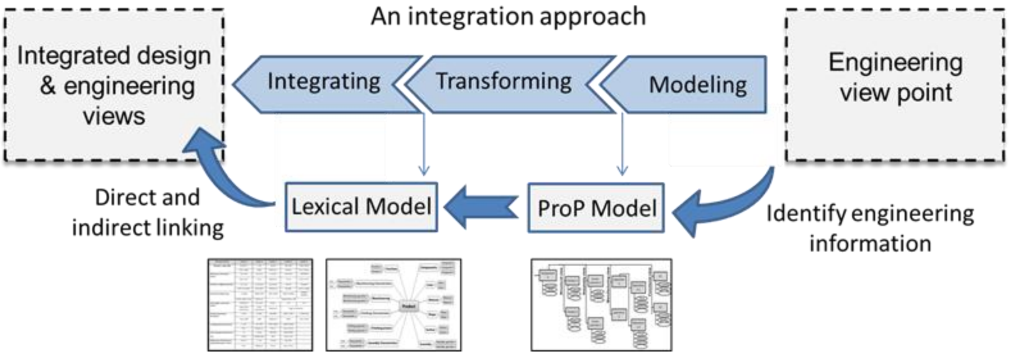



Figure 10: Proposition d'une approche d'intégration

## Application de l'approche d'intégration dans SKIPPI

Pour identifier l'information d'ingénierie à intégrer, nous avons mené les premières (in-depth) interviews dans les deux entreprises partenaires du projet SKIPPI (Diedre Design et Option France). Nous avons alors rassemblé des données reliées aux projets de conception passés, dont celles associées au projet du sac de tennis Tecnifibre pour Dièdre et du téléphone mobile PUMA pour Option France.

## Modeling

A partir de l'analyse des documents collectés, d'exemples de produits réels, et de tables de caractéristiques des différents procédés de production, nous avons construit le modèle ProP du sac de tennis et du téléphone mobile. Un modèle ProP est un modèle produit adapté à nos besoins de description des produits et processus de production des composants et assemblages. Un extrait du modèle ProP du téléphone mobile est représenté en figure 11. Nous avons extrait les noms et propriétés des composants à partir de documents proposés par Option France. Par exemple le logo frontal (Front logo) est une pièce du couvercle supérieur (upper housing) qui est lui-même une partie du corps principal (main body). Le logo frontal est en matériau plastique et est de couleur argent. Il est assemblé au couvercle supérieur par une opération de soudage. Il est obtenu par moulage par injection. Par une opération NCVM (Non Conductive Vacuum Metallization), un film fin de métal non conducteur est placé sur la surface plastique moulée. Des relations entre caractéristiques propres à des composants de différentes vues supportent la collaboration entre experts de ces différentes vues. Par exemple, pour le logo frontal, les formes (R1) et les matériaux (R2) doivent être compatibles avec le procédé de moulage par injection. La version complète du modèle ProP du téléphone mobile PUMA est représentée en annexe 4.

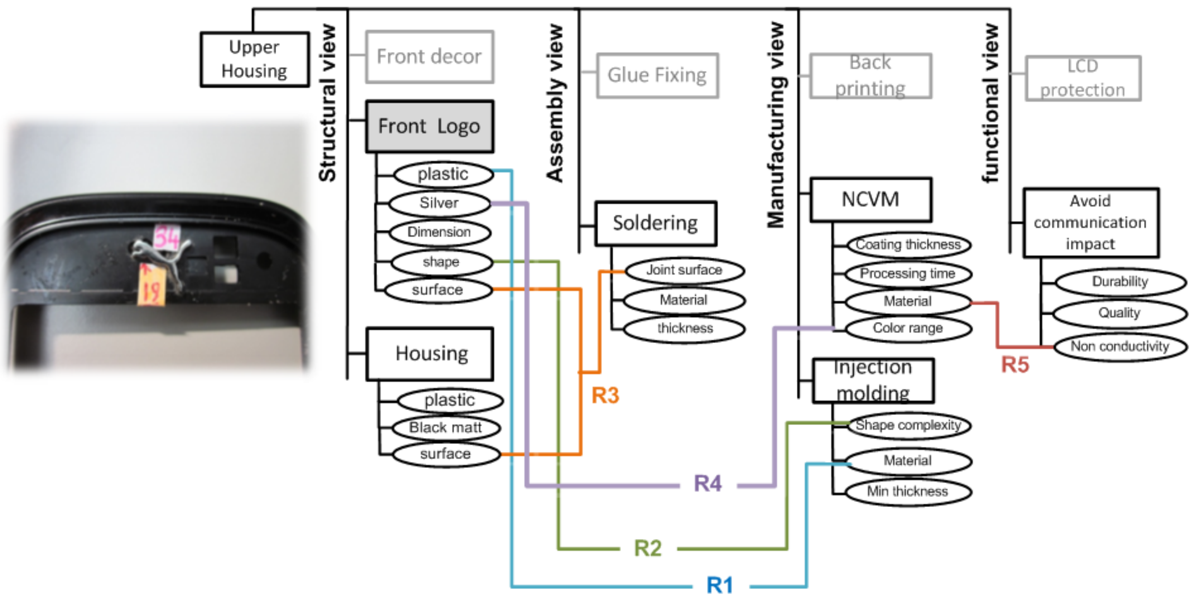



Figure 11 : Exemple de modèle ProP : une partie du téléphone mobile PUMA

## Transformation

La figure 12 montre le modèle lexical construit pour l'exemple du téléphone mobile, à partir d'une transformation du modèle ProP illustré en figure 11.Le modèle lexical du téléphone mobile PUMA contient les mêmes relations que le modèle Prop (relations R1, R2, R3, R4 et R5). Cependant, à cause des changements dans la représentation, quelques relations qui sont implicites dans le modèle ProP apparaissent dans le modèle lexical. Ces relations sont représentées en lignes pointillées de couleur grise. Par exemple 'plastic' est connecté au composant 'housing' par une ligne pointillée grise dans le modèle lexical car le matériau plastique est une caractéristique du composant couvercle (housing) dans le modèle ProP et cette relation est donc implicite dans le modèle ProP.

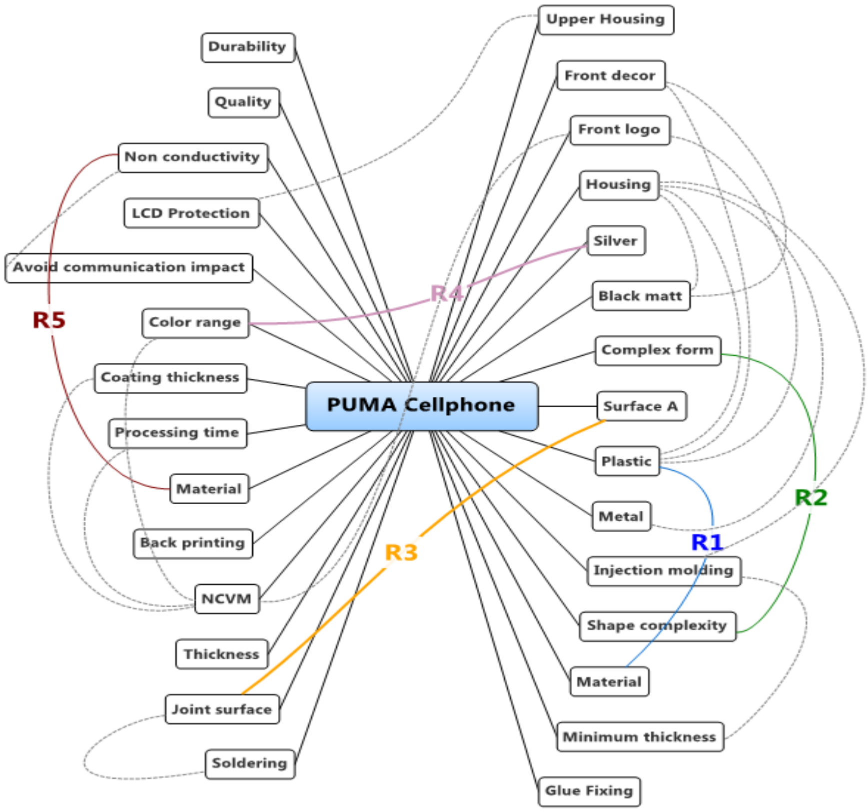



Figure 12: Modèle lexical appliqué au cas du telephone mobile PUMA

A partir du modèle lexical nous avons identifié différentes catégories (labels dans Skippi) d'informations pour les bases de données produit et processus de production de l'outil SKIPPI. Pour la base de données produit, nous avons différentié les labels suivants : composants, forme, couleur, matériau, surface et fonctions. Pour la base de données processus de production, nous proposons les labels suivants : fabrication, assemblage, finition, caractéristiques de fabrication, caractéristiques d'assemblage, caractéristiques de finition (voir table 1).

| | | | |
|---|---|---|---|
| **Product** | • Components<br>• Shape | • Color<br>• Material | • Surface<br>• Function |
| **Process** | • Assembly<br>• Assembly characteristics | • Manufacturing<br>• Manufacturing characteristics | • Finishing<br>• Finishing characteristic |

Table 1: Catégories d'information pour les bases de données produit et process

## Intégration

Dans l'étape d'intégration, les bases de données processus de production et Kansei doivent être connectées. L'établissement de liens directs et indirects entre les éléments de ces deux bases de données nécessite une collection de données et un nombre important de personnes pour évaluer les liens possibles entre éléments caractérisant les processus de production et les concepts des espaces Kansei/Marque. Pour ce faire, une expérimentation a été mise en place, impliquant notamment les partenaires industriels (Dièdre Design et Option France). Les objectifs initiaux de cette expérimentation étaient doubles : d'une part capturer et analyser les relations récurrentes entre les mos Kansei/Marque et les mots processus de production utilisables dans le graphe SKIPPI, et d'autre part capturer un maximum de relations entre les bases de données Kansei et Processus de production pour de futurs développements de l'outil SKIPPI.

Considérant le nombre total de mots dans les bases de données Kansei/Marque et process à l'instant de notre expérimentation (736 mots kansei/Marque et 176 mots process), faire émerger en même temps les relations récurrentes et le nombre maximum de relations apparait être délicat et contradictoire à cause des contraintes de temps et de la disponibilité des personnes (notamment des partenaires industriels du projet). Les futurs développements de l'outil Skippi vont demander un maximum de relations à implémenter pour permettre l'évaluation du temps de traitement des données par le logiciel et des algorithmes de recherche et de sélection du chemin optimum entre les mots. Le choix a donc été fait de la recherche de la quantité maximum de liens au cours de l'expérimentation et laisse la recherche de relations récurrentes en perspectives pour de de futurs travaux.

Pour couvrir la totalité des mots des bases de données Kansei/Marque et process pour l'établissement des relations, et aussi pour la lisibilité des mots couchés sur le papier, quatre feuilles d'expérimentation furent préparées en format A1 (841 x 594 mm) comme décrit sur la figure 13. Chaque feuille contient un total de 360 mots Kansei/Marque et process, distribués dans un ordre aléatoire sur la feuille. Chaque feuille contenait l'ensemble des 176 mots process et environ ¼ des mots Kansei/Marque (184 mots).

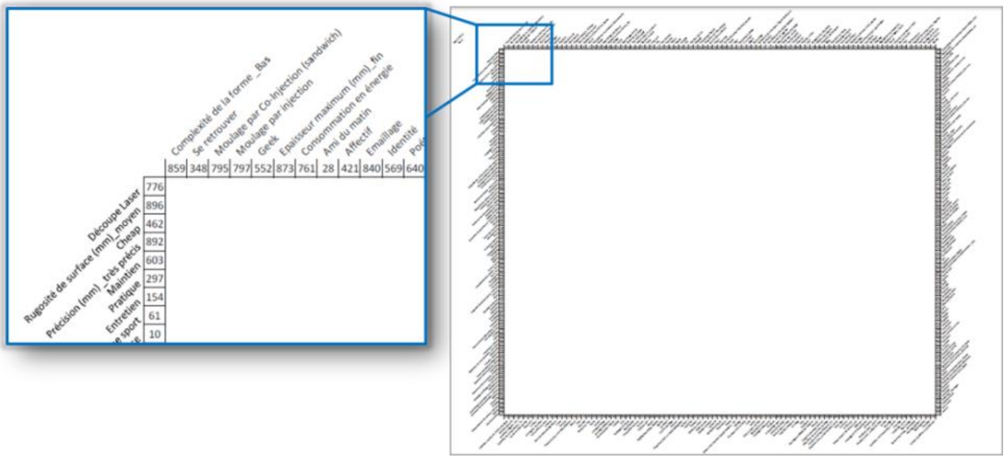



Figure 13: Une feuille d'expérimentation

L'expérimentation a été conduite par un étudiant de Master qui faisait son stage recherche au laboratoire G-SCOP, accompagné par des chercheurs du laboratoire LCPI. Elle fut réalisée dans les locaux des deux entreprises partenaires du projet. Onze personnes ont participé à l'expérimentation réalisée individuellement. Au début de l'expérimentation, le contexte du projet et es objectifs de cette expérimentation ont été expliqués et il fut demandé aux participants de relier, avec un une trace réalisée au stylo, les mots de la feuille qui leur semblaient en lien. L'expérimentation a eu une durée d'une heure. Furent également relevés les expertises des participants, les noms de l'entreprise et le numéro de la feuille d'expérimentation.

A partir des onze feuilles collectées, nous avons compté un total de 971 liens différents tracés par les participants. Tous les liens établis furent reportés pour relier les éléments des bases de données de l'outil SKIPPI. L'expérimentation a aussi produit des liens inattendus entre des mots Kansei/Marque (K-K ou B-B) et entre des mots process (P-P). Bien que l'étude des types de liens et leur récurrence puisse faire émerger des idées et des questions intéressantes au sujet de la fiabilité des liens repérés, l'étude fut reportée pour des travaux ultérieurs.

L'approche d'intégration que nous avons proposée doit permettre d'intégrer les points de vue des designers et des ingénieurs. Elle est constituée des trois étapes que nous avons décrites : modélisation, transformation et intégration (figure 14). Cependant une autre étape importante ne doit pas être oubliée, qui doit compléter dynamiquement par une boucle retour la description du produit et process d'un point de vue ingénieur. Cette étape doit traiter de comment l'information fournie par cette démarche d'intégration des points de vue des designers et ingénieurs peut, par une boucle retour, venir informer le point de vue des ingénieurs qui doivent développer le produit et les processus de production en cohérence avec le résultat de ce travail collaboratif. En d'autres termes, la prochaine étape (non traitée dans ce travail) sera de définir des méthodes et outils pour permettre aux ingénieurs de s'emparer des résultats obtenus dans cette approche intégrée pour concevoir techniquement le produit (flèche rouge figure 14).

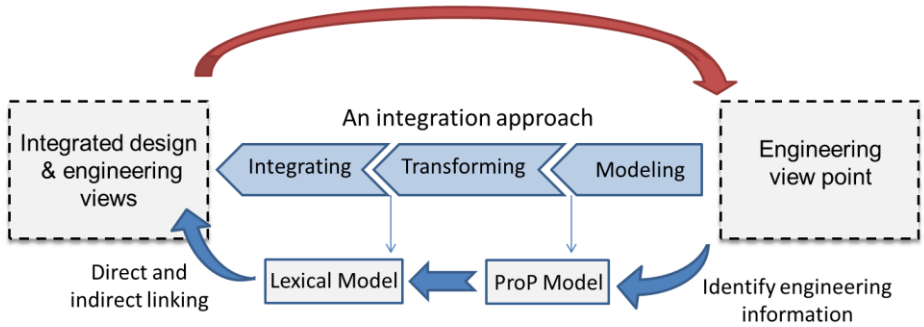



Figure 14: De l'approche intégrée à l'information du point de vue des ingénieurs en charge du développement du produit et des processus de production

Les ingénieurs doivent s'emparer des informations fournies par la démarche d'intégration quand ils définissent les spécifications techniques et les propriétés physiques du produit. Par exemple, lors de la sélection des matériaux, les choix ne doivent pas être basés seulement sur des caractéristiques thermiques, électriques, mécaniques, mais aussi sur des propriétés esthétiques, de perceptions visuelles propres aux caractéristiques de ces matériaux. De la même manière, dans la sélection des processus de fabrication et d'assemblage, avoir l'information sur la manière dont ces procédés affectent l'apparence du produit (relation Kansei-Process) doit aider les ingénieurs à déterminer une combinaison de procédés qui conviennent au mieux à la fois aux objectifs techniques et perceptuels.

## 6) Conclusion et perspectives

La recherche présentée dans cette thèse adresse les questions de collaboration entre les designers, en charge de la relation émotionnelle des clients au produit en cours de conception, et les ingénieurs, en charge des choix techniques du produit et de sa production. Les contributions clefs issues de cette recherche sont décrites comme suit :

• Dans la littérature 'Emotional design', de nombreuses études ont pour but de modéliser la façon dont les utilisateurs perçoivent ou pratiquent les produits, et répondent émotionnellement à cette expérience. Bien que ces approches soient très utiles pour comprendre les facteurs contribuant à l'élicitation de l'émotion, elles ne fournissent pas une compréhension claire de la relation entre la réponse émotionnelle à un produit et la cause de cette émotion qui se partage entre perception physique du produit et réaction à la marque. Cette thèse propose un cadre d'analyse des 'émotions face à un nouveau produit de marque' qui contribue à une compréhension de comment les clients réagissent à un nouveau produit de marque. Selon ce cadre, les réactions des clients face à un nouveau produit de marque peuvent être issues de la perception des propriétés physiques de ce produit spécifique (Kansei), mais aussi de l'association avec la marque qui le porte ou la classe de produit à laquelle il appartient. Ce cadre pointe la relation entre Marque et Kansei et fournit les bases pour de futures études. Il fait émerger des questions notamment sur le comment identifier et gérer la compatibilité et les contradictions entre l'image de la marque et les propriétés perceptives du produit. Ce cadre est présenté dans la première partie du chapitre 3.

- Beaucoup d'études qui cherchent à capturer les aspects essentiels de la marque et les émotions des utilisateurs pour la conception de nouveaux produits n'adressent pas les questions de la communication entre les acteurs pendant le processus de conception. Par ailleurs, les études sur la collaboration et la communication entre les acteurs de la conception n'adressent pas spécifiquement les difficultés émanant quand les contenus sont subjectifs ou contiennent des informations implicites comme par exemple ceux concernant les Marques et les aspects perceptifs ou émotifs associés aux produits. En cherchant à faire un pont entre ces pans de la littérature, nous voulons contribuer à une compréhension des différents facteurs conduisant à une interruption dans la communication entre designers et ingénieurs à propos des concepts Kansei et des valeurs de la Marque. Nous avons proposé le cadre d'études s'intéressant aux 'défis de la communication dans la conception de produits de marque'. Ce cadre d'études nous aide à structurer une vue théorique sur les origines de ces difficultés. Selon ce cadre, un défi est de communiquer (notamment par le fait que les concepts sous-jacents sont de nature subjective) les connaissances relatives à la Marque (eg capturer les valeurs de la Marque, communiquer ces valeurs grâce à des éléments implicites ou explicites) et les connaissances relatives aux concepts Kansei. Par ailleurs d'autres facteurs propres à la collaboration (eg différents langages techniques, différents ensembles de principes) contribuent à la rupture de la communication entre designers et ingénieurs et font que la communication des valeurs de la Marque et des concepts Kansei est un défi encore plus complexe. Ce cadre, qui est présenté dans la deuxième partie du chapitre 3, fournit également des bases pour des études dont l'objectif est d'assister cette communication.

- Pour supporter la communication entre designers et ingénieurs, en plus d'une revue théorique basée sur une étude bibliographique, une compréhension des situations réelles dans les entreprises et des problèmes auxquels font face ces acteurs est nécessaire. Nous avons donc mené une étude empirique et interviewé des designers et ingénieurs dans les entreprises partenaires du projet SKIPPI. Nous en concluons que les représentations dont ils disposent ne sont pas adéquates pour supporter la formalisation et la communication des concepts Kansei/Marque. De plus nous faisons l'hypothèse que les designers et les ingénieurs n'ont pas conscience de l'importance de cette communication. Nous nous sommes alors proposés d'investiguer le développement, l'adaptation et l'évaluation de trois approches basées sur des outils d'Annotation, de graphes de Word Mapping et de Matrices multi-domaines (MDM) pour combler ce manque dans la communication. Les interviews de vingt designers/ingénieurs exerçant dans différentes entreprises et d'une dizaine d'académiques ayant une expérience industrielle dans les domaines de la conception de produits de Marque nous a conduit à mettre en évidence l'intérêt d'un outil basé sur les annotations. Celui-ci est vu comme plus efficient pour permettre la communication des valeurs de la Marque et des concepts Kansei, mais aussi des relations entre ces concepts Kansei/Marque avec les éléments du produit. Les matrices basées sur les outils MDM sont cependant vues comme plus efficientes pour communiquer des informations sur les priorités, le degré de flexibilité et pour tracer l'influence des changements d'une propriété produit sur les autres propriétés. L'outil basé sur le Word Mapping est vu comme plus performant pour la visualisation des relations comparativement à celui basé sur l'annotation (pour lequel certaines relations sont implicites) et celui construit à partir du MDM (pour lequel certaines relations ne sont pas faciles à décrypter).

- Pour permettre l'intégration des points de vue des designers et des ingénieurs au plus tôt dans le processus de conception (qui était l'objet de notre deuxième question de recherche) nous avons proposé une approche d'intégration. Après identification de l'information d'ingénierie, notre approche se construit autour de trois étapes principales : modélisation pour structurer cette information d'ingénierie en utilisant les modèle de produit ProP ; transformation de cette information en adaptant la représentation à une structure de type Word Mapping plus proche d'une logique développée dans les premières étapes d'un projet ; intégration de cette information d'ingénierie en la reliant aux informations issues des aspects Kansei et Marque, complétant ainsi le Word Mapping avec des liens entre concepts Kansei/Marque et informations produit et processus de production. Les résultats de cette étude ont contribués à la construction du logiciel SKIPPI dont le but est d'assister la génération d'idées et la prise de décisions dans les phases amont du processus de conception de produits de marque. A partir d'un ensemble de données concernant les aspects Kansei, Marque, produit et processus de production, l'outil SKIPPI repère des chemins possibles dans les bases de données en s'appuyant sur les relations construites préalablement. Il peut ainsi à partir de mots Kansei/Marque proposer des propriétés produit ou process adéquat pour susciter les émotions souhaitées, ou inversement à partir de technologies disponibles et de propriétés produit proposer des émotions susceptibles d'être liées à ces caractéristiques technologiques. Cette approche qui a permis de fournir des données pour SKIPPI est décrite dans le chapitre 5.

## Perspectives

Nous considérons deux points principaux comme les perspectives de ce travail de recherche :

- Le premier est que nous devons continuer à développer et à expérimenter l'usage des outils basés sur l'Annotation, le Word Mapping et le MDM pendant le processus de conception pour en vérifier l'efficience à supporter la communication entre designers et ingénieurs tout en conservant les raisons des choix de conception de produits de marque
- le second est lié au fait que nous avons proposé une approche pour intégrer les points de vue des designers et des ingénieurs, approche en trois étapes : la modélisation, la transformation et l'intégration des données du processus de production dès les premières phases du processus de conception. Suite à cette proposition, l'étape de recherche à mettre en place concerne la méthode et les outils pour permettre en retour d'intégrer les données issues du travail collaboratif avec le(s) désigner(s) dans les outils de formalisation des données produit et process des ingénieurs, notamment ProP. Réaliser cette étape permettrait de disposer des données issues de la collaboration et permettant de développer le produit et les processus de production associés.

Par ailleurs, l'approche d'intégration proposée a contribué au développement de l'outil SKIPPI basé sur une représentation de type Word Mapping. Une recherche propre à la mise en usage de cet outil par les designers et ingénieurs, sur ce qui est fait des informations proposées par l'outil dans les phases amont de la conception, sur le comment cet outil aide à améliorer l'échange d'information et la compréhension partagé entre ces deux catégories d'acteurs, nous parait aujourd'hui nécessaire pour mesurer l'intérêt de cet outil.

De plus cette thèse a créé l'opportunité pour de futures recherches en faisant émerger les questions suivantes :

- Comment les réponses émotionnelles relatives à l'interaction du client avec les produits (et pas seulement les aspects visuels) peuvent être prises en compte lors de la conception d’un nouveau produit ? Peut-on aussi adresser et prendre en compte les émotions et les sentiments liées à l’usage du produit ? Comment les intentions relatives à ces aspects peuvent être communiquées entre designers et ingénieurs ?

- Comment la communication des aspects émotifs des produits et des valeurs de la marque peut être assistée entre les designers et les autres acteurs de l’équipe de conception, par exemple les responsables marketing ? Les experts environnementaux ?
- Peut-on, et comment, utiliser les logiciels existants (par exemple Annot’action ou Swift pour l’Annotation, CAM pour MDM) pour assister les concepteurs dans la communication des aspects Kansei/Marque ?
- Quelle(s) autre(s) approche(s) et outil(s) pourraient être candidats pour formaliser et communiquer les concepts Kansei et les valeurs de la marque pendant les projets de conception de produits de marque ?
- Pour l’instant, l’outil SKIPPI est développé pour supporter l’activité de génération d’idées. Peut-on, et comment, adapter l’outil SKIPPI pour assister les phases de conception suivant la phase de génération d’idées ?

# Annexes

## Annex 1. Questionnaire used during the primary in-depth interviews

### Introduction

L'objectif de ce questionnaire est de récupérer des informations sur deux téléphones portables chez Option France pour les marques PUMA et Swarowski, dans le but de compléter un modèle initial de produit/process pour les téléphones mobiles.

On envisage 2-3 heures pour une interview avec environ 3 ou 4 personnes (concepteurs ou ingénieurs) qui sont impliqués dans la conception de téléphones mobiles (pour les deux marques PUMA et Swarowski).

Il y a une liste des documents à fournir par l'entreprise, liste que nous allons demander auparavant. Lors de la réunion, on récupère ces documents au fur et à mesure des questions.

Ce questionnaire est organisé en deux parties. La première partie concerne des questions générales sur les étapes de conception/réalisation de téléphones portables chez Option France. L'objectif est d'avoir une vue globale sur la conception d'un mobile (étapes, acteurs, objets, lieux et traces des informations). Il s'agit de valider, ou de recueillir des informations pour adapter, notre modèle PP à partir des différentes visions des experts métiers sur le produit étudié.

La deuxième partie concerne plutôt des questions précises sur des données décrivant les fonctions, la structure d'un téléphone mobile, et des informations sur les processus de fabrication, d'assemblage et sur la prise en compte des impacts sur l'environnement. Ces informations vont permettre de structurer les points de vue sur les produit/process en termes d'entités et d'établir des relations entre des entités de différents points de vue.

### Les documents à fournir par l'entreprise

1. Le cahier des charges du produit développé
2. Les documents qui tracent le développement du produit (analyse fonctionnelle, solutions envisagées, matrice de choix de solution, analyse de la valeur, QFD, …)
3. Le plan d'ensemble de la solution choisie
4. La nomenclature du produit (avec matériau),
5. Les plans de détail (associés à chaque composant)
6. Notice ou rapport d'évaluation ou de simulation des performances du produit au regard des performances attendues
7. Une liste des informations de fabrication pour chaque composant (gamme et opérations de fabrication, cout, temps, tolérance, lieu de fabrication, couts et énergie de transport, etc).
8. Plan d'assemblage (gamme d'assemblage) pour le produit.

### Première partie

L'objectif des questions : obtenir une vue générale sur les étapes de conception/réalisation de téléphones portables chez Option France.

### Des étapes:

1. Sous quelle forme se présente le cahier des charges relatif à un nouveau développement de téléphone portable ?

2. Une fois le cahier des charges précisé, quelles sont les étapes de conception/réalisation du produit ? (ex : conception, fabrication, assemblage ?)
3. Qui sont les acteurs qui interviennent pendant la phase de conception du téléphone mobile ? Pour quelle raisons ?
4. Quelles sont les étapes qui sont réalisées par l'entreprise Option France elle-même (conception, fabrication, assemblage)
5. Quelles sont les étapes qui se font ailleurs (sous-traitants)?
6. S'il y a sous-traitance, à qui est confiée cette sous-traitance ? Dans quel lieu géographique ?
7. Est-ce que ces étapes (conception, fabrication, assemblage) se déroulent plutôt de manière séquentielle ? Si oui, existe-t-il des moyens pour avoir des retours entre ces étapes ?

### Des acteurs :

8. Pour chaque étape, quels sont les experts métiers qui participent (designer, ingénieur, fabricant, assembleur, responsable environnement) ?
9. Est-ce que à chaque étape il y a seulement des experts métiers de cette étape ? Ou par exemple est-ce que le fabricant participe à l'étape de conception ?
10. Est-ce que des experts sont amenés à tenir plusieurs rôles (par exemple le designer qui prend en compte des problèmes de fabrication) ?
11. Existent-ils des documents sur lesquels s'appuient les concepteurs pour prendre en compte les expertises des autres métiers ?

### Objets, lieux, traces :

12. Existe-t-il des objets (par exemple des représentations du produit) qui permettent la coopération entre les acteurs des différentes étapes ? Si oui, quels sont ces objets ? Quels sont les logiciels utilisés pour créer ces objets ?
13. Des réunions jalon sont-elles organisées au cours du projet ? Quels sont les objets (représentations du produit) présentés au cours de ce type de réunion ?
14. Ces réunions ont-elles lieu en présentiel ou à distance ? Si à distance, des outils informatiques sont-ils utilisés pour communiquer à propos de ces objets ? Lesquels ?
15. Quels sont les livrables (ou les sorties) de chaque étape pour l'étape suivante ? sous quelle forme ? (un fichier logiciel ? une liste d'informations ? un prototype ?)

Ces questions doivent me fournir suffisamment informations pour avoir une vision claire sur :

- les étapes de conception/réalisation d'un téléphone portable
- les acteurs qui interviennent à chaque étape.

## Deuxième partie

### L'objectif est l'obtention d'une vue précise sur le mobile

1. Est-ce qu'il y a une base de données relative au développement des téléphones mobiles existants ?
2. Si oui, comment les informations sont organisées dans cette base ? Relance : organisation par projet ? Mise en relation composant / processus de fabrication/ plan d'assemblage ?

### Vue fonction :

1. Comment formalisez-vous les attentes des clients ? Caractérisez-vous les performances attendues du téléphone ?
2. Une analyse des fonctions de service à rendre par le produit est-elle réalisée ? (AF ou AV)
3. Reliez-vous ces fonctions (de service, techniques) aux composants qui les assurent ? (FAST, QFD)
4. Faites-vous un bilan des fonctions que doit réaliser chaque composant ?

### Vue structure

5. Existe-t-il un plan d'ensemble ? sous quelle forme est-il disponible ?
6. Est-ce que vous avez une nomenclature des composants

7. Les plans de détails associés à chaque composant sont-ils disponibles ?

8. **Si non**, quels types d'informations propres à chaque composant sont disponibles (forme, dimension, tolérances, matériaux, poids, …) ? Sous quelle forme ?

9. Avez-vous un document qui précise les liaisons et/ou interactions entre les différents composants ?
10. Est-ce que vous prenez en considération les effets ou impacts environnementaux lors de la conception des téléphones mobiles.
    Si oui, quels sont vos critères ? (recyclabilité des pièces, réutilisation des pièces, choix de matériaux, énergie dépensée, déchets ou rejets, …)?

11. Comment vous assurez-vous que les composants du produit permettent la réalisation des performances attendues ?

### Vue fabrication

12. Pour chaque composant, quels sont :
    - le moyen d'obtention de la pièce brute
    - les opérations complémentaires qui sont réalisées pour obtenir la pièce finie (et donc les entités ainsi définies)
    - les caractéristiques de chacune de ces parties du process (nature, cout, énergie, déchets, …)

13. Quels types d'informations sur un composant sont importants pour définir le process de fabrication de ce composant ?

14. Est-ce que vous prenez en considération les effets/impacts environnementaux relatifs aux process de fabrication du produit ? (consommation d'énergie, déchets de fabrication, … etc)

15. Quelles sont les contraintes de fabrication qui limitent le travail du fabricant (généralement et sur les produits exemples) ?

### Vue assemblage

16. Existe-t-il un plan d'assemblage pour le produit ?

17. Quels sont des éléments importants pour définir les processus d'assemblage ?

18. Est-ce que l'assemblage est fait par l'entreprise ou ailleurs ? Quels sont les ensembles de pièces déjà assemblés lors de la livraison à l'entreprise et dont vous n'étudiez pas l'assemblage ?
19. Est-ce que vous avez une considération des effets/impacts environnementaux sur l'assemblage du produit (énergie dépensée, déchets, recyclabilité des pièces, réutilisation des pièces, le choix de matériaux …) ?

20. Quelles sont les contraintes qui limitent le travail des industriels de l'assemblage ?

# Annex 2. Questionnaire used for evaluation interviews

**A)**

| | |
|---|---|
| 1. Your Name | |
| 2. Educational background | |
| 3. Current role and responsibility | |
| 4. Years of experience | |
| 5. Date of interview | |

**B) Company information**

| | |
|---|---|
| 6. Company name | |
| 7. Type of products | |
| 8. Brand's name | |
| 9. Number of product designers | |
| 10. Number of engineering designers | |

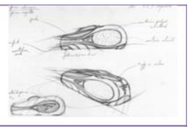
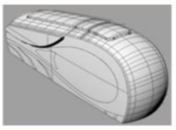
**C) Project information**

| | |
|---|---|
| 11. Name a recent project undertaken and name the product | |
| 12. What was the deliverable? | |
| 13. Number of product designers and engineering designers in the project | |
| 14. Did regular work meetings between product designers and engineering designers occur during the project? What was the periodicity? | |

Table1: Definition of information, to be used in interview as a dictionary of expressions

| Information | Definitions | General Examples |
|---|---|---|
| Structure of the product | Product architecture , the arrangement and composition of parts and elements to build the product | A car consists of several sub-parts such as body and the engine |
| Product appearance | How the product looks | Looking modern, looking feminine |
| Assembly | The process of how the manufactured parts and elements are put together | To screw, welding |
| Brand value | The added value or the premium of the product to a consumer under the brand's name | Safety for Volvo, Personalization for Nokia |
| Mechanisms | Assembly of connected moving elements and the physical operation to perform a function | Gears, locking pliers, scissor lift |
| Product elements | Component and features | Key pad , bag handle |
| Meaning of elements | The feeling , emotion and perception that an element elicits for consumer | Softness, lightness, |
| Materials | Substances from which the physical elements are made up | Plastic, metal |
| Overall form | Overall product shape and proportion | Rectangular form, rounded shape |
| Technical functions | Internal product functions to perform interaction function | Force transforming |
| Interaction functions | Function related to user's interaction with the product | Enable to staple easily |
| Brand related elements | The elements and the properties of element which are used as a reference to the brand | Logo, strong shoulder lines of Volvo cars, color scheme of Apple products |
| Geometrics | Measurements, areas and volumes | Angles , surface areas |
| Prioritizing among properties of elements | Determine the hierarchy of the importance element properties | For a red plastic element, the red color is more important than its material, Or the texture is more important than the color |
| Meaning of overall design | Overall feeling , emotion and perception that the product elicits for consumer | Luxury product , casual product |
| Manufacturing | The process of how the elements of product are made up | Casting , injection molding |
| Flexibility to engineering changes | Determine if a design element is flexible and could be changed or it is inflexible to engineering changes | The thickness of the element is absolutely important to be thin, but its material could be changed |
| Trace the effect of an engineering change | Trace the effect of a change in a design element and property, on the change of the meaning and appearance of the product | increasing the thickness of boundaries make the product look heavy |

Table2: Hand overs between product designers and engineering designers

| | | |
|---|---|---|
| Sketches | Rough representation without precise details and scales , Free-hand sketched, 2D |  |
| Drawings | Highly structured to formalize design elements, made in accordance with a set of rules , 2D |  |
| 3D Models | 3D representations to visualize function, performance and aesthetic aspects of design, models can be simple or detailed , digital or physical |  |
| Prototypes | 3D physical representation, often built to full scale, incorporate functional and working elements |  |

## Problem evaluation

**Part1**. How important do you think the information is to be communicated between product designers and engineering designers? (Use table 1 and 2)

0= Not important at all
1= Low
2= Medium
3= High

| | | Level of importance | Comments (If needed) |
|---|---|---|---|
| information about the product | 1.Structure of the product | | |
| | 2.Product appearance | | |
| | 3.Assembly | | |
| | 4.Brand value | | |
| | 5.Mechanisms | | |
| | 6.Product elements | | |
| | 7.Meaning of elements | | |
| | 8.Materials | | |
| | 9.Overall form | | |
| | 10.Technical functions | | |
| | 11.Interaction functions | | |
| | 12.Brand related elements | | |
| | 13.Geometrics | | |
| | 14.Prioritizing among properties of elements | | |
| | 15.Meaning of overall design | | |

**Part 2** For each information in the following table, consider a recent project and answer the questions (PD= Product Designer, ED= Engineering Designer)

| **1.Product appearance : How the product looks, example: looking modern, looking feminine** | | | | | |
|---|---|---|---|---|---|
| | Sketches | Drawings | 3D Models | Prototypes | If none, what else? |
| Which representation is used to exchange this information between PD and ED? | ☐ | ☐ | ☐ | ☐ | |
| How well did the representation communicate the information?<br>1= Low , 2= Medium, 3= High | | | | | |
| Did you have problems/ difficulties communicating this information? | | | | | |

| **2.Brand Value : The added value or the premium of the product to a consumer under the brand's name , example: Safety for Volvo, Personalization for Nokia** | | | | | |
|---|---|---|---|---|---|
| | Sketches | Drawings | 3D Models | Prototypes | If none, what else? |
| Which representation is used to exchange this information between PD and ED? | ☐ | ☐ | ☐ | ☐ | |
| How well did the representation communicate the information?<br>1= Low , 2= Medium, 3= High | | | | | |
| Did you have problems/ difficulties communicating this information? | | | | | |

| **3.Meaning of elements : The feeling , emotion and perception that an element elicits for consumer , example: Softness, lightness** | | | | | |
|---|---|---|---|---|---|
| | Sketches | Drawings | 3D Models | Prototypes | If none, what else? |
| Which representation is used to exchange this information between PD and ED? | ☐ | ☐ | ☐ | ☐ | |
| How well did the representation communicate the information?<br>1= Low , 2= Medium, 3= High | | | | | |
| Did you have problems/ difficulties communicating this information? | | | | | |

**4.Brand related elements : The elements and the properties of element which are used as a reference to the brand , example : Logo, strong shoulder lines of Volvo cars, color scheme of Apple products**

| | Sketches | Drawings | 3D Models | Prototypes | If none, what else? |
|---|---|---|---|---|---|
| Which representation is used to exchange this information between PD and ED? | ☐ | ☐ | ☐ | ☐ | |
| How well did the representation communicate the information?<br>1= Low , 2= Medium, 3= High | | | | | |
| Did you have problems/ difficulties communicating this information? | | | | | |

**5.Prioritizing among properties of elements : Determine the hierarchy of the importance element properties, example: For a red plastic element, the red color is more important than its material, Or the texture is more important than the color**

| | Sketches | Drawings | 3D Models | Prototypes | If none, what else? |
|---|---|---|---|---|---|
| Which representation is used to exchange this information between PD and ED? | ☐ | ☐ | ☐ | ☐ | |
| How well did the representation communicate the information?<br>1= Low , 2= Medium, 3= High | | | | | |
| Did you have problems/ difficulties communicating this information? | | | | | |

**6.Meaning of overall design : Overall feeling , emotion and perception that the product elicits for consumer , example: Luxury product , casual product**

| | Sketches | Drawings | 3D Models | Prototypes | If none, what else? |
|---|---|---|---|---|---|
| Which representation is used to exchange this information between PD and ED? | ☐ | ☐ | ☐ | ☐ | |
| How well did the representation communicate the information?<br>1= Low , 2= Medium, 3= High | | | | | |
| Did you have problems/ difficulties communicating this information? | | | | | |

## Tool evaluation

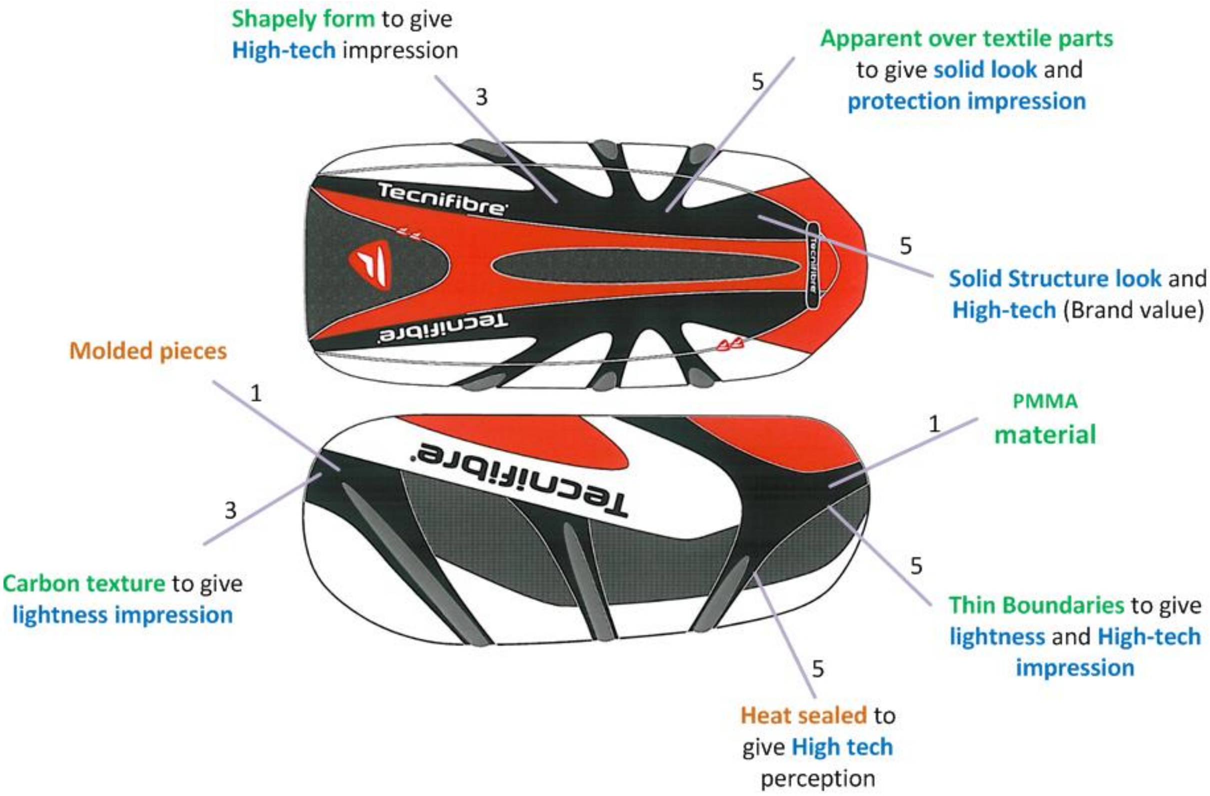
The object of our study is a tennis bag designed for Tecnifibre brand. The Tecnifibre communicates "solid" and "high-tech" impression to consumers throughout its products family. Some meanings and emotions as well as the brand values are imbedded physically in the design of Tecnifibre products. The tennis bag is designed to look light, elicit protection feeling and carry brand values "solid" and "high-tech". Our focus is on one of the components of this tennis bag which is called "structure element".


The structure element in black color

Please have a look on the 3 following diagrams and then fill the table.

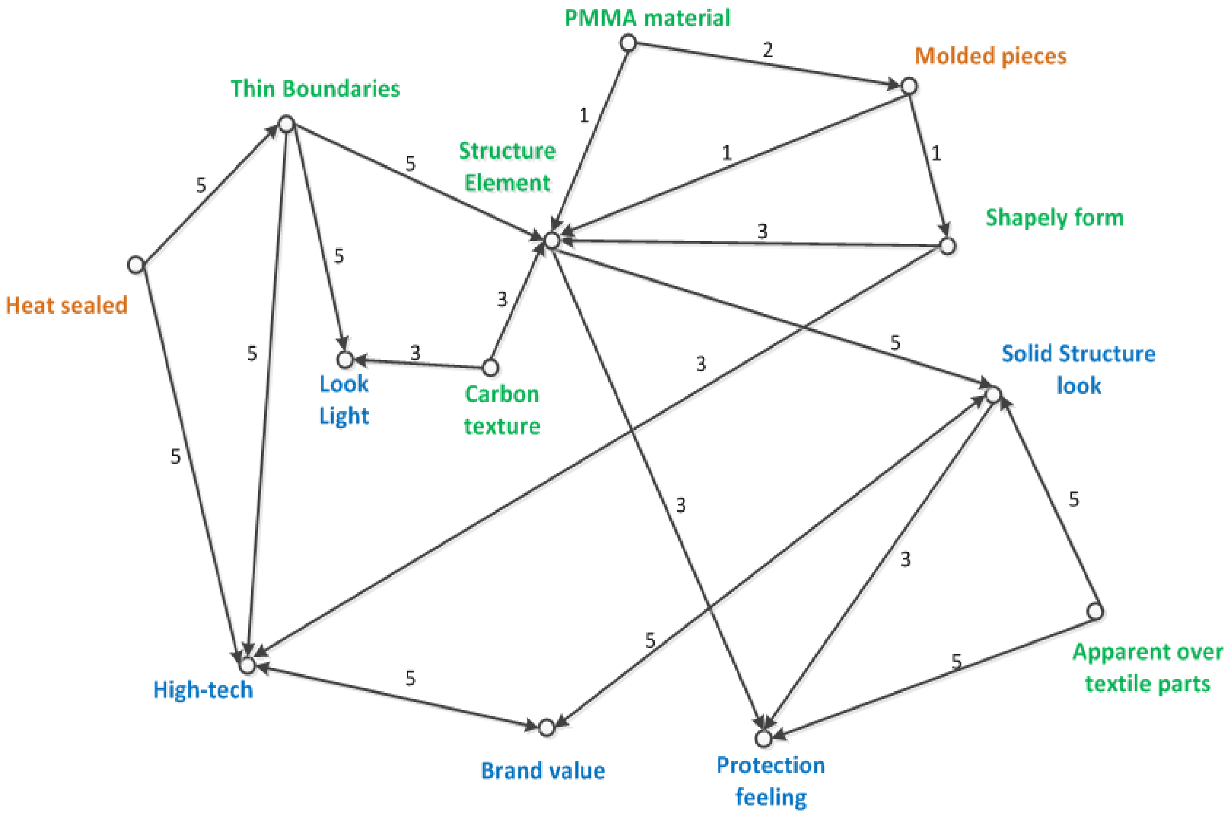
## Diagram1. ANNOTATION

- After creating the 3D models or the drawings, the annotation permits to clarify the main information about the brand and the emotion and the perception aspects of the product.
- The use of colors helps to distinguish different type of information
  - Blue text: Information related to brand, perception and emotions
  - Green text: Information related to the product properties
  - Orange text: Information related to industrial process
- The numbers refer to the level of importance from 1 to 5.



## Diagram 2: Word Mapping

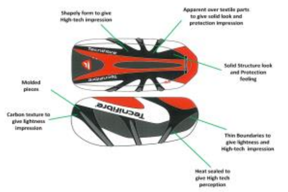
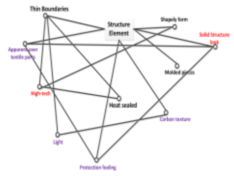
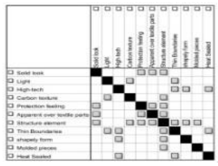
- The Word Mapping accompanies sketches, 3 models or drawings to facilitate the communication of the information that is not normally displayed on these representations.
- The use of colors helps to distinguish different type of information
  - Blue text: Information related to brand, perception and emotions
  - Green text: Information related to the product properties
  - Orange text: Information related to industrial process
- The numbers refer to the level of importance from 1 to 5.
- The orientation of the arrows: The initial element contributes to gain the terminal element. Example: "The solid structure look" contributes to gain the "protection feeling".




## Diagram 3: MDM

- The Multiple-Domain Matrix (MDM) accompanies sketches, 3 models and drawings.
- Reading across a row: The entity of the row elicits other entities. Example: The solid structure look elicits the protection feeling and the brand value.
- Reading across a column: The entity is elicited by other entities. Example: The solid structure look is elicited by the apparent structure element over textile parts of the sac, and the brand value.
- Three types of information are classified in the matrix: brand and perception related information, product properties related information and industrial process related information.
- The numbers refer to the level of importance from 1 to 5.

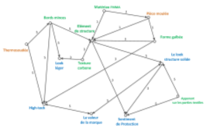
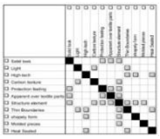

| | | Brand , Perception , Feeling | | | | | Product properties | | | | | | Process | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Solid structure look | Look light | High-tech | Protection feeling | Brand value | Structure element | Thin boundaries | Apparent over textile parts | Carbon texture | PMMA material | Shapely form | Molded pieces | Heat sealed |
| Brand Perception Feeling | Solid structure look | | | | 3 | 5 | | | | | | | | |
| | Look light | | | | | | | | | | | | | |
| | High-tech | | | | | 5 | | | | | | | | |
| | Protection feeling | | | | | | | | | | | | | |
| | Brand value | 5 | | 5 | | | | | | | | | | |
| Product properties | Structure element | 5 | | | 3 | | | | | | | | | |
| | Thin boundaries | | 5 | 5 | | | 5 | | | | | | | |
| | Apparent over textile parts | 5 | | | 5 | | | | | | | | | |
| | Carbon texture | | 3 | | | | 3 | | | | | | | |
| | PMMA material | | | | | | 1 | | | | | | 2 | |
| | Shapely form | | | 3 | | | 3 | | | | | | | |
| Process | Molded pieces | | | | | | 1 | | | | | 1 | | |
| | Heat sealed | | | 5 | | | | 5 | | | | | | |

| Rules:<br>1. Follow the horizontal lines.<br>2. For the selected "Question" use 3 diagrams one after another<br>**3.** Choose a level (zero, low, medium, high) to indicate to what extend the diagram provides the asked information. | **Annotation** | | | | **Word Mapping** | | | | **MDM** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| |  | | | |  | | | |  | | | |
| 1. Does the diagram communicate the brand value explicitly? | zero ☐ | Low ☐ | Medium ☐ | High ☐ | zero ☐ | Low ☐ | Medium ☐ | High ☐ | zero ☐ | Low ☐ | Medium ☐ | High ☐ |
| 2. Does the diagram communicate how the "structure element" in the tennis bag, is supposed to be emotionally perceived? | zero ☐ | Low ☐ | Medium ☐ | High ☐ | zero ☐ | Low ☐ | Medium ☐ | High ☐ | zero ☐ | Low ☐ | Medium ☐ | High ☐ |
| 3. Does the diagram help to recognize whether the "structure element" is concerned with the brand? | zero ☐ | Low ☐ | Medium ☐ | High ☐ | zero ☐ | Low ☐ | Medium ☐ | High ☐ | zero ☐ | Low ☐ | Medium ☐ | High ☐ |
| 4. Does the diagram show the reason behind the choice of "thin boundary" for the "structure element"? | zero ☐ | Low ☐ | Medium ☐ | High ☐ | zero ☐ | Low ☐ | Medium ☐ | High ☐ | zero ☐ | Low ☐ | Medium ☐ | High ☐ |
| 5. Does the diagram help to understand which meaning is more important to be embedded? | zero ☐ | Low ☐ | Medium ☐ | High ☐ | zero ☐ | Low ☐ | Medium ☐ | High ☐ | zero ☐ | Low ☐ | Medium ☐ | High ☐ |
| 6. Does the diagram help to understand which property of the "structure element" is more important than other? | zero ☐ | Low ☐ | Medium ☐ | High ☐ | zero ☐ | Low ☐ | Medium ☐ | High ☐ | zero ☐ | Low ☐ | Medium ☐ | High ☐ |
| 7. Does the diagram show which aspect of the "structure element" is flexible to an engineering change? | zero ☐ | Low ☐ | Medium ☐ | High ☐ | zero ☐ | Low ☐ | Medium ☐ | High ☐ | zero ☐ | Low ☐ | Medium ☐ | High ☐ |
| 8. Does the diagram show which aspect of the "structure element" is inflexible to an engineering change? | zero ☐ | Low ☐ | Medium ☐ | High ☐ | zero ☐ | Low ☐ | Medium ☐ | High ☐ | zero ☐ | Low ☐ | Medium ☐ | High ☐ |
| 9. If a property of the "structure element" is changed, does the diagram help to trace whether the perception of the element is changed? | zero ☐ | Low ☐ | Medium ☐ | High ☐ | zero ☐ | Low ☐ | Medium ☐ | High ☐ | zero ☐ | Low ☐ | Medium ☐ | High ☐ |

Comments:

10. As a support tool for communication between product designers and engineering designers, what is your preferred tool among Annotation, MDM and Word mapping? Why?

11. Name two advantages and two disadvantages for each of these tools:

| | **Two advantages** | **Two disadvantages** |
|---|---|---|
| Annotation  | | |
| Word Mapping  | | |
| MDM  | | |

12. Do you have any propositions or ideas for a support tool that could ameliorate the communication between product designers and engineering designers?

# Annex 3. Manufacturing, Finishing and Assembly tables

| | | Characteristics of manufacturing processes and their values | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Weight range (kg) | Minimum thickness (mm) | Shape complexity | Surface roughness (μm) | Economic batch size | Allowable tolerance (mm) | Material |
| Manufacturing processes | Injection molding | 0,01-25 | 0,3-10 | high | 0,2-1,6 | 10k-1000k | 0,05-1 | thermoplastic, thermosets, elastomer |
| | Rotation molding | 0,1-50 | 2,5-6 | low | 0,5-2 | 100-10k | 0,4-1 | thermoplastic, thermosets |
| | Blow molding | 0,001-0,3 | 0,4-3 | low | 0,2-1,6 | 1k-10,000k | 0,25-1 | thermoplastics, limited levels of reinforcement for composite materials |
| | Expanded foam molding | 0,01-10 | 5-100 | low/med | 50-500 | 2k-1000k | 0,5-2 | thermoplastics, polystyrene |
| | Compression molding | 0,2-20 | 1,5-25 | low/med | 0,2-2 | 2k-200k | 0,1-1 | thermoplastics |
| | Resin transfer Molding | 0,2-20 | 1,5-13 | med/high | 0,2-1,6 | 10k-100k | 0,25-1 | polyester, epoxies, vinyl esters, phenolic |
| | Die-casting 1) Cold Chamber 2) Hot Chamber | 0,05-20 | 1-8 | med/high | 0,5-1,6 | 5k-1,000k | 0,15-0,5 | aluminum, magnesium, zinc alloy |
| | Sand-casting | 0,3-1000 | 5-100 | med/high | 12-25 | 1-1000k | 1-3 | aluminum alloy, copper alloys, cast irons, steel |
| | Investment Casting | 0,001-20 | 1-30 | med/high | 1,6-3,2 | 1-50k | 0,1-0,4 | silver, copper, gold, bronze, pewter, lead, nickel, cobalt, iron based alloys |
| | Polymer Casting | 0,1-700 | 2-100 | high | 0,5-1,6 | 10-1000 | 0,8-2 | resins, thermosets |
| | Shape Rolling and Die forging | 0,1-100 | 2-100 | low | 3,2-12,5 | 10k-1000k | 0,3-2 | metals, copper alloys, steel |
| | Extrusion | 1-1000 | 0,1-900 | low | 0,5-12,5 | 1k-1000k | 0,2-2 | Aluminum, magnesium, copper |
| | Press forming , Rolling forming and spinning | 0,01-30 | 0,2-5 | med | 0,5-12,5 | 25k-250k | 0,1-0,8 | metals, steel, aluminum, copper, nickel, zinc, magnesium, titanium |
| | Thermoforming | 0,003-50 | 0,25-6 | low | 0,3-1,6 | 10-100k | 0,5-1 | thermoplastic, ABS, PA, PC,PS, PP, PVC |
| | Powder methods | 0,01-5 | 1,5-8 | low/med | 1,6-6,3 | 1k-1000k | 0,1-1 | brass, bronze, iron-based alloys, stainless steel, cobalt, titanium, tungsten, beryllium, metal, ceramic |
| | Laser Prototyping | 0,1-20 | 0,5-100 | high | 100-125 | 1-100 | 0,2-2 | ABS, Nylon |
| | Deposition Prototyping | 0,1-10 | 1,2-100 | high | 75-100 | 1-100 | 0,3-2 | ABS, Nylon |

| | | Characteristics of finishing processes and their values | | | | |
|---|---|---|---|---|---|---|
| | | Surface hardness (Vickers) | Coating thickness (mm) | Curved surface coverage | Processing temperature (°c) | Material |
| Finishing processes | Screen printing | 5-10 | 10-100 | good | 5-25 | polymer, glass, metals, wood, textiles, course paper and board |
| | Pad printing | 5-10 | 6-10 | poor | 15-30 | polymer, glass, metals |
| | Cubic printing | 5-10 | 6-10 | average | 15-30 | polymer, glass, metal, wood, ceramic |
| | Hot stamping | 5-50 | 1-50 | good | 150-300 | magnesium , brass, steel |
| | In-mold decoration | 5-15 | 10-500 | good | 125-200 | thermoplastic, polyethylene |
| | Vapor metallization | 10-40 | 1-80 | good | 18-120 | aluminum, copper, nickel, zirconium and other metal |
| | Electro-planting | same as substrate | 1-1000 | good | 5-80 | almost any metal, polymers |
| | Electro-less planting | 600-1100 | 20-120 | good | 20-50 | most metals and polymers |
| | Anodizing | 600-1000 | 1-500 | good | 0-40 | aluminum, magnesium, titanium, zirconium, zinc |
| | Mechanical polishing | same as substrate | not relevant | good | 0-30 | almost any metal or ceramic |
| | Electro-polishing | same as substrate | not relevant | good | 0-90 | low alloy steels, aluminum, brass, zinc, beryllium copper, nickel silver, tungsten |
| | Chemical polishing | same as substrate | not relevant | good | 55-140 | aluminum, copper, stainless steel |
| | Solvent-based painting | 10-16 | 10-1000 | good | 10-100 | - |
| | Water-based painting | 10-16 | 10-1000 | good | 10-100 | - |
| | Powder coating | 10-16 | 50-2000 | good | 125-400 | steel, aluminum, magnesium, brass, copper, cast iron, metallic alloys |
| | Enameling | 7k-10k | 500-1000 | | 600-900 | metal , ceramics |
| | Etching | 7k-10k | 500-1000 | depends on the process | 18-60 | glass, metal, polymer, wood, stone |
| | Texturing | depends on substrate | 18-30 | not found | not found | any material |

| | | Characteristics of assembly processes and their values | | | | | |
|---|---|---|---|---|---|---|---|
| | | Size of joint | Maximum thickness (mm) | Unequal thickness | Join dissimilar materials | Rigid or flexible | Required performance of the joint |
| Assembly processes | Glue adhesives | unrestricted | unrestricted | possible | yes | rigid | fixe |
| | Acrylic adhesives | unrestricted | - | possible | yes | flexible | fixe |
| | Sewing | unrestricted | 1-10 | limited | yes | rigid | fixe |
| | Rivets and staples | unrestricted | 0.01-10 | limited | yes | rigid | fixe/ movement |
| | Threated fasteners (screw) | unrestricted | unrestricted | possible | yes | rigid | fixe |
| | Snap fit | restricted | unrestricted | possible | yes | rigid | fixe/movement |
| | Hot gaz welding | unrestricted | 2.5-10 | limited | yes | rigid | fixe |
| | Hot bar welding | restricted | 0.05-0.5 | limited | yes | rigid | fixe |
| | Hot plat welding | restricted | 1-30 | limited | no | rigid | fixe |
| | Ultrasonic welding (metal) | restricted | 0.01-1 | limited | yes | rigid | fixe |
| | Ultrasonic welding (polymers) | restricted | 0.1-3 | limited | yes | rigid | fixe |
| | Power-beam welding | restricted | 1-200 | limited | yes | rigid | fixe |
| | Brazing | unrestricted | 1-100 | possible | yes | rigid | fixe |
| | Soldering | unrestricted | 1-10 | possible | yes | rigid | fixe |
| | Torch welding | unrestricted | 1-100 | limited | no | rigid | fixe |
| | MIG welding (Gaz metal arc) | unrestricted | 1-100 | limited | no | rigid | fixe |
| | TIG welding (Tungsten inter-gaz) | unrestricted | 0.2-10 | limited | no | rigid | fixe |
| | Resistance welding | unrestricted | 0.1-10 | limited | yes | rigid | fixe |
| | Friction welding | restricted | 1-100 | possible | yes | rigid | fixe |
| | Diffusion and Glaze bonding | restricted | 1-100 | possible | yes | rigid | fixe |

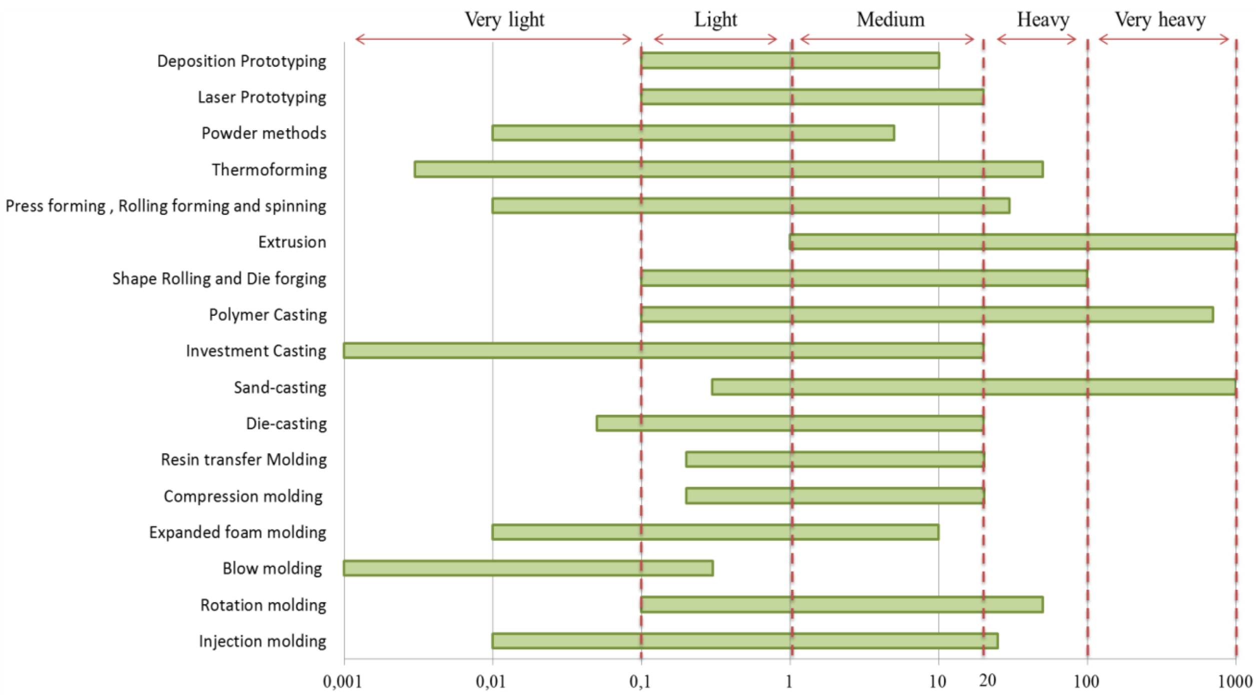



Figure A3-1: Associating qualitative categories to quantitative intervals for weight range, manufacturing table

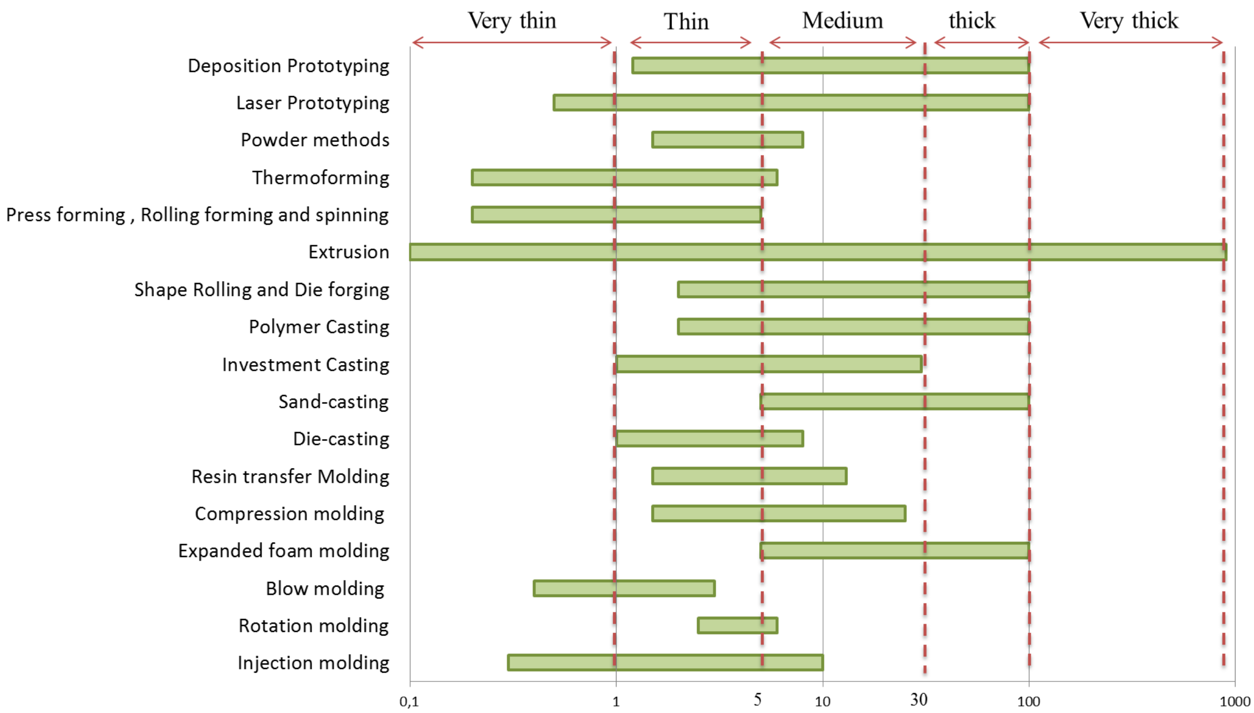



Figure A3-2: Associating qualitative categories to quantitative intervals for minimum thickness, manufacturing table

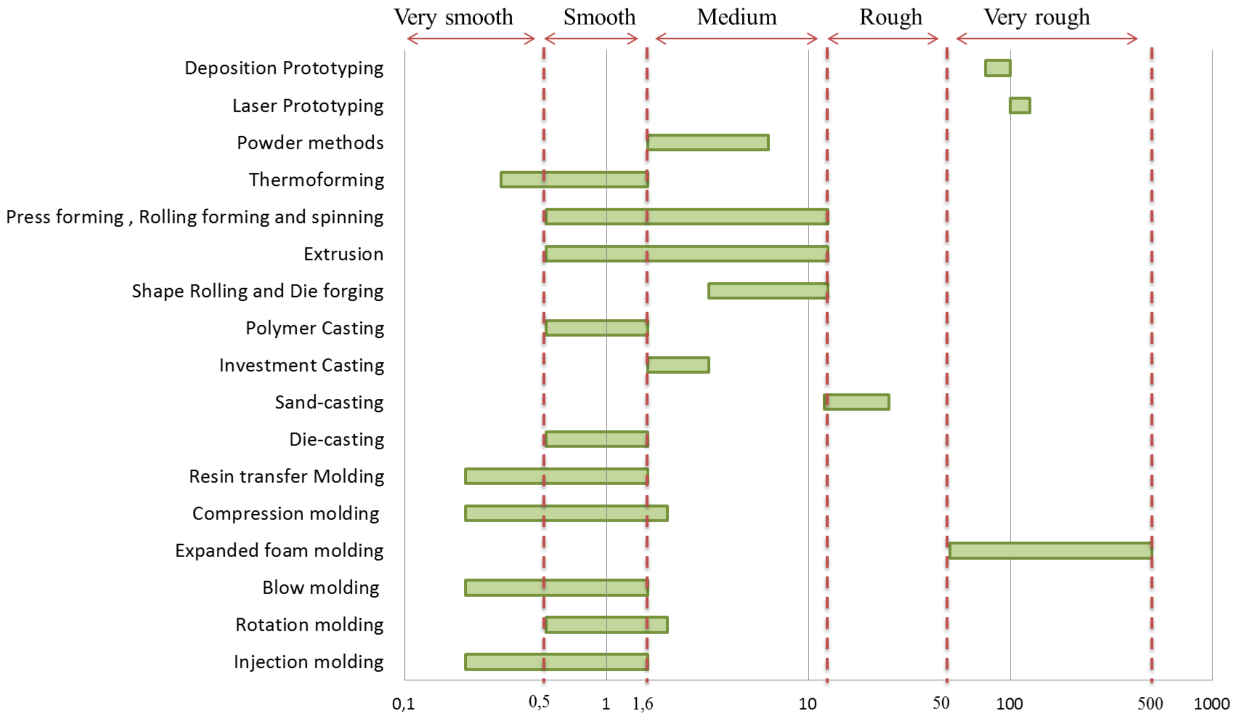



Figure A3-3: Associating qualitative categories to quantitative intervals for surface roughness, manufacturing table

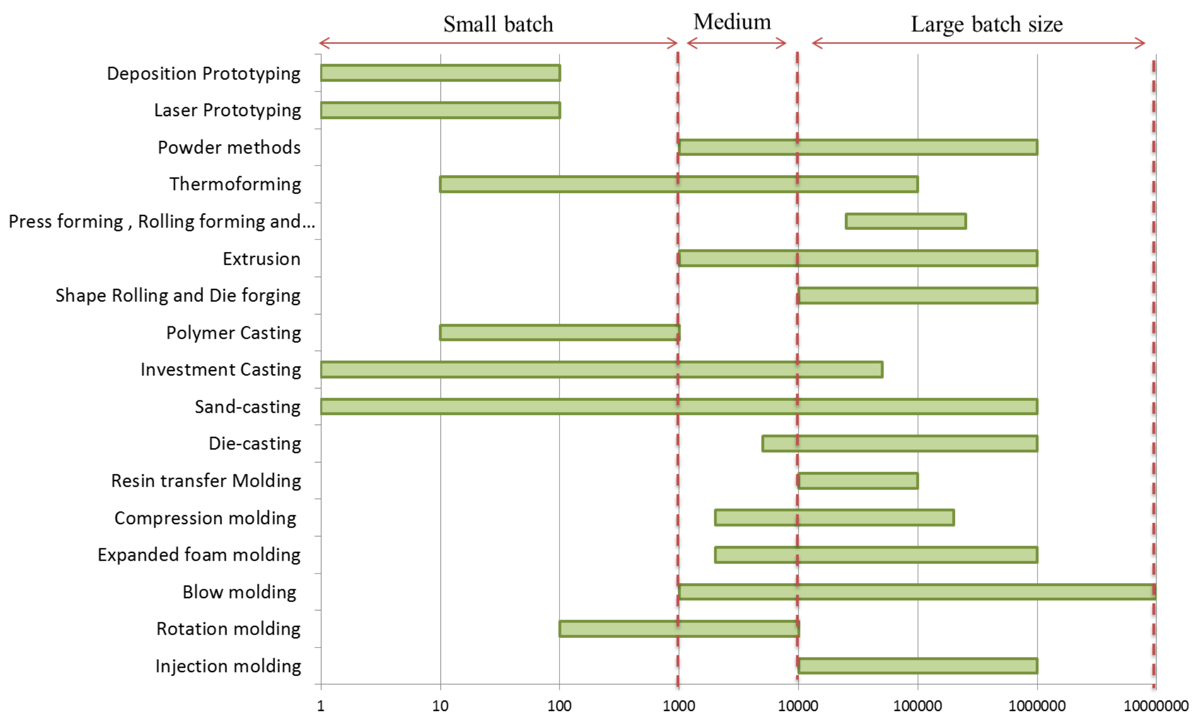



Figure A3-4: Associating qualitative categories to quantitative intervals for economic batch size, manufacturing table

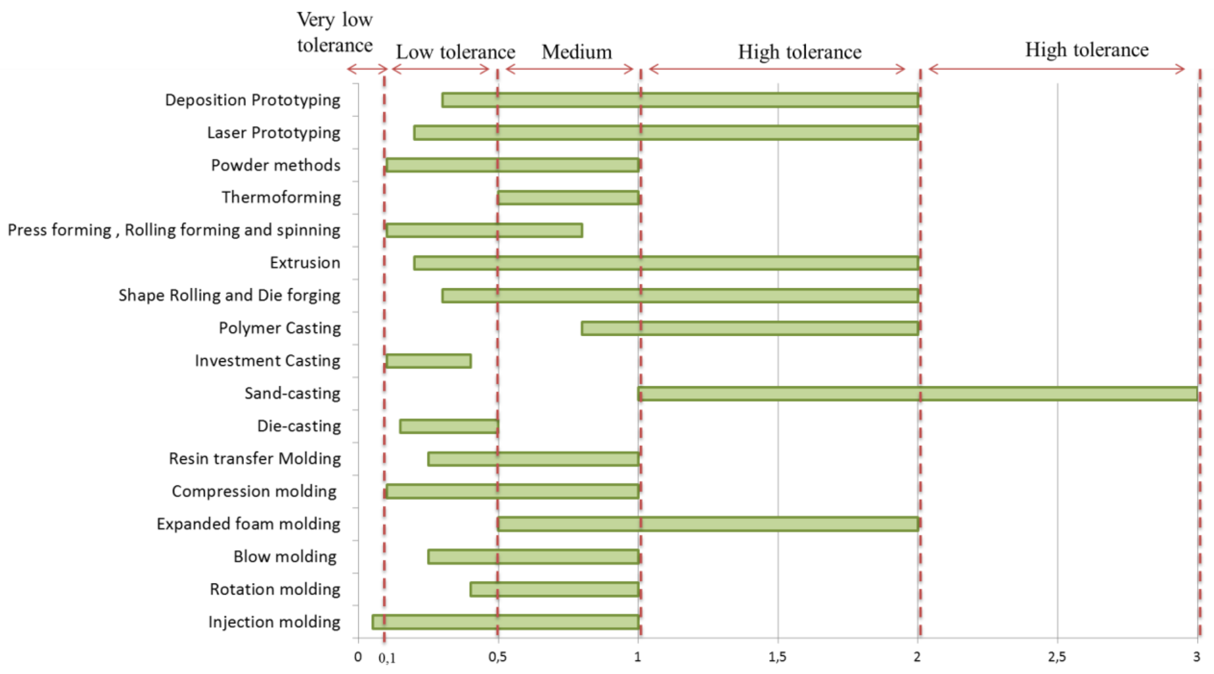



Figure A3-5: Associating qualitative categories to quantitative intervals for allowable tolerance, manufacturing table

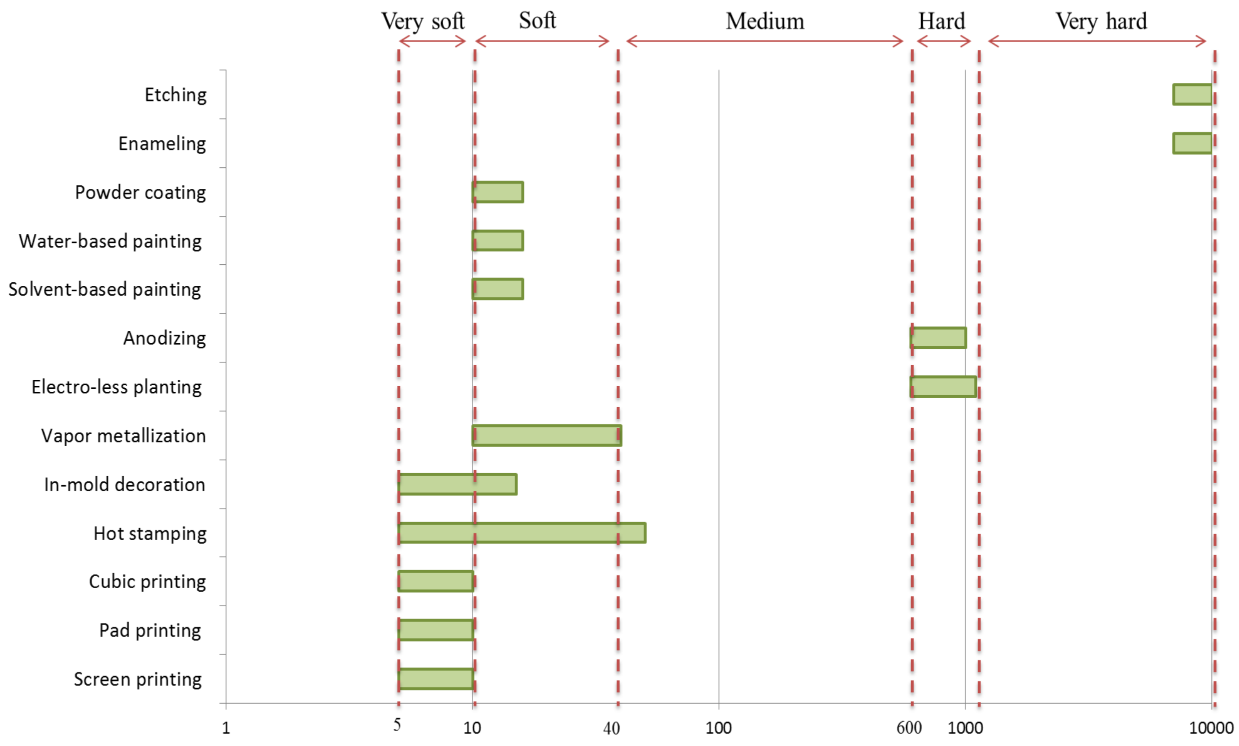



Figure A3-6: Associating qualitative categories to quantitative intervals for surface hardness, finishing table

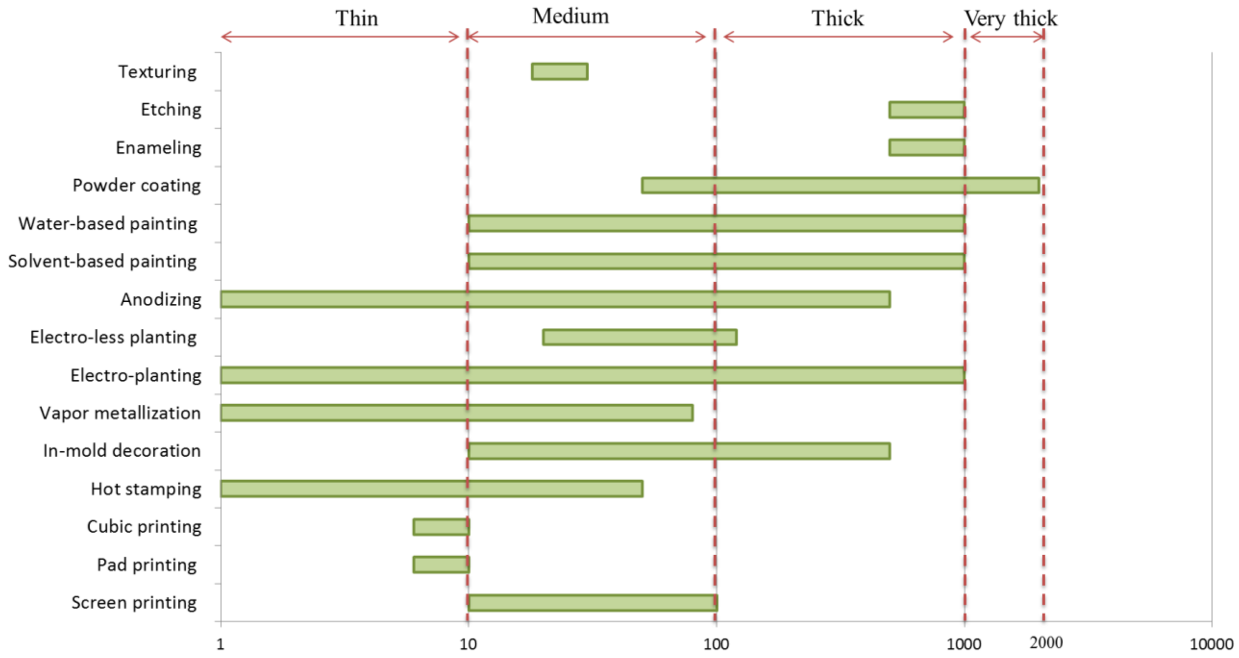



Figure A3-7: Associating qualitative categories to quantitative intervals for coating thickness, finishing table

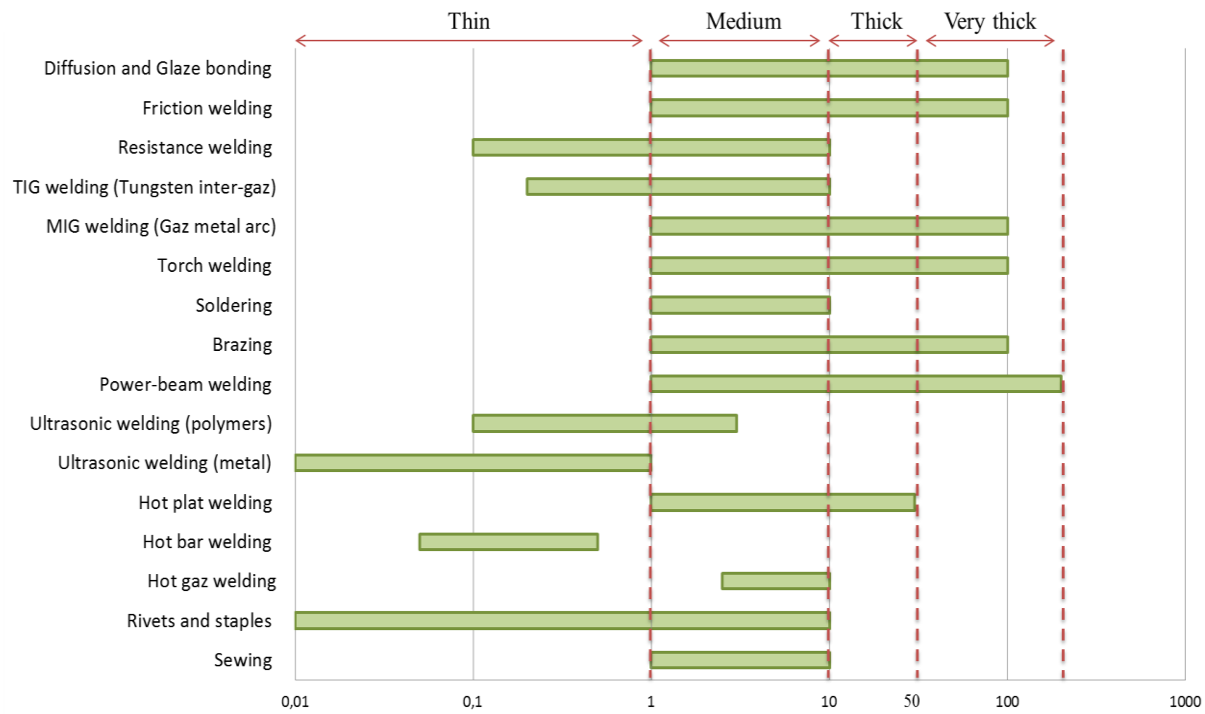
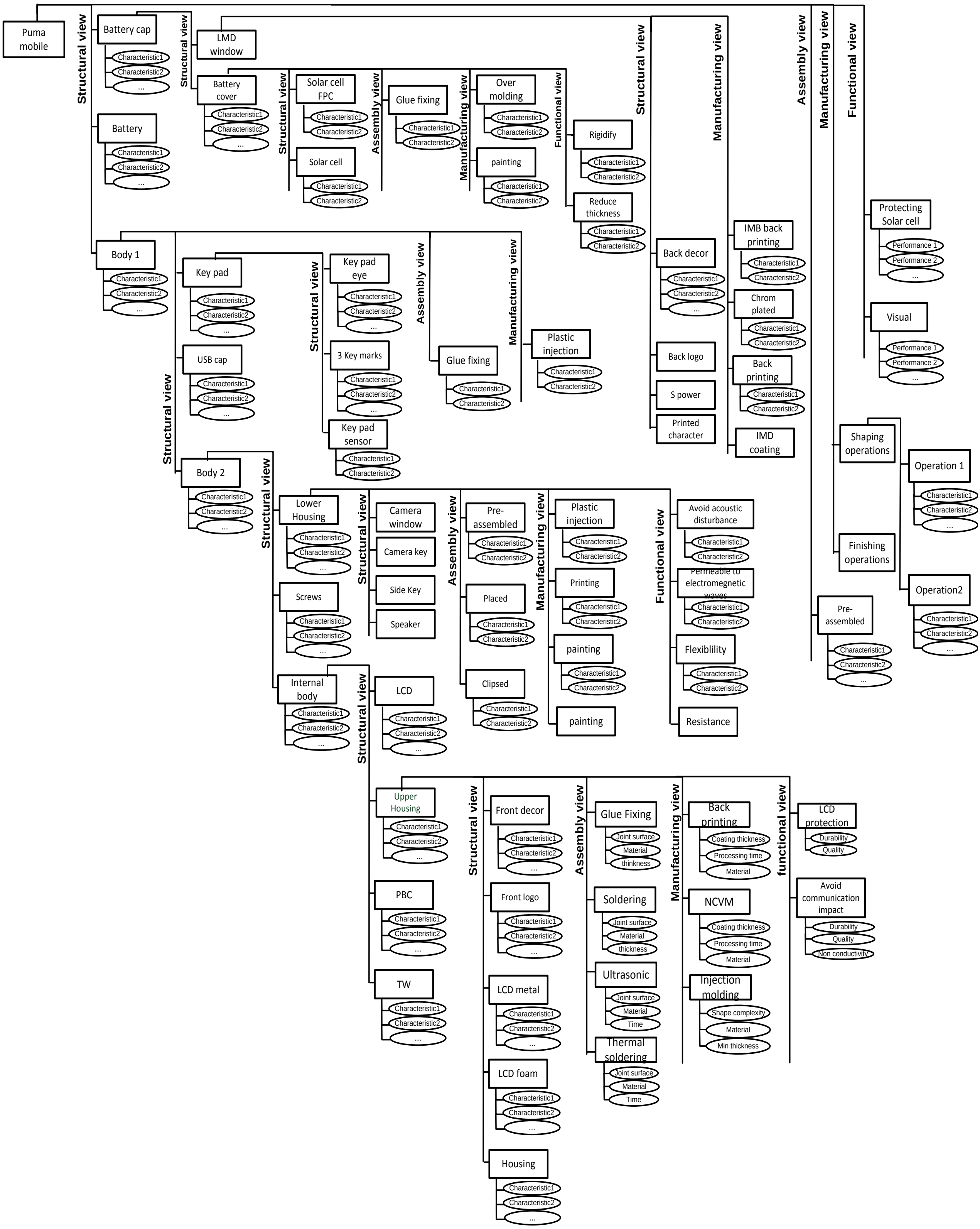


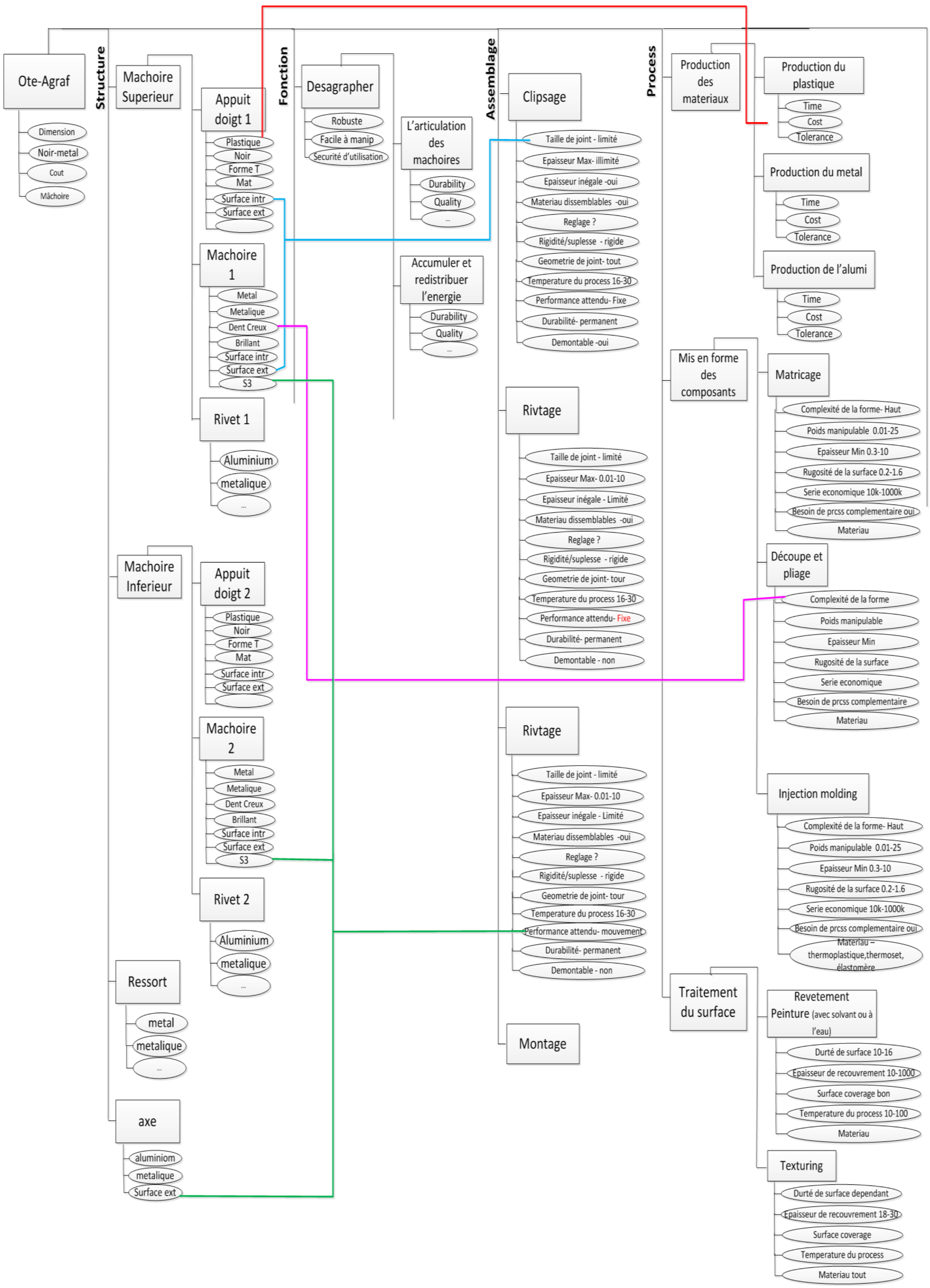

Figure A3-8: Associating qualitative categories to quantitative intervals for maximum thickness of assembled parts, assembly table

# Annex 4: Application of ProP and Lexical models

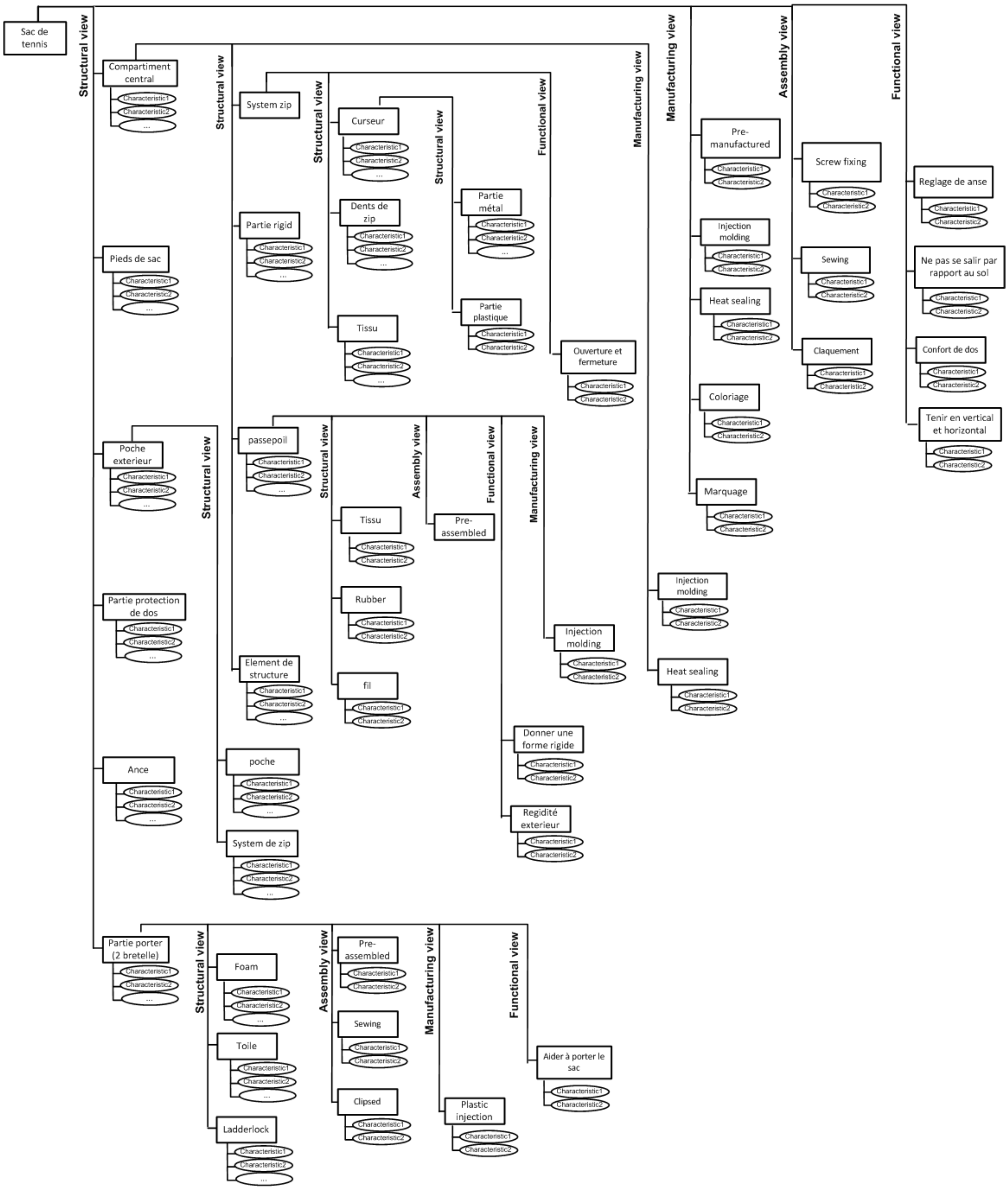
ProP model for PUMA cellphone.



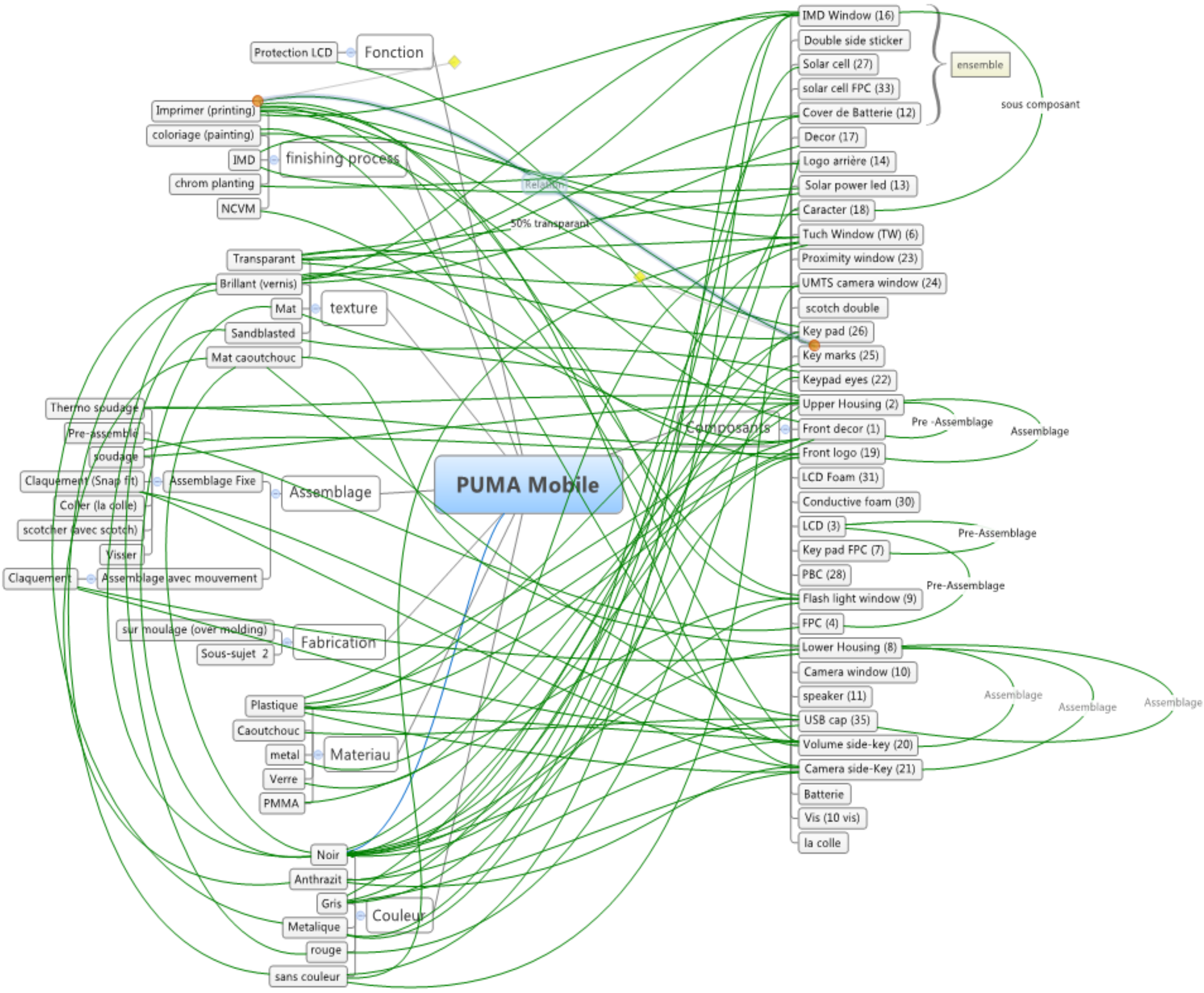
ProP model for stapler remover (ote-agraphe in french).



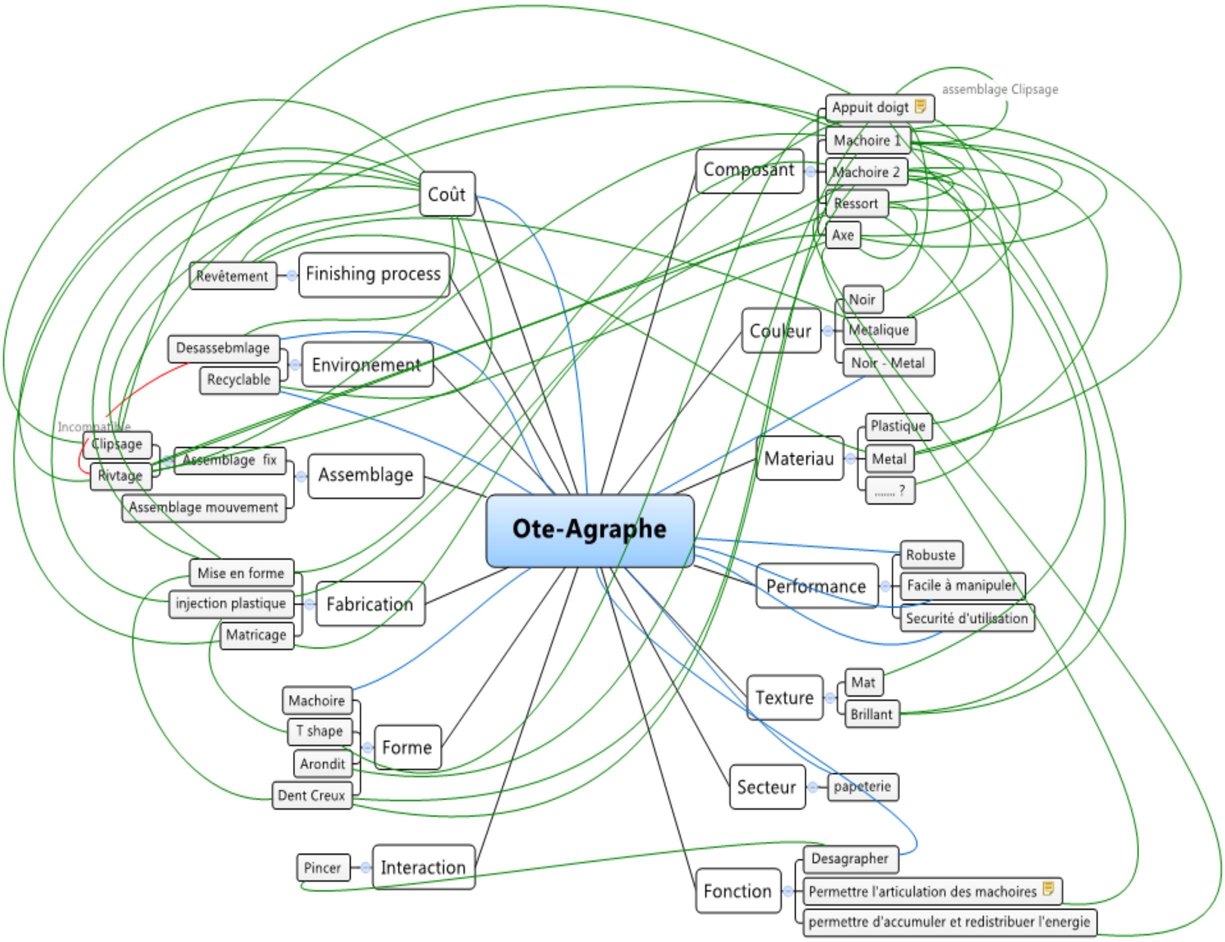
ProP model for the tennis bag.



Lexical for PUMA cellphone.



Lexical model for stapler remover.



Lexical model for tennis bag.