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MATERIAL SELECTION - A QUALITATIVE CASE STUDY OF FIVE DESIGN CONSULTANCIES

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Abstract

This qualitative case study aims at understanding when and how industrial designers, working in design consultancies, engage in activities that will influence material selection in the design process. While the extant literature presents material selection processes as a sequence of activities aimed at finding candidate materials, there is paucity of research on material criteria activities. Formulating material criteria is an activity that is performed during all design phases and they become clearer and more complete throughout the project. For the case studies, explorative semi-structured interviews were conducted with five industrial designers with 10 years of work experience or more. The results suggest (a) that risk management has a major influence on the material selection process, (b) that negotiations of project boundaries in the 'fuzzy' pre-design phase has crucial influence on the risk management aspect of the material criteria activities, and (c) a lack of awareness that design briefs usually outline material criteria expressed as sensorial characteristics, which are later translated by engineering into final material criteria used for the material selection process.

Keywords: Design practice, Design process, Design engineering, Case study, Risk management

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1 INTRODUCTION

Materials contribute to technical quality and function of products as well as the way users can interact with products (Hodgson and Harper, 2004; Gant 2005). Despite the importance of materials in product design, there is time pressure in design projects and condensed educational programs in dealing with aspects of materials (van Bezooyen, 2014). During the last decade Industrial Design Professionals have experienced many changes. Sustainability has undergone a transition from being a buzz word to becoming a part of legislation and thereby an expected design skill. The world of materials is also witnessing numerous radical changes. Diminishing resources, new challenges and stricter environmental restraints are driving changes in the working practices and mind-sets of producers and developers (Peters, 2011). With the development comes new responsibilities and the need to develop the existing methods and processes in relation to selecting materials and manufacturing processes. Mechanical engineering and industrial design activities are both concerned with material and manufacturing process selection, but the level of detail and the focus within the design work differs (Lenau, 2002; Ashby and Johnson, 2013; Granta Design, 2016). Generally material selection processes are described as formulating material criteria, making a set of candidate materials, comparing candidate materials and choosing candidate material (Farag, 2006; Chiner, 1988; Ashby et al., 2004; Jalham, 2006; Van Kesteren et al., 2006). While the extant literature presents material selection processes as a sequence of activities aimed at finding candidate materials, there is paucity of research on material criteria activities. Materials are pre-dominantly seen as the features of a physical structure, and as a result they are considered only after the conceptual design stage, in 'system/embodiment design' or 'detailed design' (Deng, Edwards, 2007). This contradicts with the notion that material selection is an interdisciplinary effort combining social, economic and environmental domains (Veelaert et al., 2016). Industrial designers have unique skills to combine technical properties and sensorial characteristics of materials in the product development process. This qualitative case study aims at investigating when and how industrial designers, working in design consultancies, engage in activities that will influence material selection in the design process.

2 THE DESIGN PROCESS AND MATERIAL SELECTION

Designers work by framing a problem in a certain way, making moves towards a solution and evaluate these moves based on the criteria of coherence, affordance and the problem-solving value. All design problems are unique and the core skills of the designer lie in determining how the problem should be tackled (Dorst and Dijkhuis, 1995). It is well understood that design problem solving is open-ended, with many potential solutions to tackle a given problem. Likewise, in material selection activities, which may occur in conceptual or detail design stages, alternatives are available, which are evaluated to make decisions (Deng, Edwards, 2007). Formulating material criteria is an activity that is performed during all design phases and they become clearer and more complete throughout the project. Hence, they do not come about at once, but are often changed and detailed. As a consequence, formulating criteria holds a central place in the iterative design process (Van Kesteren and Ilse Engel Heleen, 2008). Studies show that industrial designers gain best understanding of materials by handling physical material samples in combination with material selection software offering both technical properties and intangible characteristics (Hasling, 2015; Pedgley et al., 2015; Rognoli, 2010; Wilkes, 2011). The terms ‘properties’ and ‘characteristics’ used in this paper are adopted from the study of Hasling (Hasling, 2015). Properties that relate to the physical world of materials (mechanical, chemical, thermal etc.) are based on quantitative measures. Characteristics that relate to the social world of materials (e.g. meaning and emotions) are based on qualitative experiences. Mechanical engineers, typically working in a technical domain, often consider sensorial characteristics (e.g. warmth, softness) difficult to handle. The common properties of materials that mechanical engineers and industrial designers deal with are: technical properties, manufacturing processes and environmental issues (Ramalhete et al., 2010; Ferrante et al., 2000). Material characteristics that are particularly important to industrial designers are intangible and sensorial characteristics. The materials a product is made of play a major role in how the users experience the final product (van Kesteren, 2008; Karana et al., 2010, Hekkert and Karana, 2014; Schifferstein and Wastiels, 2014; Barati et al., 2015).

3 CASE STUDIES

Qualitative case studies offer a richness that enables sophisticated understandings of how and why specific occurrences, processes, and constellations happen (Gary, 2011). The aim of the qualitative case studies was to explore if commonalities in design practice could be found in relation to material selection processes. A 'practice' (Praktik in German) is a routinized type of behaviour which consists of several elements, interconnected to one other: forms of bodily activities, forms of mental activities, 'things' and their use, a background knowledge in the form of understanding, know-how, states of emotion and motivational knowledge. These conventionalized 'mental' activities of understanding, knowing how and desiring are necessary elements and qualities of a practice in which a single individual participates, not qualities of the individual (Reckwitz, 2002). The practice as a 'nexus of doings and sayings' is not only understandable to who undertakes that practice, but is also understandable to potential observers, at least within the same culture. To gather the data, qualitative interviews were conducted as described in Section 4.1. The challenges were first to analyse the qualitative data and then to make analytical generalization of these findings. For this reason the authors have chosen a practice theoretical perspective of Category Zooming (Halkier, 2011). Category Zooming is a way of generalizing by zooming in on particular aspects of the qualitative data material. This way of generalizing goes into depth with the details and complexities in one single point of the study. In our multiple comparative studies, comparison between cases were undertaken to ensure what was compared was analytically sufficiently identical across the cases.

Table 1. Short description of participating industrial designers

	A	B	C	D	E
Age	40-45	40-45	40-45	45-50	35-40
Gender	M	M	M	M	M
Educational background:					
Industrial designer	MFA	MFA	MFA		MFA
Design Engineer			BA	BA	
Professional experience (years)	12	14	15	16	14
Title:					
Senior Industrial Designer	X		X	X	X
Design Director		X			X
Partner		X			X
Type of case:					
Consumer electronics		X			X
Sport equiptment		X			
Health care	X			X	X
Consumer goods	X		X		
Technical equiptment			X	X	
Employees:	30-40	30-40	10-20	5-10	5-10

The participants recruited for the interview study were five industrial designers with 10 or more years of professional experience (see Table 1). The participants all work in multidisciplinary design consultancies, which is important in relation to having first-hand experience of complex material selection processes. Due to their long experience in industry, all five designers had advanced to senior design positions and two of the interviewees were partners in their respective companies. The design consultancies vary in size from 6 to 40 employees trained as industrial designers, graphic designers, interaction designers, Computer Generated Imagery (CGI) artists, mechanical engineers, etc. They mainly work with well-established international brands (e.g. medical devices, consumer electronics and sports equipment) and occasionally with smaller start-up companies. In the screening process 8 design consultancies in Scandinavia were found and contacted. From these 8 design consultancies, 6 participants were recruited, one interview was unfortunately cancelled by the participant for personal reasons. All 5 participants came from different design consultancies. It is worth noting that all participants are male and that no females were found in the screening process.

4 METHOD

For the case studies an explorative semi-structured interview form was chosen. To obtain realistic, not edited, accounts of material selection activities in the design process, the interviewees were not informed in advance of the research background and specific aims. The interviewees received a short general introduction when scheduling the interview. Each interviewee was asked to choose a typical case and was asked to 'talk us through it'. The informant prepared visual portfolio material from a typical 'bread and butter' design project to be used as a guide during the interview. It was considered important to avoid 'innovation' projects since they generally do not represent a typical 'everyday' design process. The interviews were carried out in the interviewees' design offices so that visual and physical materials were easily accessible during the interviews.

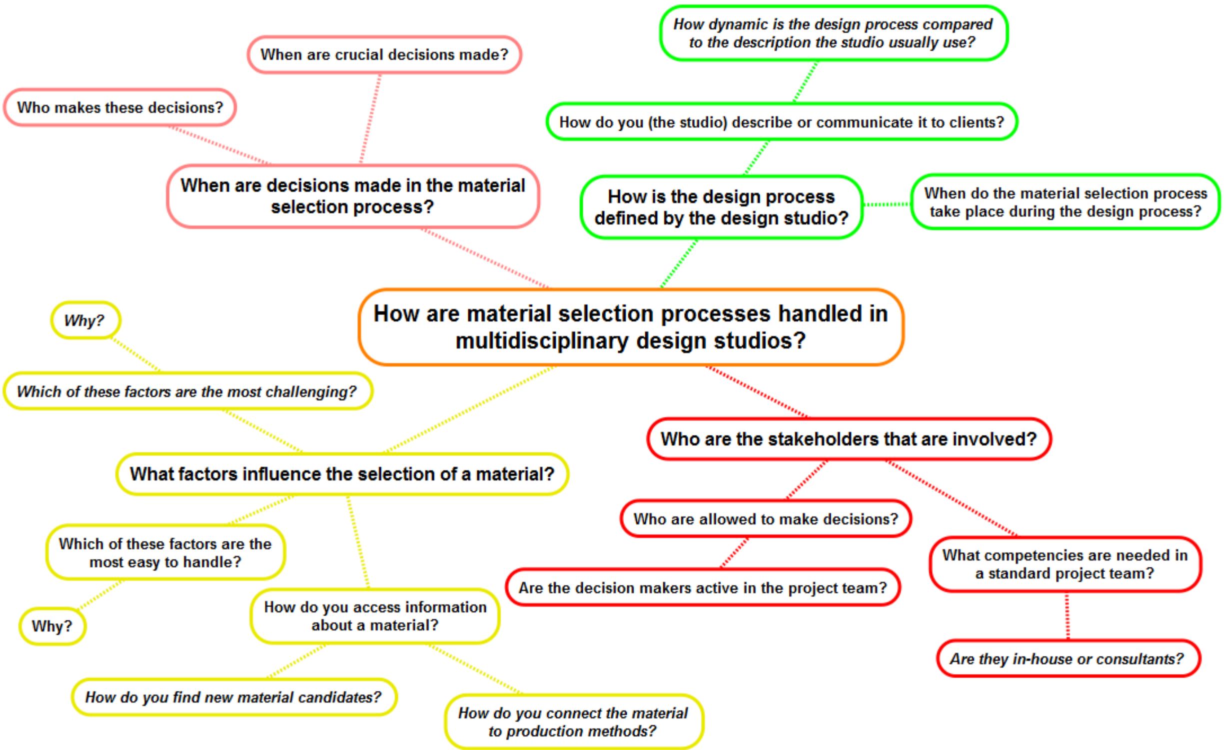

Figure 1. Interview guide with four main topics used during the interviews, italic text indicates questions added after the initial interview

The four main topics (see Figure 1) remained the same during all interviews, but after each interview, transcription and coding were undertaken, the questions were refined and some questions were added, so that the depth of information could be optimised. The interviews lasted between 48-72 minutes. The interviews were recorded, transcribed, coded in NVivo with open coding, and then analysed using a cross-case comparison approach (Gibbs, 2008). Four of the interviews were conducted and transcribed in Swedish and the fifth was conducted and transcribed in English. No translations were made before coding the data, instead the final results were translated, to avoid losing important details in the data. The interviewer has experience of working as an industrial designer in the automotive industry. This was helpful in conducting the interviews, being familiar with the vocabulary and the context, as one of the interviewees pointed out. This experience might also have a disadvantage, e.g. interviewees may hold back some information believing that it is common knowledge in the industry.

The main themes that recurred during the open coding were:

- Multidisciplinary or interdisciplinary.
- The 'fuzzy' pre-design phase.
- Material criteria activities.
- Material selection activities.
- Risk management .

5 FINDINGS

5.1 Multidisciplinary or interdisciplinary

The results of our interviews indicate that the design consultancies applied different strategies. The smaller design consultancies (5-10 employees) tended to work in multidisciplinary manner, whereas the bigger ones (20-40 employees) strived to work in an interdisciplinary way. One of the smaller consultancies worked in an interdisciplinary manner with some of their regular clients in the healthcare industry as they had developed strong relationships over time. The relationship contributed to increased influence already in the pre-design phase. While multidisciplinary work is characterised by the disciplines using their distinct methods, joining to work on a common task, then splitting apart unchanged, interdisciplinary work occurs when disciplines actually question their own approach and integrate, forging a new field or discipline. Divergence and convergence is a typical indication of multidisciplinary work, whereas simultaneous and integrative approaches point towards interdisciplinary work (Mansilla, 2006). Non-design participants typically start to envision an innovation from their own 'world' or domain but the object to be designed takes shape when ideas circulate from one domain to another. Acknowledging the absence of knowledge is also significant; it pushes the team participants to go into a co-design mode (Lehoux et al., 2011).

5.2 The fuzzy pre-design phase

In the pre-design phase, boundaries were negotiated between the design consultancy and the client. Starting point for the negotiations were often a brief with the optimal design process from the design consultancy’s point of view. The communication skills of the lead designer became crucial in the negotiation of the project boundaries. The results of our research indicate that the more skilled the negotiator is in understanding the consequences of the different stages of the design process, the greater influence he/she has on the final brief (see Figure 2). The industrial designers had all developed abilities over time to identify problems and to see 'the bigger picture', this also contributed to identifying opportunities in a project.

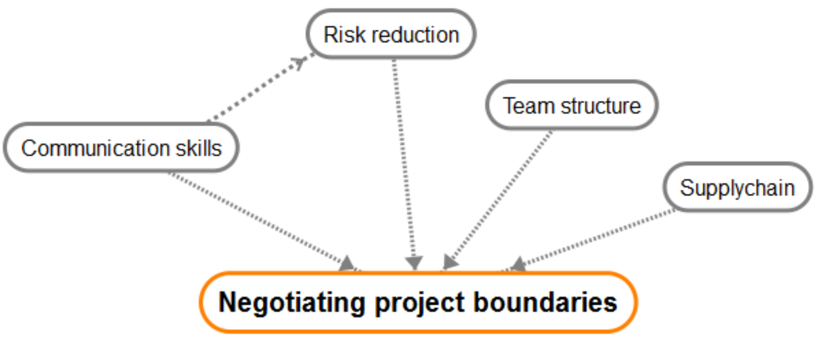

Figure 2. Factors that influence the negotiations of project boundaries

The pre-design phase is often referred to as ‘fuzzy’ because of the ambiguity and chaotic nature that characterises it. Several studies point out that an individual's tolerance of ambiguity is an important capacity of being creative (Merrotsy, 2013). Ambiguity is a powerful tool for raising topics or asking questions, while renouncing the possibility of dictating answers (Gaver et al., 2003). The goal of the exploration in the front end is to determine what is to be designed and sometimes what should not be designed and manufactured. The fuzzy front end (see Figure 3) is followed by the traditional design process where the resulting ideas for product, service, interface, etc., are developed first into concepts, and then into prototypes that are refined on the basis of the feedback of potential users (Sanders and Stappers, 2008).

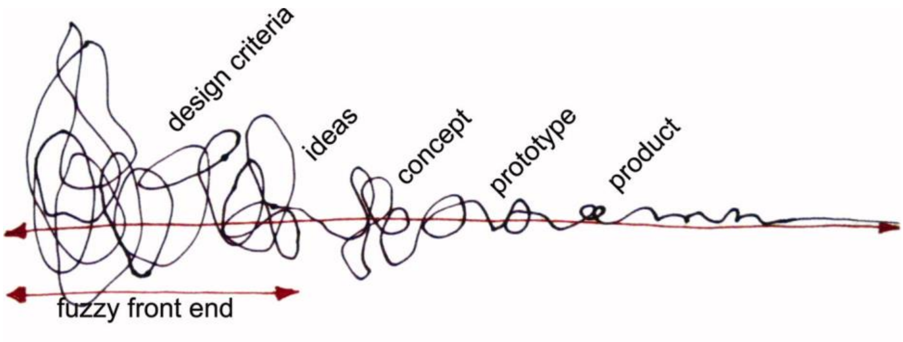

Figure 3. Fuzzy front end of the design process (Sanders, Stappers 2008)

The interviewees described their relationship with new clients as a maturing process and they nurtured the client to become a skilled design client. The Design Ladder (see Figure 4) is useful in understanding the client's experience and relation to design.

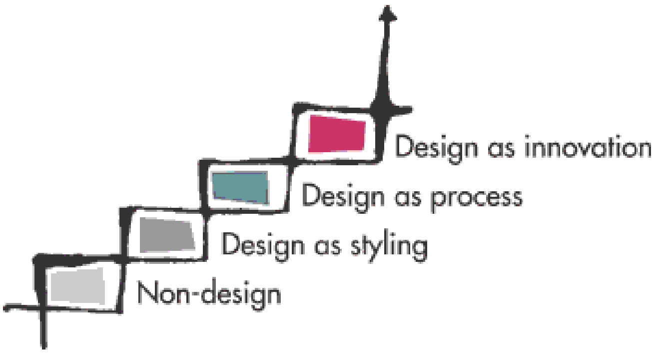

Figure 4. The Design Ladder is a tool for rating a company's use of design and was developed by the Danish Design Centre in 2001 to illustrate that companies' use of design may take on a variety of forms

Our results indicate that a lot of new information is gathered during the 'fuzzy front-end' of the design process. Many aspects are considered in this critical phase, e.g. understanding of users and contexts of use, exploration and selection of new technologies such as new materials and information technologies, etc. When time available to gather and process information in the fuzzy front-end is limited, the designers tend to rely on the re-use of their own experience about products, processes and materials. A creative start-up session is an efficient tool to frame the problem-space and the solution-space together with all the relevant stakeholders. This allows everybody to personally engage in the project, creating ownership and a sense that everybody can contribute with knowledge in stages that not necessarily within their area of expertise and comfort zone. These creative start-up sessions attempt to bring as much knowledge as possible in the project and to visualise some of the initial ideas. Previous studies suggest that design sketches serve not only as external memory or as a provider of visual cues for association of non-visual information, but also as a physical setting in which design thoughts are constructed on the fly (Suwa et al., 1998). Already in the 'fuzzy front-end', initial material criteria activities are performed.

5.3 Material criteria activities

Awareness of when initial steps are taken to define material criteria in a project was generally lacking in all of the design consultancies. They regarded the material criteria as mainly the engineers' responsibility. A reason for this might be that the industrial designers interpreted material criteria as purely technical properties and not sensorial characteristics. In the pre-design phase it is possible for the design consultancies to influence how the brief is written. By describing the interaction between the product and the user as rich as possible in the brief, one opens up the problem-space as well as the solution-space. For example, a brief for a medical device described how the product should feel when it came in contact with the user's body. The brief also described that the product expression in some of the parts *should signal the short lifespan of the part* and that *it is ok to dispose of* as the main housing *should be made a trusted friend*. The brief outlines material criteria expressed as intangible and sensorial characteristics. Being aware of this can contribute to that intangible and sensorial characteristics later on in the design process are carefully translated into technical properties. These translated technical properties contributes to formulate the final material criteria used for the material selection process by the engineers.

5.4 Material selection activities

In the interviews, two scenarios of material selection processes emerged. In projects based on incremental design, e.g. a new up-dated version of a mobile phone, the possibilities to influence the material selection as a design consultancy is very limited. In projects based on new product development or radical design, the influence depends on the material knowledge embedded in the project team and the skills of the negotiator in the pre-design phase. Earlier studies have shown that material selection should be taken into account from the early design phases in order to create an impact on the product life cycle cost and to support the conceptualisation (Veelaert et al., 2016). Materials considered in the fuzzy front end of the design process are dealt with on a more abstract and holistic level where materials can be used for creating a material vision and material criteria. Material selection refers to the well-defined process applied in the later stages of a design process where the materials selection criteria finally are defined by context of manufacturing and cost to realize an already mature product concept. Moving from the conceptual level of ideas towards the selection of tangible qualities can be challenging for designers, because of the diversity of aspects to consider (Camere et al., 2016). Often the material selection becomes a secondary priority for the industrial designers in complex projects; instead, they tend to rely on the skills of engineers. Consequently, it is crucial to translate the sensorial properties into technical properties so that the result from the design process keeps its qualities in the final stages of the embodiment design and pre-production. All product features contribute to users' holistic appreciation, and although products will be experienced as a whole (Schifferstein and Desmet, 2008), it is important for designers to fine-tune every detail. The materialization of their experiential vision brings the experience to life (Hassenzahl et al., 2015). For these reasons, moving from conceptual intentions to tangible qualities is a delicate moment of transformation, in which every decision matters, and on which the final success of the product depends (Camere et al., 2016). Reflection is crucial in a material selection process since there is no specific answer; only contextually related material candidates are available (Asbjørn Sörensen et al., 2016).

5.5 Risk management

Risk management is often mentioned in the interviews as an argument for not implementing alternative materials that could contribute to improve the performance of a product. The interviewees indicated that the project timelines did not accommodate in depth risk management. Ambitious product development projects, working within tight time and resource constraints are difficult to handle in small to medium sized businesses. A key challenge faced by new product development projects is how to acquire knowledge and manage sources of uncertainty in order to reduce the risk of failure of either the project or the resulting product. The product can "fail" due to intrinsic problems (e.g. does not meet performance, reliability, or safety requirements in the environment for which it was designed) or extrinsic problems (e.g. flops in the market, changes in regulations), while the project can "fail" by violating constraints (e.g. delay, over budget), not delivering the product, or not surviving the intense competition. Uncertainty exists relative to both possible outcomes and their likelihood of occurring (Cooper, 2003). Risk management becomes an especially dominant factor in the implementation phase of a product development project, (Narayana, 2005) but affects the design process as a whole. As a design consultancy, it can be valuable to identify and understand what is considered a risk by the client and then to systematically address them one by one.

6 FINAL REMARKS

In the case studies the material selection process was difficult to extract from the intricate web of activities in the design process. Industrial designers work both on inspirational and analytical levels in material selection processes. Material characteristics are closely related to manufacturing processes and these becomes intertwined in the creation of a products' function and expression. In a design project, material selection is generally a team-based activity, with contribution from, amongst others, industrial designers, mechanical engineers, and marketers. The industrial designers' skills in translating sensorial characteristics into technical properties are important in team-based activities, and can have great influence, especially in the later stages of the material selection process. Risk management is another important factor that influences the material selection activities throughout the design process and therefore the lead designers need a basic understanding of the mechanisms of risk management. This would assist the lead designers to develop more powerful argumentation when negotiating project boundaries in the pre-design phase. The designers' communication skills also play a central role in the early stages of the design process when creating representations of ideas together with the client. Creating these representations are important early steps of the material criteria activities.

The findings implicate a need for increased awareness amongst industrial designers: (a) of when material criteria activities actually are performed during the design process; (b) that material criteria activities are negotiated and outlined already in the pre-phase of the design process; and (c) about how risk management influences both material criteria activities and material selection activities. Industrial design students would benefit from being taught how to undertake activities in the pre-design phase.

Exploratory semi-structured interviews are rich in information but time consuming to analyse. To further validate the findings, a complementary survey is planned and further interviews will be conducted. In the case studies, the selection of interviewees was limited to design consultants and did not include in-house designers. Further studies are planned to identify possible differences in material criteria activities and material selection activities between design consultants and in-house designers.

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