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STRUCTURING PERCEIVED QUALITY ATTRIBUTES FOR USE IN THE DESIGN PROCESS

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Abstract

Perceived quality has received much attention the last decade, mainly in the automotive industry. The focal drivers are the competitiveness within the premium segment, and customers' high demands. The existing definitions of perceived quality found in the literature are fuzzy. Methods for assessing perceived quality do exist, however the attributes need to be incorporated into existing design support systems to be efficiently used in the design process. This paper is a first attempt to merge a new terminology framework of perceived quality with an apparent problem, observed at an automotive company, of incorporating perceived quality in the product design process. A case study was conducted at an automotive company to depict the current state of managing information. It was uncovered that information is scattered across systems and that the way to package information is assorted. A new framework, introducing Value Based Perceived Quality and Technical Perceived Quality is presented. To better incorporate the attributes into the design process, a platform system model is proposed. In this way, perceived quality attributes can be reused for various design applications.

Keywords: Perceived quality, Technical Perceived Quality, Automotive, Platform, Information management

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1 INTRODUCTION

The superiority of the automotive companies in the modern world is no longer solely driven by zero defects, but depend increasingly on customers' perception of quality (Robinson, 2000). Studies show that perceived quality plays a significant role when a customer judges the quality of a product (Petiot et al., 2009; Schmitt et al., 2008.). Within the premium segment of the automotive industry, this is of major concern, due to the competition among the players. Thus, customers compare the relative perception of quality between the automotive players. Similar to the conceptual model of service quality, proposed by Parasuraman et al. (1985), there is a gap between customer perception of product quality and functionality, and the quality attributes incorporated in the design by engineers. To minimize the gap between design and manufacture for perceived quality, and the actual customer perception of the design, there is a need to define and structure perceived quality attributes. Likewise, there is a need to precisely measure and assess the importance of these characteristics regarding customers' purchasing choices. In practice, it corresponds to the implementation of methods used to quantify perceived quality attributes. However, the evaluation of perceived quality is claimed to remain highly subjective (Eckert et al., 2014).

The agile automotive manufacturer will not only recognize the need to assess attributes objectively, but also the need to store attributes neatly to support reuse for various design applications better. To integrate information regarding perceived quality attributes in information management systems for future reuse is fundamental in order to eliminate rework and frequent manual interventions. However, storing information of perceived quality for reuse in design has many limitations. Therefore, decisions that the design engineer has to make will be based on individual experience and intuition (Ranscombe et al., 2012). These decisions may affect the product, and how the customer perceives the quality of the product. Thus, the perceived quality attributes need to be carefully assessed and utilized in the design. Due to the competitive nature of the automotive industry, there is a lack of time, lack of money and overflow of rework, thus little room for making proper inclusion of perceived quality attributes. To minimize rework there is a need to reuse information regarding perceived quality, however there exist no comprehensive framework that structures and defines perceived quality, which can be used to efficiently incorporate these means to be reused in various design applications.

1.1 Methodology

This paper is based on theory of perceived quality, as well as touches upon areas of information management and platform-based development. The reason for this scope was derived from numerous discussions with engineers and R&D group leaders at a case company from the automotive industry in Sweden (2014). It was agreed that a more generic definition of perceived quality attributes is needed to structure and prepare integration of quality attributes efficiently into the design process. The need for structure of this kind is shown by a case study made at the automotive company. In 2013, ten semi-structured interviews were conducted with senior-level engineers and managers working cross-functionally between departments, dealing with information integration, spanning from marketing, R&D and aftermarket. The interviews were voice recorded and transcribed to text. The transcripts were sent to the interviewees for verification. The results were hereafter analyzed and categorized.

This paper is disposed as follows: Chapter 2 is a state-of-the-art review of existing definitions of perceived quality in literature as well as a brief review of information management and platform-based development. Chapter 3 is presenting the result and analysis of the literature review and the current state at the case company. Chapter 4 concludes and summarizes the most significant findings.

2 BACKGROUND

In order to grasp the vast body of literature on perceived quality, a comprehensive review was made. Also, a short literature review on information management and platform-based development is included to support the understanding of the current state at the case company.

2.1 Quality in the Literature

There are a number of studies that admit multidimensional nature of product quality and customer perception of the quality attributes. Garvin (1984a) introduced five quality dimensions, such as value based, transcendent, user based, manufacturing based and product based. The value based approach is a definition of quality related to cost and price. According to Garvin, implication of this approach is rather difficult in practice, because the quality is determined by the excellence or superiority of the product and it is difficult to define acceptable cost. The transcendent approach states that the quality cannot be defined precisely and has roots in Plato's discussion of beauty. The user based approach is based on the assumption that the product with the highest quality is the one that satisfies the individual needs of the customer, thus a highly subjective view of quality. The manufacturing based approach is contrasting the user based approach, and focus primarily on manufacturing and engineering aspects. This approach can be described shortly as "conformance to requirements". The product based approach considers quality as the measurable variable that can be assessed objectively. Furthermore, Garvin established a framework for the eight essential dimensions of product quality:

1. Performance (primary product characteristics)
2. Features (secondary attributes)
3. Reliability (uptime)
4. Conformance (match with specifications)
5. Durability (product life)
6. Serviceability (speed of repair)
7. Aesthetics ("fits and finishes")
8. Perceived quality (reputation and intangibles)

Though, Garvin (1984b) define aesthetics and perceived quality as highly subjective elements of the product quality. Zeithaml, (1988) presented a model where quality has two dimensions: objective or actual quality and perceived quality. The perceived quality according to Zeithaml can be defined as a "consumer's judgement about a product's overall excellence or superiority". The definition of perceived quality from the marketing perspective can be illustrated by Aaker (2009), "the customer's perception of the overall quality or superiority of a product or service with respect to its intended purpose, relative to alternatives". Perceived quality is, first, a perception by customers. It thus differs from several related concepts, such as:

- Actual or objective quality: the extent to which the product or service delivers superior service
- Product-based quality: the nature and quantity of ingredients, features, or services included
- Manufacturing quality: conformance to specification, the zero defect goal

Analyzing this, it becomes clearer that perceived quality presented as a subjective and not measurable unit among the other types of quality.

To conclude, it is noticeable that the traditional views on perceived quality is opposing to the "actual" or "objective" quality mainly because of the assumption that perceived quality attributes cannot be assessed objectively.

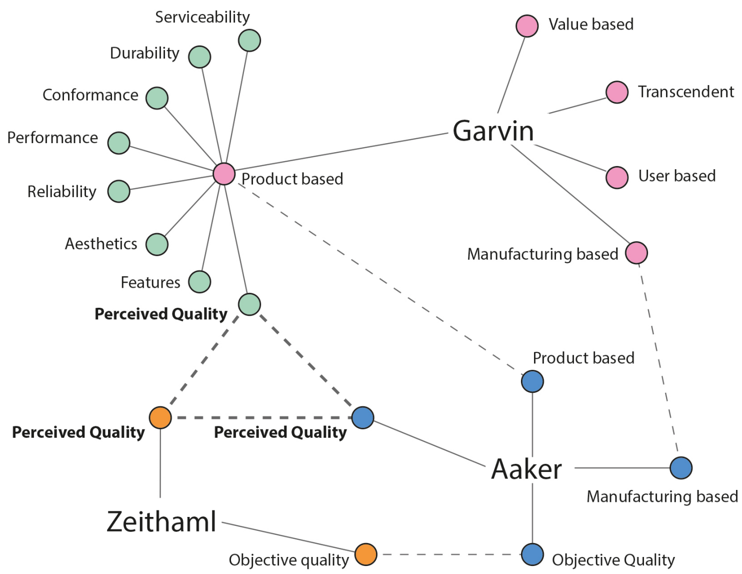

Figure 1. Schematic representation of the quality dimensions, approaches and the links within, derived from a state-of-the-art review within the area of perceived quality.

2.2 Perceived Quality in the Automotive Industry

In the automotive industry, research regarding perceived quality has multidimensional nature mainly focused on the product based and user based approach. There are numerous studies on quality related to brand image and brand heritage, aesthetics and perception of craftsmanship. Taking the user based approach to quality into consideration, Wiedmann et al. (2011) presented a methodology including customers' perception of the heritage brands in the automotive industry. Homer (2008) demonstrated a relationship between brand image and the quality and portrayed the conflicts between "actual" product quality and its perceived "image". Law and Evans (2007) explained the meaning of the luxury and premium in relation to the exclusive automotive market. It is important to realize that studies regarding brands, customer behavior, core values are extremely valuable in order to improve communication strategy towards customers.

Contrary to these softer values of perceived quality, research is also focused on technical aspects, such as material quality, sound quality, split line and squeak & rattle assessments. Extensive research is made regarding technical aspects of aesthetics in the automotive industry. Ranscombe et al. (2012) investigated the influence of different aesthetic features on brand recognition by the consumer and presented the decomposition technique to support designers. The proposed method can improve evaluation of product appearance. Penzkofer et al. (2008) presented visual analysis method for non-ideal assemblies since the deviations from the ideal geometry can influence the aesthetic quality. The literature on different aspects of visual quality includes effects of geometrical variation in perceived quality, optical quality, visual sensitivity (Forslund and Söderberg, 2008; 2009; Forslund et al., 2006), split lines appearance (Dagman et al., 2004) with gap and flush evaluations (Stoll and Paetzold, 2008; Wickman and Söderberg, 2007). In the work presented above, authors bring a number of concrete terms in order to describe visual aspects of perceived quality, for instance: optical quality, visual sensitivity, visual quality appearance and quality appearance index. Furthermore, there is a controversy in the literature regarding aesthetics as a part of the visual quality and the nature of this subject. Maxfield et al. (2002) claim "aesthetic quality has no precise definition since it is a qualitative attribute that is perceived by a customer through visual inspection and comparison. It may be loosely defined as the 'look' of the product". Previously Juster et al. (2001) introduced the term cosmetic quality with a similar approach. Alternatively Hazra et al. (2013) presented a method for determining cosmetic quality of automotive skin panels. Generally speaking, the aesthetic quality as a part of visual quality is not clearly defined; therefore this method was introduced to quantify and measure customer perception.

Craftsmanship in the automotive industry is usually interpreted as another definition of perceived quality. Several studies show the importance of craftsmanship in the overall customer perception of quality (Ersal et al., 2011). Petiot et al. (2009) portrayed users' perceptions of craftsmanship in vehicle interior design as a cross-cultural study. Ersal et al. (2011) demonstrates a methodology that analyses vehicle interior characteristics and describes perceived craftsmanship attributes. Bhise et al. (2005) presented a methodology for measurement of the customer perceptions regarding the interior materials of a vehicle. Although, craftsmanship is a complex construct based on human perceptions, hence it is difficult to formalize and quantify all attributes included. Turley et al. (2007) defined craftsmanship as "…perception of quality experienced by the customer; it is based on sensory interaction and emotional impact". That is to say similar to the traditional view of perceived quality.

Another key point is in the understanding of perceived quality by the Kansei Affective Engineering. Kansei is a Japanese word that has no direct translation into English, however "*in the new product development context, it can be defined as the image a person has of a determined product, environment, or situation, when sensed through the senses of sight, hearing, taste, smell, and touch. Kansei is the consumer's feeling and mental image regarding a product*" (Okamoto, 2010).

As deliberated above, there are gaps and convergences in the definition of quality and its components (see Figure 1), as well as in regard to the different perceived quality attributes (see Figure 2).

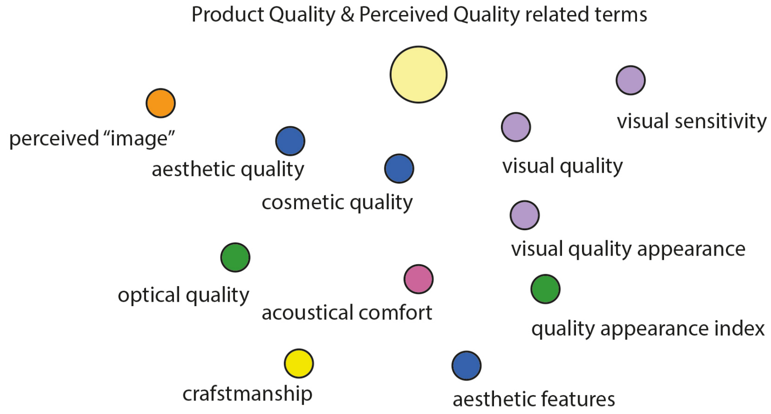

Figure 2. Schematic representation of the terms related to the perceived quality in the automotive industry which are used by different authors.

2.3 Limitations of Incorporating Perceived Quality in the Design Process

Information management in the automotive industry usually incorporates a powerful set of tools used to manage the lifecycle of the product, by Product Lifecycle Management (PLM) systems. PLM solutions consist of product-related data, engineering processes and integration of various applications (Abramovici, 2007), e.g. CAD models, Design Prerequisite (DPR) documents and standard documents. However, CAD modeling is restricted and does not support structuring and decoupling of functions from a functional feature, represented as a physical part. Knowledge-based engineering does however support inclusion of for example design constraints into an actual design, however they are usually integrated into a specific application or model. DPRs have its advantages, e.g. provide rich descriptions of how to design; however using only documents makes it cumbersome to apply information between various design applications. Usually, these documents are created one by one in different settings or with standards of a specific department.

2.4 Platform-based Development

The focal argument for platform-based development is the emphasis on reuse. Accordingly, a platform supports reuse of assets (Robertson & Ulrich, 1998), subsystems and interfaces (Meyer & Lehnerd, 1997). The primary intent of preparing a platform is to form a common structure. The platform can be used to develop and produce a stream of derivative products. This stream of products is commonly referred to as a product family.

2.4.1 Reusable Platform Elements

The Configurable Component (CC) concept is an object-oriented approach to describe system platforms. It contains reusable elements. Reusable platform elements can be used to structure information about a product. The CC concept was proposed by Claesson (2006) as an object model. Since then, the platform system model has been developed to encompass support when developing product platforms, manufacturing systems platforms (Marcel T. Michaelis, Johannesson, & ElMaraghy) and technology platforms (Levandowski et al., 2013).

Each CC element holds a system family, containing information about the system solution itself, the means to compose system variants and its underlying requirements and motivations, i.e. its Design Rationale (DR). The Design Rationale is based on Enhanced Function-Means (E-FM) modeling, deliberated by Schachinger and Johannesson (2000). E-FM modeling describes the interactions between Functional Requirements (FRs), Design Solutions (DSs) and Constraints (Cs). An illustration of a CC object and the theory behind EF-M modeling is shown in Figure 3.

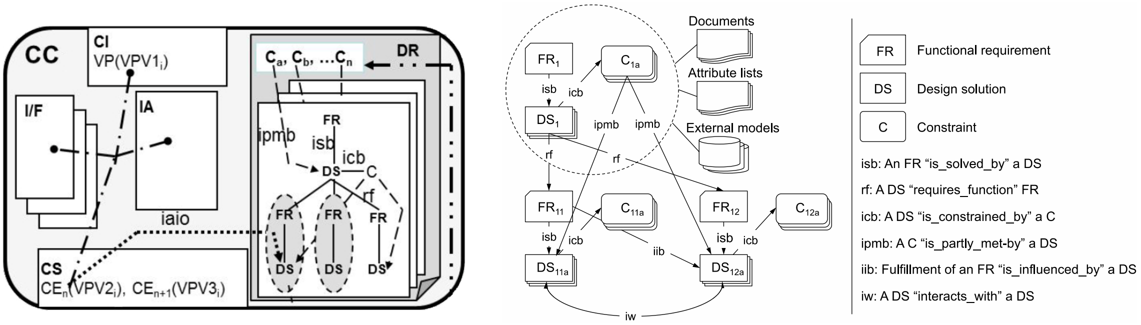

Figure 3. Illustration of elements adhering to the platform system model Configurable Components (CC) concept. To the left, a CC element with its Design Rationale (DR) and entities; Control Interface (CI), Composition Set (CS), Interface (IF) and Interaction (IA). To the right, the DR with its description of Enhanced Function-Means (E-FM) modeling describing Functional Requirements (FRs), Design Solutions (DSs) and Constraints (Cs) and their defined interdependencies (as drawn in Michaelis (2013), adapted from Johannesson and Claesson (2005)).

3 RESULTS AND ANALYSIS

From reviewing literature and examining historical events in the automotive industry, it is interesting to note that perceived quality has evolved, both in academia and in industry. The concept of perceived quality has expanded to something that needs to be further incorporated into the design process in more detail compared to early initiatives. This shift is very roughly illustrated, utilizing the common S-curve, in Figure 4.

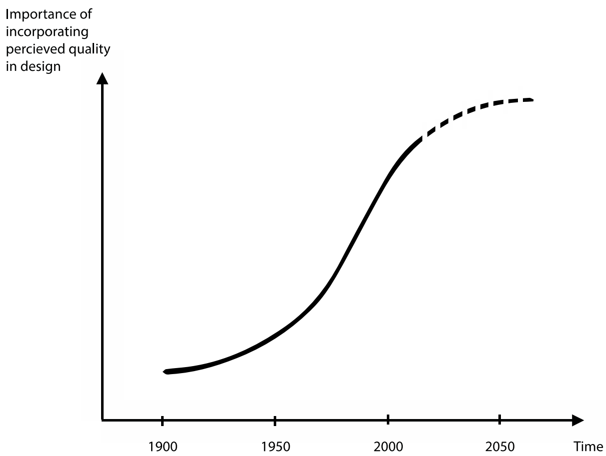

Figure 4. A rough illustration describing the importance of incorporating perceived quality attributes for an automotive company to satisfy ever-demanding customers over time (the dotted line is an uncertain projection).

The definitions of quality in literature either includes perceived quality as a property of the product quality (Garvin, 1984a), or as a subjective perception or judgment by the customer (Aaker, 2009; Zeithaml, 1988), which is different from any definition of objective quality. To assess subjective perceived quality into objective means is not trivial task. Likewise, it is difficult to organize such information, when the objective attributes are assessed.

In this paper, a comprehensive terminology framework, tailored for the premium segment of the automotive industry is presented. It is a step towards a generic structure of perceived quality attributes. The framework is illustrated in Figure 5. It is derived from a broad literature review that depicts the major elements of perceived quality, where perceived quality in the automotive industry supposedly has a dualistic nature. Therefore, we propose to divide perceived quality into Value Based Perceived Quality (VPQ) and Technical Perceived Quality (TPQ). VPQ advocate the total customer experience of the product attributes including subjective factors through human senses and cognition (e.g. customer expectations, brand, core values, etc.). TPQ, on the other hand, is representing the engineering approach to perceived quality. TPQ is based on the level of individual technical aspects of the product, perceived with the purpose to fulfill customer requirements and the competition relative the players in the premium segment. TPQ is a sub-system of VPQ. TPQ is based on four of the five human senses: Sight, Touch, Hearing and Smell. The top level of TPQ is divided into four major elements: Visual Quality, Feel Quality, Sound Quality and Smell Quality. These elements have a complex structure and construct forms, including specific components. On a lower level of granularity, major clusters).

Visual Quality consists of the sub-systems Aesthetic Quality, Geometry Quality, Illumination, Surface Finish and Paint Finish. Feel Quality consists of the sub-systems; Solid Function, Material Quality, Geometry Quality and Paint Finish. Sound Quality consists of the sub-systems Operational Sound Quality, Dynamic and Static Squeak & Rattle and Material Quality. Smell Quality consists of the sub-systems Interior Smell and Odor Intensity. The sub-systems of TPQ have clear interactions. For instance, Material Quality is affecting Visual Quality, Feel Quality and the Sound Quality. The Geometry Quality influences not only the Visual Quality but also Feel Quality.

It is worth noting that the importance of the elements on a lower level of granularity in the presented model will change over time. An example that illustrates this assumption is passive safety, which is an important perceived quality attribute, however studies shows that in order to communicate safety in the premium automotive segment it is necessary to make shift towards active safety systems (Stylidis et al., 2014). There is a need to incorporate perceived quality attributes better into the design process. Within the presented framework, it is possible to structure perceived quality attributes and assessments regarding every component of the TPQ.

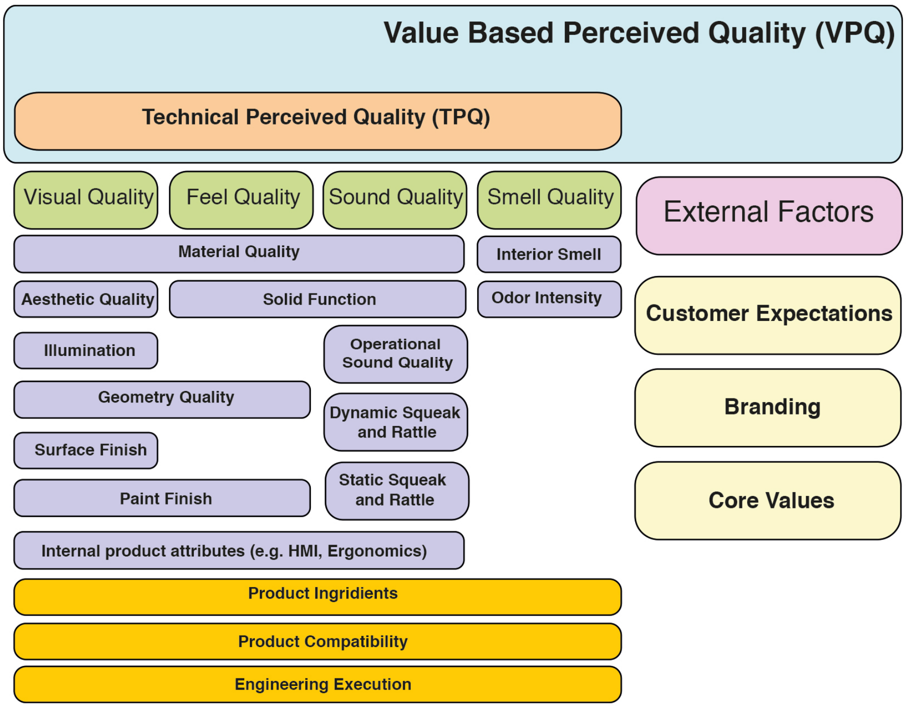

Figure 5. The terminology framework of the perceived quality in the automotive industry

3.1 The Current State at the Case Company

The company has one distinct group working with perceived quality. However, there are four additional groups working with technical perceived quality, according to the presented terminology framework illustrated in Figure 5. The five groups are, as for now, scattered throughout the organization. Thus, even though there are unifying similarities between the groups, such as recurring interactions between various applications in the design process, the groups are partitioned into different departments. Each department has its way of managing documents with restrictions to certain users. However, all departments use the same centralized PLM systems. It is apparent that the information is scattered and that there is a need to better integrate information between the departments and the systems that they use. This becomes apparent when users outside the department need to incorporate information from one application to another, and specifically between the five groups. The need to share information about perceived quality attributes has become significant for the company due to the premium segment strategy. However, it is not clear and requires continuous manual intervention. Today, perceived quality attributes are managed by the use of a vast body of systems within the PLM environment, however none seem to be well suited for structuring and storing requirements to be used in the design process. The information is rather stored in large documents and Excel sheets, and due to lack of structure and standardization between departments and groups, perceived quality attributes are not well suited for reuse.

4 CONCLUSION

This paper presents a terminology framework for perceived quality, applicable for the automotive industry. A broad literature review has shown that the definitions of perceived quality and its elements are rather fuzzy, especially for automotive application. The fuzziness has lead to difficulties in incorporating design specific perceived quality attributes in the design process. An initial study at an automotive company concluded that incorporating perceived quality attributes in the existing PLM systems is cumbersome. For this reason, there is a need to package the information to provide reusable assets for several design applications. The terminology framework was constructed to define and structure perceived quality attributes. To further structure and integrate these attributes ready for use in the design process, the concept of platform-based development and reusable platform elements has been introduced.

Future work will be employed to further investigate the limitations of incorporating perceived quality in the design process, model an illustrative case of perceived quality attributes using Enhanced Function-Means (EF-M) modeling to verify and to promote the ability to reuse information in the design process. Consequently, each of the TPQ elements will be elaborated into systems of lower levels of granularity using the illustrative case.

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