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Design of the top tether component for the premium car market segment: Case study of Volvo Cars

Kostas Stylidis [a, *], Elias Al-Saidi [a], Arun Thomas Erinjery [a], Lars Lindkvist [a], Casper Wickman [a, b], Rikard Söderberg [a]

[a] *Chalmers University of Technology, Department of Industrial and Materials Science, 412 96, Gothenburg, Sweden*
[b] *Volvo Car Corporation, User Experience & Craftsmanship Centre, 91300 Torslanda PV3A, 405 31, Gothenburg,, Sweden*

* Corresponding author. Tel.: +460317728284; *E-mail address:* stylidis@chalmers.se

Abstract

The positive correlation between successful car design and high perceived quality is indisputable. In the highly competitive premium car market segment, the implementation of methods for perceived quality evaluation is an integral part of the strategic development plans of car manufacturers. However, to correctly define the perceived quality requirements and address market opportunities, the car manufacturers need to capture diverse customer demands. This study seeks to understand how customers perceive and prioritize attributes that are associated with the perceived quality of the premium car market segment. During the study, we evaluated the next generation top tether design concepts for Volvo Cars sedan models S60 and S90. The top tether is the part of an ISOFIX system used to connect a forward-facing child seat in a car and is a critical safety component significantly reducing potential injuries. We applied the Perceived Quality Attributes Importance Ranking (PQAIR) methodology to understand the importance of different perceived quality attributes from a customer perspective. In other words, we investigated the meaning of "premiumness" for the customers, applied to the specific car component. This approach was tested on 200 respondents representing the customer target group and was performed in collaboration with Volvo Cars technical experts. Our results verify the rationality of the applied method and indicate the improvement of engineering practices regarding the evaluation of perceived quality.

Keywords: perceived quality, automotive, Volvo, premium, product development;

1. Introduction

Traditionally, high manufacturing quality was one of the major success factors for car companies operating in the premium market segment. Nowadays, technical excellence is just a basic requirement – the entry ticket to the premium car manufacturers' league [1]. Hence, new success factors must be determined to differentiate one car manufacturer from competitors. Consequently, for the premium car market, product differentiation largely derives from the customer's assessment of perceived quality. Previous research demonstrated that only a balanced combination of manufacturing quality and subjective factors related to customer perceptions (i.e., quality impression, brand value perception, design factors, aesthetics) could make a difference in the highly competitive market [2-3]. Volvo Cars is one of the well-recognizable premium car brands. The company operates globally, performing manufacturing, research and design operations in Europe, Asia, and the Americas. Volvo Cars seeks to find a justified solution to transform a current top tether design into one with a premium appearance. The initial work on this project was performed at Chalmers University of Technology, Sweden, within the frame of a master's degree project in collaboration with Volvo Cars [4]. However, the primary goal of this study is to evaluate the next generation top tether design concepts for the current Volvo Cars sedan models

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S60 and S90. To find a tangible solution that can satisfy given criteria regarding the appearance, design, and materials we implemented the Perceived Quality Attributes Importance Ranking (PQAIR) method in combination with the Perceived Quality Framework (PQF) [5]. While PQF has previously been applied to the mapping of product attributes related to perceived quality, a process of using PQAIR method for the specific task related to the evaluation of geometry and appearance attributes within the broader context of the premium car market segment has not been addressed. We tested this approach on 200 respondents representing Volvo Cars target group. The obtained results exposed critical (in terms of their importance to customer perception of "premium quality") aesthetic appeal, geometry and material-related attributes. Analysis of the results allowed Volvo Cars professionals to obtain knowledge of the end customer's perception regarding the sense of "premium" design of the top tether component and quantify the impact of different perceived quality attributes on the overall quality perception of the given component. This illustrated that the proposed research approach is viable in the context of an understanding of customer perceptions related to product design.

This paper is structured as follows: Section 2 discusses related work and motivation for this study. Section 3 describes a methodology applied in this study. Section 4 examines evaluation of perceived quality attributes related to the design of the top tether component and discusses the results. Section 5 offers conclusions.

2. Background

Perceived quality is a multi-dimensional entity, an outcome of designer/customer convention. The correct perceived quality attributes prioritization for the new product must lead to a successful design and customers' appreciation. This approach in industrial practice is often called "craftsmanship" and includes not only methods for elicitation and definition of perceived quality requirements but also incorporates a process of perceived quality communication to the customer [3].

The complex nature of product quality is recognized by many scholars [6-8]. A variety of approaches to the perception of quality have been established in the past. The major viewpoints can be differentiated as the "manufacturing" approach [9-11] and the "marketing" outlook [12-14]. Both viewpoints share a common agreement - they tend to see perceived quality as the antagonistic entity to the "real" or "objective" quality (i.e., not quantifiable, imaginary, subjective). However, recently there has been an increasing effort by researchers and practitioners to develop general models and methods able to quantify customers' perceptions of quality [8], [15-16]. From the engineering viewpoint, perceived quality is a domain where the product meaning, form, sensorial properties, and their execution intersect with human experience. Such an experience is driven by the interplay between product quality and its context. An inevitable part of the engineering tradition regarding perceived quality is to produce events that make the customer aware of how things are done [5]. High perceived quality means attractiveness of the product to the customer. However, automotive design engineers are continuously challenged with a choice between equally important perceived quality attributes i.e., should engineers invest their time and resources in the minimization of gaps around the top tether component, or focus on execution of materials? Development of the models for objective assessment of perceived quality attributes in the automotive industry is an arduous task because the modern car is an extremely complex product where actual quality is not always visible to, or perceived by, the customer. The majority of the existing models require further development of practical methods and tools regarding perceived quality evaluation for industrial use in product development.

2.1. Approach to perceived quality in the automotive industry

In the automotive industry, the desired performance and properties of a vehicle are handled by a variety of product attributes. A typical automotive OEM uses around 20-120 perceived quality attributes, depending on organizational structure. The perceived quality attributes are responsible for the definition of requirements and requirement levels that determine the perceived quality of the product. Consequently, these attributes can be associated with the complete vehicle requirements, but also the component and system-level requirements. The perceived quality evaluation is an ongoing process throughout the project. The group of engineers responsible for the perceived quality competence area defines requirements for engineering and design, and then predicts issues, verifies engineering and design status and validates target values and status in production throughout the product development. This is an iterative process, as one issue can be solved while a new can occur at a new design release. The issue-related work continues until all decisions are taken. Every new decision affecting a visible component can become a potential new issue.

2.2. Top tether

The top tether is the part of an ISOFIX (International Standard for attachment points for child safety seats in passenger cars) system used to connect a child seat in a car. It provides the third anchorage point to secure the child seat firmly. The system consists of an anchorage, a connector, and a strap. To secure the child seat the user takes the webbing strap, which has a hook or a connector, and attaches it to the anchorage. The anchorage is placed such that it can transfer the load to the vehicle body [17]. The anchorage point can be located at different positions in a car. Furthermore, research using a child test dummy indicates that a third anchorage tends to reduce the load exerted on a child's head and neck region during a crash. Overall, this reduces the extent of injuries in a car crash [18]. The use of the top tether also decreases misuse caused by use of a regular seat belt. Recent legislation has made mandatory a third anchorage point for forward-facing child seats [19]. For ease of understanding and consistency, hereafter we consider only the anchorage and the housing/compartment as parts comprising the top tether. Currently, Volvo Cars has two solutions for the design of top tethers. These solutions are implemented in the S90 and S60 models (see Fig. 1a and 1b). Volvo Cars have three top tethers located at the parcel shelf, one behind each rear seat headrest.

(b) S60

Fig. 1. (a) Current design solution for the top tether in the Volvo S90; (b) Current design solution for the top tether in the Volvo S60.

The top tethers can be described at two different levels; the components-level and the system-level. The components-level is mainly focused on functionality and design. The top tether is positioned on the parcel shelf in relation to the headrest. It contains two parts, the lid, and the body (see Fig. 2). The component is available in two colors, "charcoal" and "pale," and is usually colored to match the parcel shelf.

Fig. 2. Components-level views of the top tether.

Both the lid and body are made of plastic. The lid is secured to the body at six attachment points. It is detached from the body by the user to access the anchorage point. To disengage the lid, the user has to pull it up. To place it back down, the user has to press it back down into its position. The body is firmly attached to the parcel shelf and has a hole cut out for the anchorage. The body has enough space for an average-size human hand to access the anchorage without obstruction.

The system-level consists of the lid and body, anchorage, parcel shelf, and hook & strap coming from the child seat. The anchorage is a metallic loop designed according to the legal requirements. It is mounted on the vehicle's body-in-white (BIW) at the level of the parcel shelf and is positioned behind the headrest. The parcel shelf consists of three anchorages. The anchorages at the far ends are bolted to the BIW, whereas the middle anchorage is pre-welded in place by the supplier. The parcel shelf currently has a textile surface with holes cut out for the ability to host the top tether compartment (see Fig.3). The system-level has many dependencies that make it difficult to evaluate as a complete solution. Therefore, to decrease complexity, parts of the system, such as the parcel shelf and the hook & strap from the child seat, were not considered. According to the Perceived Quality Department at Volvo Cars, the current top tether design displays four main problems:

- The component has unacceptable execution regarding its design and appearance.
- The component consists of large plastic parts.
- The gap for the belt is too large.
- The space inside the component exposes visible foam and body color.

Fig. 3. System level views of the top tether.

All of the above-mentioned does not contribute to the "premium" feel of the component's design and appearance. As a result, the engineering team needs to know which parts of the top tether they have to focus on to achieve the highest customer appreciation.

2.3. Perceived Quality Attributes Importance Ranking (PQAIR) method.

The Perceived Quality Attributes Importance Ranking (PQAIR) method was created to assist the engineer or designer in the decision-making process regarding the evaluation of the relative importance of perceived quality attributes for the final product. The PQAIR method intentionally combines the objective, measurable information of perceived quality with the subjective customer's evaluation of product quality by the utilization of the Perceived Quality Framework (PQF) sensorial approach (see Fig.4) [5].

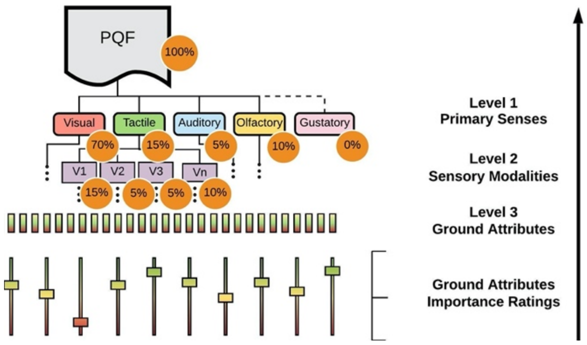

Fig. 4. The attribute-centric sensorial approach of PQF combined with the PQAIR method.

PQF constitutes the primary human senses: olfactory, visual, tactile, and auditory. The quality perception related to the primary human senses form the first level of attributes: Visual Quality, Tactile Quality, Auditory Quality, and Olfactory quality. The second attributes level of PQF is organized in Sensory Modalities. The Sensory Modalities are the nine distinctive sets of product attributes encoded for presentation to humans. Each of these sets has a description and includes several Ground Attributes (GA). The GA is the "lowest point," where the engineers can still communicate with the customer to receive meaningful feedback. Therefore, PQF acts as a communication channel and frame-of-reference for both the engineer and the customer. The core of the PQAIR method is that all identified GA are ranked regarding their importance, utilizing either knowledge obtained within the company and/or customer data. These rankings, in combination with the PQF, contribute to the importance score for each branch of the attribute structure at all levels. Consequently, each OEM can apply the importance ranking on their own, internal attribute structure (usually internal perceived quality attributes definitions and requirements are part of the classified documentation). As a result, the OEM can obtain an importance score for each perceived quality attribute, considering the PQF as a reference model for product quality assessment.

3. Methodology and experiment design

The PQAIR method, as a part of engineering design, addresses the open problem of perceived quality evaluation that involves objective and subjective elements. Therefore, we designed the experimental study according to the procedures of the PQAIR method (see Fig.5).

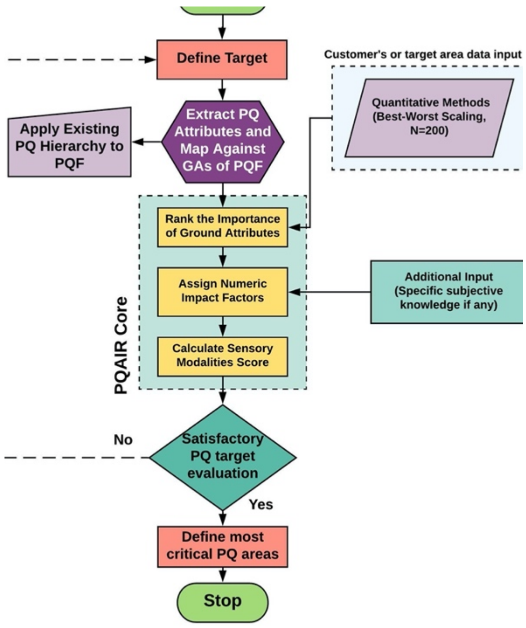

Fig. 5. PQAIR method analysis procedure applied to the case of top tether.

The study procedure was first a listing of the Volvo Cars internal perceived quality attributes primarily responsible for the visual appearance of a top tether design. To be able to communicate the top tether design to the customers, several of Volvo Cars internal perceived quality attributes involved in the design solution have been mapped against GA of the PQF. The identified attributes were analyzed further regarding the possible appearance, positioning, and execution variations according to the current design and manufacturing capabilities of Volvo Cars. As soon as all possible variations were listed, we created a set of photo images depicting a specific perceived quality attribute, or several in combination. The list of the Sensory Modalities and Ground Attributes involved in the study are presented in Table 1.

Table 1. List of sensory modalities and GA involved in the design evaluation.

Sensory Modality	*Ground Attribute*
Geometrical Quality	Gap
	Flush
	Parallelism
Material Quality	Materials Harmony
	Material Pattern
Illumination Quality	Illumination Function
Appearance Quality	See-through Parts
	Spatial Harmony
Joining Quality	Separable Joints

The descriptions and meaning of each of the Ground Attributes listed in the study are explained in Table 2.

Table 2. List of the *Ground Attributes* and their descriptions [5].

Ground Attribute	*Description*
Spatial Harmony	A harmonized layout of components that creates an appearance of natural relations among the components.
Flush	A perceived step between visible components.
Gap	The perceived distance between visible components.
Parallelism	The gap or flush has an agreement in direction and tends towards being parallel along a complete split-line.
Metallic Details	The top tether is decorated with a chrome lining.
Metal	The surface of the top tether is metallic.
Separable Joints	Appearance, number, and placement of visible joining techniques that can be fastened permanently (e.g., rivets) or reassembled (threaded fasteners).
Carbon Fiber	The surface of the top tether is made of carbon fiber.
Plastic	The surface of the top tether is made of plastic.
Illumination Function	The logical function of the illumination.
See-through Parts	The degree to which gaps and holes are covered and free from see-through effects.
Material Pattern	A regular sequence of material properties to form a consistent design.
Leather	The surface of the top tether is covered by leather.
Wood	The surface of the top tether is made of wood.

Consequently, the Ground Attribute "Material Harmony" was depicted by six different materials: plastic, wood, leather, carbon fiber, metal (chrome) and metallic details. This decomposition resulted in fourteen attributes (n=14), comprising the subset of total Ground Attributes number (n=32) included in PQF. For the estimation of *Ground Attributes* relative importance, a quantitative survey technique, called Best-Worst Scaling (BWS), was implemented. The experimental design was constructed using the Sawtooth Discover online survey software module [20]. The BWS method was initially developed by Louviere [21] to understand a respondent's or respondent group's relative valuations of product attributes. During the survey, three attributes (photorealistic image, representation and description) were displayed per set, with a total number of eighteen sets (see Fig.6). The choice tasks were presented to the respondents with different permutations of the fourteen attributes. In each task the participants (N=200) were asked to select the "most important" and "least important" attributes for the "premium" look of the top tether design. The average competition time was approximately 20 minutes.

Fig. 6. Example BWS choice task for respondents.

4. Results and discussion

The results of the BWS rank-order exercise performed by the respondents representing the "premium" market segment target group are shown in Table 3. As can be seen, the top five choices were GA "Spatial Harmony," "Flush," "Gap," "Parallelism," and "Metallic Details." The attributes "Flush," "Gap," and "Parallelism" altogether form a spatial relationship between the mating parts in an assembled product called "split-line". The split-lines in turn create visual cues that allow the customer to detect manufacturing variation. The importance of the split-lines in the perceived quality evaluation process could not be underestimated [22]. "Spatial Harmony" ranked as the most influencing factor in the design of the top tether component. This fact supports the idea that the perceived quality attributes do not exist or are judged in isolation, but they influence one another. At this point, we can track link to the phenomenon of gestalt in design with the famous principle of "The whole is 'other' than the sum of its parts." Monö et al. [23] defined product gestalt as "a discernible whole; an arrangement of parts so that they appear and function as a whole which is more than the sum of parts." The engineering challenge here is to minimize visual imbalance and create a "natural" relation between parts. Nevertheless, an experienced designer might say that the choice of the first four attributes as the most influencing for the perception of quality is rather obvious – the appearance of "Metallic Details" attribute in the list is hard to predict. According to the interviews with the automotive industry professionals the "Metallic Details" or chrome parts are considered to be an "old" and "dying trend" in car interior design. The results of this study indicate that these types of generalizations can be detrimental to design for high perceived quality.

Table 3. The Ground Attributes importance ratings obtained from the target group.

Ground Attribute Label (n=14)	*Importance score (N=200) with 95% confidence intervals*
Spatial Harmony	12.66 (13.25, 13.25)
Flush	11.89 (11.33, 12.46)
Gap	11.31 (10.74, 11.87)
Parallelism	10.72 (10.15, 11.30)
Metallic Details	7.81 (7.10, 8.52)
Metal	7.62 (7.00, 8.24)
Separable Joints	6.12 (5.57, 6.68)
Carbon Fiber	5.66 (5.06, 6.26)
Plastic	5.00 (4.49,5.51)
Illumination Function	4.94 (4.33, 5.55)
See-through Parts	4.88 (4.22, 5.54)
Material Pattern	4.83 (4.30, 5.37)
Leather	3.28 (2.80, 3.75)
Wood	3.26 (2.78, 3.74)

In addition, the materials usually associated with premiumness and craftsmanship such as "Leather" and "Wood" were ranked lowest. However, there is a clear explanation of the observed phenomenon. Analyzing the customers' feedback, we received an explanation for these choice rankings. Many respondents stressed the point that proper top tether component execution is more important for them than the choice of materials. Moreover, the perceived cost and the usage ratio of the top tether component were commented on. For example, one respondent stated, "*Top tethers are not used by many. Wood, leather, or carbon fiber looks wrong to me; it looks like wasted money and highlights a function seldom used*." This mindset is in line with the general perception of "premiumness" by the target customers. Previous studies [5], [24] have shown that the premium car market segment demonstrates a general tendency to communicate product quality and functionality, contrary to the luxury car market segment where aesthetics, form, color, and symbolic values play a primary role, communicating a personal approach to the product development. Generally speaking, the application of the PQAIR methodology to the top tether design provided engineers with meaningful information about customer preferences regarding the elements comprising the particular component. This information has a significant impact on the process of customer requirements definition. A new design concept for the top tether component was developed. The major idea behind the new design concept was to present the parcel shelf as an integrative arrangement of different parts to create visual harmony and balance. This fact makes the new design concept more than just a design of the top tether component in insolation, but rather includes the design of the whole parcel shelf. Therefore, we incorporated three top tethers into a single unit. Two alternative design variants were rendered (see Fig.7). One variant shows dark shaded wood on a charcoal parcel shelf, and the other shows a pale parcel shelf with light shaded wood. Both of the designs have a chrome border. However, this was kept minimal to avoid reflections. In any case, the materials used for top tether design should match the materials used for interior trim at the front of the car.

Fig. 7. The top tether design concept with a charcoal textile parcel shelf and dark shaded wood decorated with the chrome lining (left) and design concept with pale textile parcel shelf and light shaded wood decorated with the chrome lining (right).

To summarize, currently there is no reliable methodology (except the PQAIR methodology) found in the literature that is able to quantify the impact of the specific perceived quality attributes on quality impression. The understanding of the importance of different perceived quality attributes from a customer perspective can improve the effectiveness of the design processes in the early product development phases.

5. Conclusions

The new design for the top tether component improving its visual and functional perception was presented. This study also demonstrated that the implementation of the PQAIR methodology was able to help to identify customer preferences regarding the different product attributes and can be applied for new product development.

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