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A PRELIMINARY STUDY OF TRENDS IN PERCEIVED QUALITY DESIGN ATTRIBUTES IN THE AUTOMOTIVE LUXURY MARKET SEGMENT

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1. Introduction

Successful automobile design in competitive markets is characterized by a combination of both technical manufacturing quality and customer perceived quality [Petiot et al. 2009]. While the idea of manufacturing quality as a "conformance to specification" [Juran 1993] is straightforward and quantifiable, perceived quality refers to customer emotional responses to a particular design, e.g., Norman [2005], often associated also with craftsmanship [Hossoy 2003], [Hossoy et al. 2004]. Identifying attributes mapped to perceived quality, craftsmanship, and emotional design is an ongoing challenge in design research and practice [Burnap et al. 2015], [Yumer et al. 2015].

The market segment for 'premium' automobiles has historically excelled in manufacturing quality, resulting in product differentiation largely derived from the customer's assessment of perceived quality [Schmitt and Quattelbaum 2010]. In other words, manufacturing quality in the premium automobile segment is not the primary determinant of customer satisfaction, but rather it is only an entry requirement for this segment [Robinson 2000].

In contrast, the automobile luxury market segment has focused historically on an emotional and personalized approach to design [Bastien and Kapferer 2013]. During the design process, emphasis has been placed on prioritizing design attributes [Hauser 1988] most related to symbolic values such as aesthetics and brand image [Wiedmann et al. 2013]. Less emphasis has been placed on measurable manufacturing quality design attributes, such as gap and flush measurements of vehicle body split lines, or other perceptual design attributes, such as squeak and rattle [Stylidis et al. 2014].

In the study described in this paper, we find preliminary qualitative evidence from semi-structured and unstructured interviews of design engineers at leading Italian luxury automotive manufacturers that:

- Customers of luxury vehicle manufacturers now expect the same level of perceived quality amongst design attributes as in the premium segment.
- Luxury vehicle manufacturers now benchmark their products to the premium segment and are interested in additional methods of evaluation and benchmarking.
- Luxury vehicle manufacturers gather customer feedback through the lifetime of vehicle ownership in contrast to the premium segment of the automotive industry.

We cast these findings quantitatively within a model of design as a communication process [Monö et al. 1997], [Crilly et al. 2004], [Forslund et al. 2006], [Crilly et al. 2008], capturing also the design *information asymmetry*. Information asymmetry, developed initially in economics [Spence 1973] and biology [Zahavi 1975], was originally explained in signalling theory as a behaviour of two parties when

they have access to different information [Connelly et al. 2011]. In our case, information asymmetry can cause misinterpretation due to differences in the existence or misprioritization of perceptual design attributes between designer and customer. Assuming that such asymmetry is detrimental to a product's success, a design process goal should be to reduce information asymmetry, such that designers and customers are considering the same set of design attributes in the same priority when assessing perceived quality. In this paper, we propose and create a simulation of design as a communication process under information asymmetry, and show that automobile luxury segment manufacturers that do not benchmark the premium segment's perceptual design attributes are at risk of being associated with low perceived quality.
The remainder of the paper is structured as follows: Section 2 introduces the qualitative and quantitative methodologies used in this work; Section 3 discusses early findings and provides recommendations for further research; Section 4 offers conclusions.

2. Methodology

We describe the qualitative and quantitative methodologies we use to study the information asymmetry between designers and customers in the luxury automotive segment. The qualitative methodology includes interviews with senior designers and managers of premium and luxury market automotive manufacturers that explore their processes and understanding regarding perceived quality attributes.
The perceived quality attributes can be seen as design attributes for the perceived quality e.g. measurable requirements. This particular case study is still in progress, and here we include only preliminary results.
The quantitative methodology adopts the model of design as a communication process and includes the connection between entropy minimization and perceptual attribute modelling used in the design community.

2.1 Qualitative methodology

There are various forms of interview design and typically an interview study can be classified as informal, conversational interview, structured interview, and semi-structured interview with the follow-up question [Creswell and Clark 2007]. The semi-structured interview ordinarily comprises elements from both structured and unstructured interviews. "A fixed set of sequential questions is used as an interview guide but additional questions can be introduced to facilitate further exploration of issues brought up by the interviewee, thus almost taking the form of a managed conversation" [Cachia and Millward 2011].
In this work, we used semi-structured interviews, informal unstructured face-to-face interviews and a previous study on automotive industry professionals [Stylidis et al. 2014].

2.1.1 Luxury segment of the automotive industry

We interviewed four professionals from the two leading vehicle manufacturers in the luxury segment of the automotive industry. The main reason for the selection was the opportunity to obtain a holistic view regarding the company's methods and approaches for defining and addressing perceived quality issues. A secondary objective was the determination of perceived quality attributes and their dissemination among different departments within the companies.
The average length of each interview was about 60 minutes. Interviews were voice recorded and transcribed to text. Text coding and analysis was performed with the NVivo qualitative data analysis software [Welsh 2002]. Questionnaires were created to reveal the interviewee's opinion on perceived quality, determination of perceived quality attributes, communication strategies, subjective importance rating among different perceived quality attributes and areas, and knowledge sources and ways regarding information asymmetry.
We asked the same questions of professionals from all companies involved in the study. At the beginning of the interview, questions were quite open and general. For example: "How would you define perceived quality?" and "What are the prerequisites for a good perceived quality?"
The subsequent questions narrowed the interest to mapping perceived quality attributes and addressing information asymmetry. For example: "On what perceived quality attributes you focus assessing Illumination?" or "How do you "code" designer's intentions so customer will understand it?" During

the interviews the authors sometimes had to ask additional questions to explore topics widely and determine perceived quality attributes clearly. For example: “So how did you get feedback from the customers?”
During the analysis, the material was organized into topic areas (or ‘nodes’): (1) perceived quality, i.e., data related to the perceived quality; (2) competitors, i.e., data regarding benchmarking strategies; (3) manufacturing process, i.e., data related to the specific manufacturing processes such as surface finish standards; (4) perceived quality attributes, i.e., data regarding particular perceived quality attributes; and (5) shift to premium, i.e., new phenomena derived from the interviews. Throughout the analysis we used a bottom-up approach: Reading the interview data and creating codes as they appeared; for example, the above five nodes is a result arisen from the data analysis.
The interviews provided us with information regarding luxury automotive companies and their view on perceived quality and communication strategies. We were able to identify perceived quality attributes that are the focus of attention for the companies and that revealed new significant trends in quality perception for the luxury market segment.

2.1.2 Premium segment of the automotive industry

Eight professionals from Swedish, Italian, and American premium vehicle manufacturing companies were interviewed. The questionnaire and primary goals were the same as in the case of luxury automotive companies. The average length of each interview was approximately 60 minutes. Interviews were voice recorded and transcribed to text. This particular study is still in progress and the complete coding and analysis of the entire raw data are the subject of continuing research. In the case of premium automotive companies, the data were complemented by face-to-face unstructured interviews and data from an earlier study regarding core values and perceived quality [Stylidis et al. 2014].

2.2 Quantitative methodology

In this section, we define information asymmetry quantitatively as design communication, building on well-known concepts from information theory and market segment design preference modelling techniques used in design and marketing research. We then use these definitions to simulate the manifestation of information asymmetry between designers and customers within the luxury and premium market segments studied in the qualitative portion of this research. In particular, we show how designers who create designs for the luxury segment without benchmarking perceived quality attributes against the premium segment may fail to capture market share as a result of decreased customer-design preference in a market with multiple competing design alternatives.

2.2.1 Design as communication

Previous work has detailed the relation between a designer and a customer as that of a communication process [Monö et al. 1997], [Crilly et al. 2004], [Forslund et al. 2006], [Crilly et al. 2008]. We adopt this framework together with the established quantitative formalization stemming from Shannon’s information theory [Shannon 2001]. We also employ design preference modelling techniques such as conjoint analysis [Green et al. 1981] and discrete choice analysis [Wassenaar et al. 2005] often used within the decision-based design framework [Hazelrigg 1998], [Thurston 2001], [Chen et al. 2013]. The associated information of each distribution is measured by its entropy, with units of “nats” when using a logarithmic base of e, and is defined as $H(p) = \mathrm{E}_p[-\mathrm{p}]$ in which E_p is the expectation of distribution p. To out knowledge, this is the first time that design communication has been quantified alongside preference modelling.

2.2.2 Perceived quality function of design attributes

For simplification, we assume the following scenario: Customers comprising a homogenous market segment, each of whom have bought a premium segment vehicle, are now looking to purchase a luxury segment vehicle. We assume that these vehicles may be wholly represented according to a set of attributes, $\mathbf{a} \in \mathcal{A} \subseteq \mathbb{R}^M, \mathbf{a} = \{a_1, a_2, \dots, a_M\}$ in which each a_m is a separate design attribute related to

perceived quality (e.g., seat material quality) existing in the space of possible vehicles $\mathcal{A}$, which itself is defined according to constraints on engineering, marketing, and manufacturing considerations.
We next define $p(y|\mathbf{a})$ as the true perceived quality distribution over design attributes of customers making up the market segment, in which $y \in \{0,1\}$ refers to whether a customer actually feels a vehicle design $\mathbf{a}$ has "bad" or "good" perceived quality. Note that we assume homogeneity of perceptions for this market segment. In practice, we do not know the distribution of p, given the possibly complex statistical dependencies between design attributes (e.g., seat material is good, seat stitching is good, but good seat material AND good seat stitching is more than both effects combined). Instead, the goal of designers is to estimate this distribution using a simple distribution $q(y|\mathbf{a}, \mathbf{w})$, parameterized by $\mathbf{w}$, and statistically estimated using empirical data from our customer segment's previously purchased vehicles $\{\mathbf{a}^{(n)}, y^{(n)}\}_{n=1}^{N}$.

2.2.3 Information asymmetry between designers and customers

We define information asymmetry according to the cross entropy $H(p, q)$ between the customer's true distribution p and our approximation of it q which is defined as

$$H(p, q) = \mathrm{E}_p[-\log q] = H(p) + KL(p||q), \tag{1}$$

where $KL(p||q) = \int p \log\left(\frac{p}{q}\right) d\mathbf{a}$ is the Kullbeck-Leibler Divergence of the difference between the two distributions.

3. Preliminary results and discussion

The interviews revealed several interesting trends and insights. In the luxury segment, perceived quality is a relatively new area despite the fact that both companies studied have a long tradition of capturing individual needs of their customer and translation of those into technical specifications. The identified trends brought a new viewpoint on design process recently adopted by the luxury automotive manufacturers. A significant gap regarding information asymmetry and prioritization of perceptual design attributes between designer and customer identified. To address this problem a development of a robust methodology for assessing design attributes is essential.
In Table 1, the nodes derived from the interview data are mapped against two luxury automotive companies (Luxury Manufacturer 1 and 2) with the numbers of quotes related to each node. The table highlights a correlation between coded data among both companies that can be explained by the fact that particular automakers work in the same segment of the automotive industry and have a similar approach to the perceived quality issues.

Table 1. Number of quotes related to nodes of interest for two luxury segment manufacturers

Node	Luxury Manufacturer 1	Luxury Manufacturer 2
Perceived Quality	36	20
Competitors	3	0
Manufacturing process	12	12
Perceived Quality Attributes	17	10
Shift to premium	3	2

A word frequency analysis for the 1000 most frequent words shows that for the luxury segment the second most important aspect, after vehicle quality is the words "customer" and "difference," which in the context of the interviews addresses information asymmetry regarding customer's perception. To some extent, the data support the assumption that there is a lack of understanding about which components comprise luxury: Where should money be spent and which perceived quality attributes make a difference [de Jongh Hepworth 2007].

3.1 Preliminary finding 1 – Customers of luxury vehicle manufacturers now expect the same level of perceived quality amongst design attributes as in the premium segment

A classic view of the luxury segment, e.g., Dubois et al. [2001], Wiedmann et al. [2013], states that "... key characteristics of luxury brands include a perceived high price; excellent quality; exclusivity and uniqueness in the sense of scarcity or severe availability; aesthetics of form and colour; a long history and the reputation of a holistic and continuous brand presence; and non-necessity, as symbolic values which dominate over the functional characteristics."

In contrast, our interview data revealed that the understanding of perceived quality requirements and attributes has now become important for the luxury vehicles manufacturers. There is a need to make luxury vehicles comparable to the premium segment vehicles with respect to functionality and quality. More specifically, the luxury car is usually the second vehicle for the customer. Moreover, this second vehicle is what a customer normally uses during the weekends to provide a very special experience.

3.2 Preliminary finding 2 – Luxury vehicle manufacturers benchmark their products to the premium segment

A concern emerged from the interviews that customers could not find in a luxury vehicle the commonly expected features they have in their first car. This became an issue and even the reason for customer complaints. As the result, today's leading luxury automobile manufacturers are benchmarking their vehicles not only against the competitors in the same segment but also in the premium one.

3.3 Preliminary finding 3 – Luxury vehicle manufacturers gather customer feedback through the lifetime of vehicle ownership in contrast to the premium segment of the automotive industry

Looking at the existing information asymmetry between designer and customer, it is first necessary to understand how customer's feedback for luxury and premium automotive companies is collected. Significant differentiation was revealed during analysis of the qualitative data. The luxury automotive manufacturers are usually in very close contact with their individual customers. They receive feedback from interviews with the customers performed during the lifetime of the vehicle. A dedicated group of engineers continuously perform interviews and assessment of the vehicle after the sale. Another source of information is jury tests usually performed with selected luxury car dealers. This approach is very similar to the truck market where the truck fleet owners are the source of the feedback for vehicle assessment [Stylidis et al. 2015].

In contrast, premium segment automakers usually gather feedback from customer clinics, surveys, and focus groups. The biggest problem for these automakers is a large number of constraints with short time available for design decision making, which makes prioritizing areas of perceived quality in the correct way to be difficult.

3.4 Simulation of information asymmetry on perceived quality

We simulate the scenario of a luxury manufacturer that benchmarks its design concepts, represented by a set of design attributes $\mathbf{a}$, against known luxury segment design attributes, yet neglects design attributes from the premium segment. We define spaces $\mathcal{A}_L$ and $\mathcal{A}_P$ accounting for luxury attributes and premium attributes, and assume that $\mathcal{A}_L \subseteq \mathcal{A}_P \subseteq \mathcal{A}$; luxury vehicles are a subset of premium vehicles which themselves are a subset the total space of vehicles $\mathcal{A}$, and thus are feasible designs.

The designers goal during benchmarking may be to understand how we should allocate finite time and resources to various attributes. While this may be done via ranking or choices, we assume that we are getting more specific with a value for each attribute through $\mathbf{w}$. A popular model of q is given by conjoint analysis [Green et al. 1981]. In this case, minimizing the cross-entropy ends up equivalent to maximizing the likelihood of the data, since the entropy of the empirical distribution $H(p)$ is fixed. Furthermore, maximizing this likelihood function becomes a convex optimization problem with regard to the parameter $\mathbf{w}$:

$$\min_{\mathbf{w}} \frac{1}{N}\sum_{n=1}^{N} H\left(p^{(n)}, q^{(n)}\right) = \min_{\mathbf{w}} \frac{1}{N}\sum_{n=1}^{N} y^{(n)} \ln\left[\frac{1}{1+e^{\mathbf{w}^T\mathbf{a}}}\right] + (1-y^{(n)}) \ln\left[1-\frac{1}{1+e^{\mathbf{w}^T\mathbf{a}}}\right]. \quad (2)$$

We first simulate a set of designs $\{\mathbf{a}\}_{n=1}^{N}$ as sampled from a uniform distribution in the range [0,1], and a true perceived quality generating distribution according to Gaussian distributed "true" weight vector $\mathbf{w}$. We find the corresponding set of binary "good" or "bad" perceived quality ratings of the designs with $\mathbf{y} = \text{sign}(\mathbf{a}^T\mathbf{w})$. We then estimate the weight vector $\hat{\mathbf{w}}$ by minimizing Equation (2), in which m denotes the number of perceived quality design attributes benchmarked by the luxury manufacturer; i.e., $\mathbf{w}_{:m} \in \mathbb{R}^m,\ m = |\mathcal{A}_L|$. In other words, the number of design attributes considered by the luxury manufacturer is a fraction of the total number of design attributes imposed by the premium manufacturer, i.e., $|\mathcal{A}_L|/|\mathcal{A}_P|$. The optimal estimate $\hat{\mathbf{w}}_{:m}$ for each setting of $m = \{1,2,\dots,M\}$ is found using BFGS optimization [Papalambros and Wilde 2000] of Equation (2), with which we predict the perceived quality of a held out set of designs.

Figure 1 shows how a luxury automotive design's perceived quality increases with the number of benchmarked design attributes from the premium automotive segment. This plot shows 100 simulations of both randomly initialized designs and randomly initialized "unknown" true perceived quality functions. This analysis minimized information asymmetry between the customer's true perceived quality distribution and the empirically assumed conjoint analysis distribution, which varies in number of luxury design attributes along the x-axis.

Interpreting Figure 1, we observe that luxury automotive manufacturers are at risk of losing perceived quality according to the customer if they do not adequately cover premium segment design attributes. While these findings make naïve assumptions, more realistic measurement of customer perceived attribute importance, parameterizations of the assumed distribution q, and uncertainty quantification of the measurement of attributes of $\{\mathbf{a}\}_{n=1}^{N}$ may be obtained by suitable survey techniques.

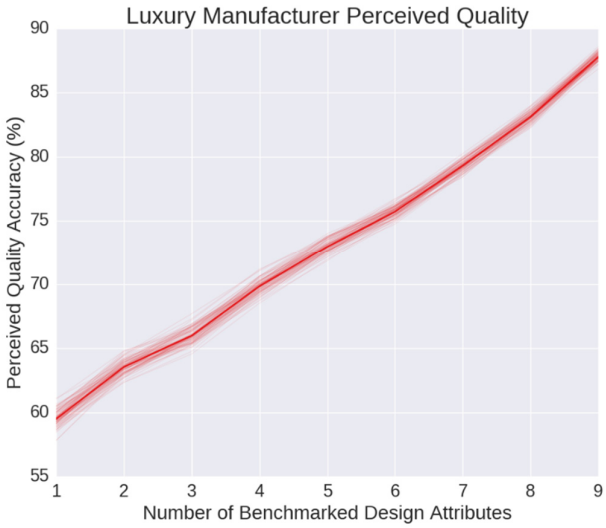

Figure 1. Perceived quality score of luxury automotive manufacturer as a function of benchmarked perceived quality design attributes from the premium vehicle segment

3.5 Limitations and future work

There are a number of limitations in this work. First, we focus only on two luxury automotive manufacturers and four Italian, Swedish, and American automotive manufacturers. There are also complications amongst manufacturers in understanding in which segment their vehicles are positioned. Second, we focus only on automotive designs, so our preliminary findings are less clear for other luxury goods. Third, our preliminary qualitative data analysis was performed by a single coder, with future work needing intercoder agreement with Cohen's Kappa [Cohen 1960] or Krippendorff's Alpha [Hayes and Krippendorff 2007]. Fourth, the quantitative model makes major assumptions on the spaces of attributes, particularly that luxury segment design attributes were a subset of premium segment design attributes. Future work into getting real data from both designers and customers from both the luxury

and premium design segments will help understand which assumptions must be relaxed to better represent the reality of perceived quality in the luxury vehicle segment.

4. Conclusion

Successful automotive design requires a combination of technical manufacturing quality and customer perceived quality. Premium segment automotive designs have historically maintained excellent manufacturing quality, differentiating amongst competing designs via perceived quality. We give preliminary results suggesting that luxury automotive designs must now be benchmarked against perceived quality design attributes of the premium automotive segment.

These results were ascertained through semi-structured and unstructured interviews with design professionals from Italian, Swedish, and American luxury and premium automotive manufacturers. We cast these findings in the model of design as a communication process, incorporating information asymmetry according to differences in considered design attributes. This model is used in a simulation to show that luxury automotive manufacturers that do not benchmark design attributes from the premium segment are at risk of low perceived quality.

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