Application of Kansei Engineering to Design an Industrial Enclosure

Lluís Marco-Almagro (lluis.marco@upc.edu)
Xavier Tort-Martorell Llabrés (xavier.tort@upc.edu)

Department of Statistics and Operations Research
Universitat Politècnica de Catalunya - BarcelonaTech

Abstract:

Kansei Engineering (KE) is a technique used to incorporate emotions in the product design process. Its basic purpose is discovering in which way some properties of a product convey certain emotions in its users. It is a quantitative method, and data is typically collected using questionnaires. Japanese researcher Mitsuo Nagamachi is the founder of Kansei Engineering. Products where KE has been successfully applied include cars, phones, packaging, house appliances, clothes or websites, among others.

Kansei Engineering studies typically follow a model with three main steps: (1) spanning the semantic space: defining the responses, those emotions that will be studied; (2) spanning the space of properties: deciding on the technical properties of the products that can be freely changed and that might affect the responses (factors in a DOE factorial design) and (3) the synthesis phase, where both spaces are linked (that is, how each factor affects each response is discovered).

In an earlier paper (Marco-Almagro, Tort-Martorell 2012) we claimed that KE is a good example of what Roger W. Hoerl and Ron Snee call statistical engineering: focusing not in advancement of statistics – developing new techniques, fine tuning existing ones – but on how current techniques can be best used in a new area. This presentation is a practical application of the ideas exposed there to the design of electrical enclosures.

The paper shows how well-known statistical methods (DOE, principal component analysis and regression analysis) are used together in conjunction with other non-statistical techniques and in the presence of practical real world restrictions to discover how different technical characteristics of the enclosures affect the selected “emotions”.

Keywords: Kansei engineering, statistical engineering, perceived quality, factorial designs, industrial enclosures

1. Introduction and contextualization

Incorporating emotional aspects into the design of products is important nowadays. The reasons for that are described in Section 1.1 of this paper. In fact, this need will become apparent when we explain the motivation of the industrial enclosure case study described in Section 2. Kansei Engineering, the specific and more innovative tool used in the case study, is briefly described in Section 1.2.

1.1. The importance of emotional design

Users of products and services – all of us – are becoming more and more demanding. In this beginning of the XXI century, we do not only want products that work well and satisfy our needs, we also want products that we like. When customers are questioned on what they want, a list of needs normally referring to functionality is obtained. Designers and engineers can translate this voice of the customer into technical parameters, so that the product fulfills those needs. However, customers do not usually explain their emotional needs, probably because they are not aware of having them or are unable to tell which they are. Even when those emotional needs are discovered, it is not obvious which technical properties of the product will elicit those desired emotions.

For many years, designers were not very interested in emotions. The focus was more on making usable products. But making products that work well and fulfill user expectations is not enough. When analyzing the products we normally use, we realize that we love some gadgets that are far from perfect, but that we just like them. Or we have a deep appreciation for a product because of the person that gave it to us as a present, or because it reminds us of the good times we had using it. These emotional aspects attached to products cannot be disregarded.

How do designers incorporate this "emotional touch" when creating a new product? They usually rely on their intuition, creativity and experience. But they also use different qualitative and quantitative methods to collect information on how products are perceived and used. Several of these methods can be grouped under the umbrella term "emotional design". One of the methods is the so-called Kansei Engineering (KE). The japonese word Kansei (感性) means sensitivity or sensibility. Simon Schütte (2005, p.36) proposes the following explanation of Kansei: "*Kansei is an individual's subjective impression from a certain artifact, environment or situation using all the senses of sight, hearing, feeling, smell, taste and the sense of balance as well as recognition".* Kansei Engineering (KE) is a method for incorporating emotions in the product development phase. The main purpose is discovering which technical parameters of a product elicit the chosen emotions. The method was first proposed by researcher Mitsuo Nagamachi in the 1970's. He had a background in psychology and medicine and was working at that time in Hiroshima University's Faculty of Engineering (Childs et al. 2003). The term Kansei Engineering was first used in 1986 by Kenichi Yamamoto, then the president of Mazda Motor (Schütte 2005). Professor Nagamachi soon adopted this term.

In the 1980's and the 1990's he created systems – which usually implied the use of computers for collecting data and statistical methods for analyzing it – for capturing users' Kansei and connecting it with product properties. Professor Nagamachi and his team collaborated with companies from many sectors during those years: automotive (Mazda, Nissan), apparel (Wacoal, Goldwin), electronic home products (Sanyo, Sharp), office machine (Fuji, Canon), and cosmetics (Shiseido), among others (Childs et al. 2003). In 1995, a paper with Mitsuo Nagamachi as sole author was published in the journal "Applied Ergonomics". This paper – "Kansei Engineering - a New Ergonomic Consumer-Oriented Technology for Product Development" (Nagamachi 1995) – can be considered as a seminal paper where Professor Nagamachi presents his proposal to the scientific community in the world.

One of the most distinctive characteristics of Kansei Engineering is that it is based on collecting quantitative data (usually ratings made by users), as opposed to other qualitative methods used in emotional design. Once data are collected, statistical methods are commonly used to link the physical properties to the elicited perceptions.

1.2. A Model for conducting Kansei Engineering Studies

In 2002, researcher Simon Schütte from Linköpings Universitet, with a background in engineering, proposed a model for developing Kansei Engineering studies in his licentiate thesis. The model was further developed after a stay in Japan working with founder Mitsuo Nagamachi and his colleagues (professors Ishihara and Nishino among others). The model, together with a description of the idea behind Kansei Engineering, was explained in a 2004 paper co-authored by Simon Schütte, Jörgen Eklund and Jan Axelsson from Linköpings Universitet, together with founder Mitsuo Nagamachi (Schütte et al. 2004). This model systematizes the procedure and is a milestone in the effort of translating the ideas of Professor Nagamachi to the Western World.

Figure 1 shows the steps in the proposed model and are briefly described below:

- Choosing the product domain: The product domain is defined. This means not only choosing the product that will be the protagonist of the study, but also the target group for the product. For example, the product domain could be analogue watches to be used by middle aged women.
- Spanning the semantic space: Words that emotionally describe the product (called Kansei words) are collected from different sources. The initial set of words is reduced either using affinity diagrams or multivariate techniques such as cluster analysis. The output from this step is a list with all the Kansei words that will be used in the study. Examples of Kansei words for the watches could be modern, elegant, comfortable...
- Spanning the space of product properties: Design attributes from the studied product are collected. For each attribute, several possible values are considered. Attributes that designers think can have an effect on the emotional response are prioritized. Attributes in the example of the watches could be face color (white or brown) or face shape (rectangular or round).

A set of products (either real working products or prototypes) is prepared to be shown to participants in the study. The output from this step is the collection of products for the KE study (these products must differ in the properties just selected). In the example of the watches, four watches could be used: a rectangular watch with a white face, a rectangular watch with a brown face, a round watch with a white face and a round watch with a brown face.

Notice that design attributes used can be considered factors (with two or more levels) in a factorial design. The set of products to be shown to participants in the study can then be selected following the design matrix of a factorial design.

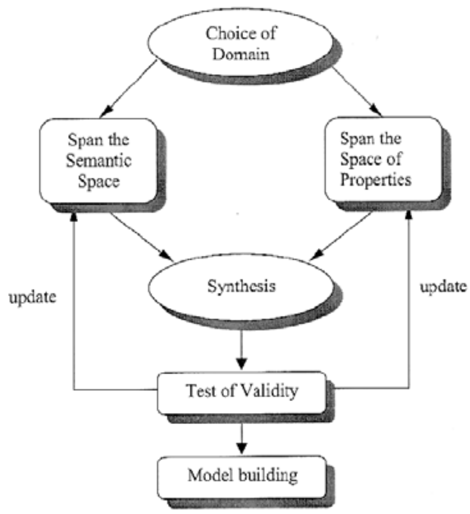

Figure 1. The original model for conducting Kansei Engineering studies, directly reproduced from the paper "Concepts, methods and tools in Kansei Engineering" (Schütte et al. 2004)

- Synthesis: Using statistical methods (usually linear regression models, sometimes ordinal logistic regression models), a link between product attributes (space of properties, the factors in a factorial design) and Kansei words (semantic space, the responses of the factorial design) is established. For every Kansei word, product properties are found that affect the Kansei word. In the watches example, one conclusion could be that watches with a rectangular face are perceived as elegant.
- Test of validity: Principal component analysis is used to locate the Kansei words on the first principal components. This gives an idea of which words are perceived similarly, and can be the basis for some confirmatory experiments.
- Model building: After being validated, several final models are proposed that relate the product properties with each Kansei word.

Several modifications and enhancements of the model, especially in the statistical tools used in the synthesis phase, have been suggested in Marco-Almagro (2011). For instance, the use of mixed effects ordinal logistic regression for linking the semantic space (the kansei words used as responses) with the space of properties (the factors, the design properties used in the study). Some of these enhancements have been used in the project with the electrical enclosures described in the following section.

2. Application to the Design of an Industrial Enclosure

This section describes the origins of the case study explained in this paper: an industrial enclosure. The company where the product is produced is presented, together with the concerns (related with bad perceived quality in the product) that motivated the project. Although a Kansei Engineering study, done following the steps briefly presented in section 1.2, is the main source of information for the company, two other previous steps were done. We will clarify the importance of these two previous phases, and also the relevant information that could be extracted from them.

2.1. Motivation

The case study is conducted using electrical enclosures produced by a multinational corporation that has electricity distribution and automation management as its core business.

The company has factories in countries all over the world, and several production plants are located in Spain. Some of these factories come from acquisitions of local companies performed during the last decades. Two factories located close to Barcelona produce, basically, electrical enclosures, such as the one presented in Figure 2.

Although the electrical enclosures produced in these factories are of very good quality and obviously comply (and even surpass) all standards, customers were not completely satisfied. Both industrial visits to customers (done on a regular basis) and a pair of surveys conducted gave clues showing that there was a problem basically related with perceived quality. To give an example: robustness is an especially important property of electrical enclosures. Although objective measurements done on the enclosures showed robustness was fine, customers complained on this issue. Customers complained to the point of preferring competitor's enclosures based on its supposed superior robustness, even though it was not true that robustness was better in enclosures from other brands. Some characteristics in the design of the enclosures made them appear (be perceived) as less robust. Which are these characteristics? How can the enclosures be redesigned in order to solve all these problems of perceived quality?

Figure 2. An example of the kind of electrical enclosures studied in this project

In the beginning of 2013 people from the company contacted the department of Statistics and Operations Research at Universitat Politecnica de Catalunya · BarcelonaTech to precisely pose these questions. The objective of the study was, therefore, discovering the factors of the enclosure that affect perceived quality, and how they affect it.

2.2. Steps followed

After some talks, a series of steps for accomplishing the objective were decided. The three steps followed are summarized below:

- Phase 1: Collection and study of all possible sources of information. Before starting a new data collection, it seems very reasonable extracting as much information as possible from already available data. The available data used came from existing questionnaires and customer visits. Data came basically from Spain and France; in this study, the focus has been in data from Spain.
- Phase 2: User's focus group. This focus group was conducted to complement the knowledge acquired in phase 1 and to provide information useful for the next phase. This is the first time in the project that customers are called to directly participate. As we will see later, many interesting discoveries appear just by carefully listening to customers.
- Phase 3: Conduction of a Kansei Engineering study on the enclosures. This followed the model for Kansei Engineering studies described in the first part of this paper. After a final selection of Kansei words and enclosures' design parameters, prototypes were prepared and presented to a selected group of customers (different from the customers used in the focus group). Customers participated in several experiences to discover issues related with perceived quality in enclosures, but basically rated the

prototypes on each one of the Kansei words. A statistical analysis of the collected data was conducted and final results presented.

3. The Studies and its Results

This section explains in detail the set of studies done with the enclosure, following the 3 phases' structure presented above.

3.1. Customer surveys and visits

A detailed analysis was done based on answered questionnaires and customer visits. Data from these sources was basically qualitative, with scarce quantification, so a great effort was done in categorizing issues, trying to detect those more important.

An interesting fact here is something in fact already known or intuited: when talking about perceived quality, there is much more to enclosures than the enclosures itself. For instance, customers valued a lot the instructions included with the enclosures or the service provided. Strong points were the individualized and professional attention or the quick reaction to unexpected problems.

Another relevant issue is the fact that having all quality production problems solved is a precondition to perceived quality. For instance, during some time there were problems in the painting of the enclosures. The fact of having enclosures arriving to customers with some (small) points lacking paint or with an excess of paint destroyed all possible efforts to increase perceived quality. In fact, when stated clearly, it is very reasonable: Perceived quality is bad when there are quality problems.

3.2. Focus group with customers

The first session with customers (focus group) took place at one of the company's site in September 2013. Its purpose was listening to the voice of the customer: knowing their needs and sensations related to the studied enclosure. Eight customers attended the meeting (representing different types of customer, but all coming from Catalunya). Personnel from the company also attended the meeting (but without actively participating in the discussion).

The schedule of the session was the following:

- General valuation and affinity diagram: Participants individually wrote positive and negative aspects about the company's enclosure, made an affinity diagram with them, and finally commonly discussed each idea in the affinity diagram.
- Triading: 3 different enclosures were displayed (the studied enclosure from the company and two competitors). Participants had time to "look and play" with them. Finally, each customer explained which enclosure was different from the other two, and the reason.

- The ideal enclosure: A brainstorming session where each customer said the characteristics an ideal enclosure should have. Ideas were later voted by participants to detect the most preferred ones.

Customers also visited the factory for an hour, and were invited to a coffee break and a final lunch together with personnel from the company.

In our session, although it was obviously guided to extract information in an orderly way, participants were on purpose not directed to focus on any aspect of the enclosure. Customers basically talked about functionality (they suggested several issues that could be improved in the enclosures) and about the "enclosure ecosystem" (things like packaging, catalogues…). Some discoveries were surprising for the company's personnel, either because they thought customers did not value things that they were not offering, or the opposite, they put a lot of effort in issues that were not important to the customers. This alignment between what matters to the customer and what matters to the company is important, and cannot be achieved without this kind of meetings. As in a couple, communication matters…

Aesthetic aspects of the enclosure were only named in a general way, especially in the second activity of the morning, the triading. Several customers revealed that one of the three enclosures (and not the one from the company) was very beautiful, but were unable to explain the reason (this is something common with perceived quality, and in fact the reason to use Kansei engineering to discover properties affecting perceived quality)

3.3. Kansei Engineering Study

In order to prepare the kansei engineering data collection, a meeting with both technicians from the company and UPC experts took place in September 2013, one week after the focus group. A short presentation of conclusions from the first session with customers served as discussion starter. All company professionals came with "homework" done: a list – as long as possible – of emotional words (basically adjectives) related with enclosures, and a list of properties (factors) of the enclosures that could be changed and could – possibly – affect the perceived quality.

An affinity diagram was used to reduce the initial list of kansei words, as it is usually done in the methodology. Finally, 11 words (perceptions conveyed by the enclosures, such as being robust) were selected.

The second part of the meeting was devoted to decide on the list of enclosures' properties that could be changed to create a set of prototypes to be presented to customers for evaluation. The list of properties (factors) and each of the values for each property (levels) was decided based on the expected importance of the factor, possibility to change it in a new enclosure design, and property aligned with the company strategy.

It is important to stress one aspect of KE studies at this point: the purpose of the study is learning how different properties affect the transmission of certain sensations. Even if it is not clear if one particular set of a property will be feasible in normal production due to cost, technical restrictions or being "too risky" to implement, we might be interested in discovering its effect in terms of perceived quality. The results of the KE study give a data-based approach to sensations conveyed by the products: the final decision on what to implement necessarily takes into account other aspects of design, production and company strategy.

Finally, 8 different factors were used, and 16 different prototypes were built according to a design matrix suggested by UPC. The design matrix was prepared in order to be orthogonal and allow the estimation of main effects free of confusion. Of course, at this point, technical restrictions regarding the construction of prototypes become very relevant.

The day of the data collection, a neutral room was prepared with the enclosures disposed on tables in a U shape. An explanation of the purpose and the procedure was given to the participating customers, representing different typologies and geographical areas in Spain. Before the proper kansei engineering study, some other experiments were done focused on specific parts of the enclosure.

When the kansei engineering data collection started, each participant was provided with a folder that had a piece of paper for each enclosure. Each piece of paper had a form to rate the 11 kansei words on a specific enclosure. Enclosures where clearly labeled with numbers, with no more information provided. Each participant stood in front of an enclosure and rated the 11 kansei words on 7 point Likert scales. Only one enclosure was evaluated by one participant at each time. The order in which each participant rated the enclosures was randomized to avoid any possible trend bias. The whole data collection lasted a bit less than one hour.

The analysis of the data from the kansei engineering study allowed the deployment of the semantic space (which sensations are perceived as similar to others, and which ones are different), using a principal component analysis. A cluster analysis was also used to group those enclosures globally perceived as more similar.

In order to link the semantic space with the space of properties, thus discovering which properties affect each one of the responses, and in which way, a mixed effects ordinal logistic regression was performed, as recommended in Marco-Almagro (2011).

Relevant conclusions could be extracted that facilitate design decisions for the new enclosure.

4. Final thoughts and recommendations

To sum up, some final conclusions, classified by topics:

4.1. Preparation of studies

- The group of people that accepts to participate in a focus group or in a kansei engineering study tends to diminish when day D arrives. For some reason, even people that have confirmed they will attend are not in the meeting room when expected. So it is quite reasonable inviting 20% or 30% more people than the final number you want to have.

- The number of people necessary should be related with the expected variability between users. If everybody thinks the same, we do not need a huge sample of people. If there is more variability, a higher sample might be necessary. In that case, try to have a group of people that correctly represents all “varieties”.
- As always happen when data are analyzed, a huge amount of collaboration between company technicians and statistical experts is necessary.

4.2. Output from studies (focus groups, kansei engineering)

- A lot of information can be extracted when listening to customers in a proactive way. Do not invent customers’ needs, on the contrary, ask them what they want. Not only customers feel satisfied because their providers are interested in knowing their opinions, but also really interesting information can be obtained.
- Quality problems are a precondition for perceived quality. We need to have those quality problems solved if we want to convey the idea of good quality.
- There is much more than the product itself to give the idea of “good perceived quality”: instructions, packaging, service… The brand is also important and has many emotional qualities associated to it (but that is a whole other topic).
- At some point when dealing with perceived quality, a kansei engineering study is necessary to discover those “hidden” factors that affect perceived quality. Customers are not able to explain how design factors should be changed to give the idea that, say, an enclosure is robust, simply because they do not know.

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References

Childs, T., De Pennington, A., Rait, J., Robbins, T., Jones, K., Workman, C., Warren, S. & Colwill, J. 2003, "Affective Design (Kansei Engineering) in Japan", *A Report from a DTI International Technology Service Mission*.

Marco-Almagro, L. 2011, *Statistical Methods in Kansei Engineering Studies*, Universitat Politecnica de Catalunya | BarcelonaTech. http://hdl.handle.net/10803/85059

Marco-Almagro, L., Tort-Martorell, X. 2012, "Statistical methods in Kansei engineering: a case of statistical engineering", *Quality and Reliability Engineering International*, vol. 28, no. 5, pp. 563-573

Nagamachi, M. 1995, "Kansei Engineering - a New Ergonomic Consumer-Oriented Technology for Product Development", *International Journal of Industrial Ergonomics,* vol. 15, no. 1, pp. 3-11.

Schütte, S., Eklund, J., Axelsson, J. & Nagamachi, M. 2004, "Concepts, methods and tools in Kansei engineering", *Theoretical Issues in Ergonomics Science,* vol. 5, no. 3, pp. 214.

Schütte, S. 2005, *Engineering Emotional Values in Product Design: Kansei Engineering in Development*, Linköping University.