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Designing Feelings into Products

Integrating Kansei Engineering Methodology in
Product Development

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Abstract

Tendencies in product development of today make it likely that many future products will be functional equivalent and therefore hard to distinguish between for the customer. Customers will decide by highly subjective criteria which product to purchase. One task for product development in this context is to be able to capture the customer's considerations and feelings of products and translate these emotional aspects into concrete product design.

Today a number of different methods, such as Quality Function Deployment (QFD), Semantical Environment Description (SMB), Conjoint Analysis and Kansei Engineering exist and are used in practical applications.

The purpose of this thesis is to understand and apply Kansei Engineering methodology and explore ways to integrate the methodology into an industrial product development process.

This was done by conducting a study on forklift trucks in different European countries and business areas and by exploring ways of integrating Kansei Engineering in product development processes.

The number of Kansei words collected was reduced based on the result of a pilot study using a combination of different tools. A computerized data collection method was used in combination with a modified VAS-scale in order to reduce the time for filling out the evaluation forms. The results of the study in the visited Northern and Middle European companies make it evident that Kansei Engineering has to be adapted in several aspects to the circumstances in each situation. The data showed that there are differences in attitude towards reach trucks in the different European countries. These results were used in order to adapt the product requirements for each specific country. Starting at Cooper's stage gate model Kansei Engineering was applied on a macro level, a micro level and for verifying purpose. Using QFD, Kansei Engineering helps to identify customer needs their importance and the technical responses as well as to conduct benchmarking and to connect the customer needs mathematically to the technical responses.

This study of Kansei Engineering revealed that there was no general model on the methodology available in English literature. Outgoing from a previous flowchart, a conceptual framework of Kansei Engineering was developed integrating the existing Kansei Engineering Types and future tools.

Acknowledgements

Arriving in Linköping on the 17th of August 1998 I could not guess that I should stay another four years. I came here from Braunschweig's university as an exchange student and planned to stay here about 12 months. That I stayed, finished my studies and began my Ph.D. studies is the credit of many, that I finally could finish this thesis and hopefully go for the doctor is the credit of many more, I can not count all who contributed in some way, but I will make a brave attempt.

I met my supervisor Professor Jörgen Eklund for the first time in spring 2000 while I was conducting my master thesis. It was he who brought me into the department and helped me with my first unsteady steps in this new milieu. Thank you for inspiring discussions and your enthusiasm for my project. I also want to thank Dr. Jan Axelsson for giving me support and important impulses in my work so far. Janne, I am looking forward to more exciting projects and discussions- hope I will learn more about your "work-ability". Moreover, I would like to thank Professor Jens-Jörn Dahlgård for many interesting and motivating discussions and providing me an optimal infrastructure for my work.

In June 2001 I had the opportunity to travel to a conference in Singapore and met Professor Nagamachi, the inventor of Kansei Engineering for the first time. I learned a lot in only 5 days and I am looking forward to visit Hiroshima International University and meet him and his colleagues Professor Ishihara and Professor Nishino at your institution in Hiroshima in fall. Thank you for offering me this great opportunity.

During my work I found in BT Industries a reliable partner for testing my results in reality and supporting my projects financially. Special thanks to Erik Berg and Sven Wirenhammar, who are the initiators of the PRODERGO-project. Thanks also to Magnus Senneryd, Mats Wingmo, Daniel Nåbo, and Per Axner, who welcomed me in the company and gave me maximal support for conducting my studies.

In 1999 the two divisions Quality Technology and Industrial Ergonomics were merged to the new division of Quality and Human-Systems Engineering. From the early beginning I have been a border-crosser between these two areas and I hope that this thesis will contribute to a further coalescence. Anette, Beata, Bo, Bozena, Chen, Cecilia, Elisabeth, Eva, Gunilla, Gunnella, Håkan, Kjell, Lasse, Lena, Linda, Magareta, Martin, Nalini, Per, Tilman, Roger, Sidney, Susanne, Vincent, thank you for the good times we shared.

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At the time my brother Fabian began his Ph.D.-thesis within his medical studies, we bet that he who becomes a Ph.D. first would invite the other to a dinner. Well, he is in a better position, but I will do my very best!

Thanks to my brother Justin for correcting my German. *Ich hoffe wirklich, dass bei allem Schwedisch und Englisch, das ich hier jeden Tag benötige noch ein bisschen von meinem Deutsch übrig bleibt. Viel Glück in Deinem Studium.*

Rilda thank you for your support during the editing of this thesis. Thank you for being my steady power source and soul mate. You are really the “universal genius” I need.

Finally I want to thank my parents Hartwig and Christa. When I first came to Sweden I had the dream about flying, but it was them who made it possible to try my wings and encouraged me on my way...and do you believe this...I am flying....

Linköping, June 2002

Simon Schütte

I do not know who said this first, but this guided me all the way here, and hopefully towards the future.

*Versuche es perfekt zu machen,
aber sei mit dem Bestmöglichen zufrieden*

List of appended papers

Paper I

Schütte, S and J. Eklund. (2001)

An Approach to Kansei Engineering-Methods and Case Study on Design Identity;
Conference on Human Affective Design, Singapore June, 27-29,
Asian Academic Press, London

Paper II

Schütte, S. and J.Eklund (2002)

User Impression of Warehouse truck design
Submitted for publication in an international journal

Paper III

Kammerlind,P. and S. Schütte (2001)

Integrating Kansei Engineering and QFD in Product development;
QMOD, Linköping University

Paper IV

Schütte, S., J. Eklund, J.Axelsson, M.Nagamachi (2002)

Methods and Tools in Kansei Engineering
Submitted for publication in an international journal

Kansei Engineering publications at the division of Quality and human-Systems Engineering at LiTH:

Papers

Schütte, S. and J.Eklund (2002) User Impression of Warehouse truck design
Submitted for publication in an international journal

Axelsson, J. R. C. (2001)
Engineering of Impressions-A framework and example.
Proceedings of the 33rd Annual Congress of The Nordic Ergonomics Society.
Tampere, Finland

Axelsson J.R.C., Eklund, J. et al (2001)
Suspension and dampning of a lowlifter platform-An application of Kansei Engineering.
In M.J. Smith and G. Salvendy, Systems, Social and Internationalisation Design Aspects of Human-Computer Interaction, Vol 2, New Jersey, pp 333-337

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Introduction

This chapter guides the reader towards an introduction to the research area. The historic situation in the fields of quality, ergonomics and economics are briefly illuminated, facilitating the understanding of the following findings. In addition the research problem is expressed and explained theoretically in a scientific philosophical way.

1.1 Advancing production methods from an historical angle

In the beginning of the 20th century technology developed rapidly. Industrialisation had its starting point in Europe and soon reached Northern America. New product and production methods were developed making it possible to produce cheap consumer products in large quantities. Taylor published his main work about the “scientific management” already in 1903/1911 (Taylor 1972) and created a philosophy later known as Taylorism. His ideas led to an increase and optimised productivity in many cases but with negative consequences for the workers situation. On the other hand the workers were paid relatively well. So they could afford products and the companies could assess new markets. The economic situation during the “Roaring 20’s” was characterised by steady growth until the “Black Fridays” on the 13.5.1927 and 25.10.1929 set a sudden stop.



Figure 1: Ford's T-Model was closely connected to the Roaring 20's and one of the most successful products using Tayloristic production philosophy.

A similar situation occurred in the 70's again, after an almost 20 year long period of growth in Europe when the damage from the Second World War had been repaired.

Since the markets were saturated the strategy of producer-controlled supply did not work any more. In the 1930's the Second World War prevented an industrial adaptation, but in the late 1970's companies began more customer-oriented production, due to increased customer demands. Based on these production methods the new decade started with enhanced product ranges, in order to better satisfy customer demands. Hence, the variety of products increased.

New methods of measuring the customers voice and more flexible production-systems made it possible from the early 1990's onwards to satisfy the wants of even selective and highly sophisticated customers with high demands on quality and adaptability. Not only did the variety of products increase, but so did the variety of product features within the different product groups.

In the 60's and 70's cars were almost identical in design and function. Ten years later the number of models available from the same brand was considerably greater. Even the number of deliverable features has increased. Since the middle of the 90's cars can be ordered in highly individual compositions due to improvements in production and design methods.

1.2 Designing the quality dimension into products

1.2.1 Definition of quality

The word quality originates from the Latin word ‘qualitas’ and means “of what”. In general usage it describes the property or the nature of things (Cicero). In a technological context the definition of quality shifts depending on the context and time:

The ISO 9000 definition provides a direct connection between quality and the properties of a product:

Quality is “*the totality of those properties and characteristics of a product or an activity that relate to its suitability to fulfil stated requirements.*”

Even more affective oriented definitions occur and reveal connections to the field of ergonomics:

“*A product/service is of quality when it makes a maximum contribution to the health and happiness of all people involved in its production, use, destruction, and reuse*” (Aune 1999)

Tribus defines quality in even more emotional terms: “*Quality is what makes it possible for a customer to have a love affair with your product or service. Love is always fickle. You must be ever on the alert to understand what pleases the customer, for only customers define what constitutes quality*” (Tribus 1990).

Focusing on product development processes two aspects of the above presented definitions are of importance:

- Affective aspects (emotional impact of the new product)
- Design aspects (product properties)

Affective impact on the user is consequently a result of the composition of the different product properties. Hence, the goal must be to choose the best combination possible in order to maximize the customer satisfaction. Figure 2 lists some quality dimensions of an article.

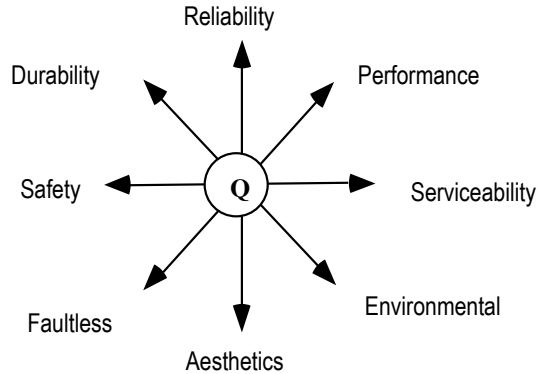


Figure 2: Some quality dimensions of an article (adapted from Bergman and Klefsjö, (1998)).

1.2.2 Historical development of the quality movement

The modern history of quality began in the 1920ies in the USA. Men like Sheward and Radford stand for a systematic research on this area (Axelsson 1999). They recognized, that good quality in products supports the sales. However, it was in Japan the ideas were applied in full scale.

Quality thinking was introduced in Japan after the Second World War. Japanese society had been isolated for many decades before the Second World War and struggled with social problems caused by the new open society. Japanese industry saw itself confronted with the competition on the global market. A bad reputation and bad quality of the products made in Japan made them difficult to sell. However the Japanese learned quickly to take advantages of the changed situation and were open to new impulses from abroad. They began to manufacture foreign products under license and tried to improve their quality. Two Americans, W. Edward Deming and Joseph. M Juran played an important role in quality development.

In the middle of the 1970's Japanese companies had not only survived the challenges, but had grown stronger and now produced superior products. The world depression made it possible for Japanese, Products to enter European and American Markets, since customers ranked quality products at a reasonable price higher than brand-fidelity. It was mainly cars and cameras, which sold best but soon Japanese brands took over even big shares of the electronic market. European and American companies were forced to react, but the Japanese superiority could not be broken, even with

increased import taxes on Japanese products. Many companies in the West became insolvent, the survivors adapted and integrated quality thinking in their organizations.

1.2.3 The principles of Total Quality Management (TQM)

Integrating quality into a company's products assumes a secure establishing of quality thinking in the company's organizational structure. In many cases this is a protracted process, requiring a big commitment from the top management (Karatsu 1988). Bergman and Klefsjö (1994) suggest a model setting the customer in focus surrounded by four important elements, the corner stones of quality. Their model is portrayed in Figure 3. Top managers have to focus on processes using a customer's perspective. Process thinking means to realize that everybody and every action in a company is in some way linked to the final result. This means in consequence that all the employees in the company not only have to be familiar with quality aspects but also be committed. Improvement in the processes is necessary and should be continuous. In order to prevent a relapse after every improvement step the improvements have to be secured and rooted in the system. All decisions must be based on facts in order to increase transparency and repeatability.

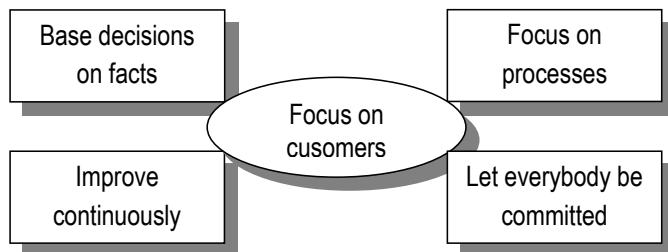


Figure 3: Important elements in a successful quality strategy (adapted from Bergman and Klefsjö ,(1994)).

In product development the point “base decisions on facts” is of special importance. Serving the customer in product design means to know the customer's needs from the product. However, to integrate customer demands, they must be captured, measured and conditioned in a suitable way. Hence, a number of tools is available e.g. Quality Function Deployment (QFD) (see Section 2.5.2) and Conjoint analysis (see Section 2.5.3).

1.2.4 The role of the Kano Model in Product Development Processes

When Kano, Seraku and Takahashi carried out investigations into customer needs in the early 1980's, they discovered that customer needs could be grouped into different categories on different levels. This discovery led to the introduction of the basics of the model later called the Kano Model (Kano et al. 1984). Figure 4 shows the Kano model in its later version. The x-axis displays the degree of achievement and the y-axis the degree of customers' satisfaction with the certain type of achievement. Depending on the product property being considered, different function-characteristics can be obtained.

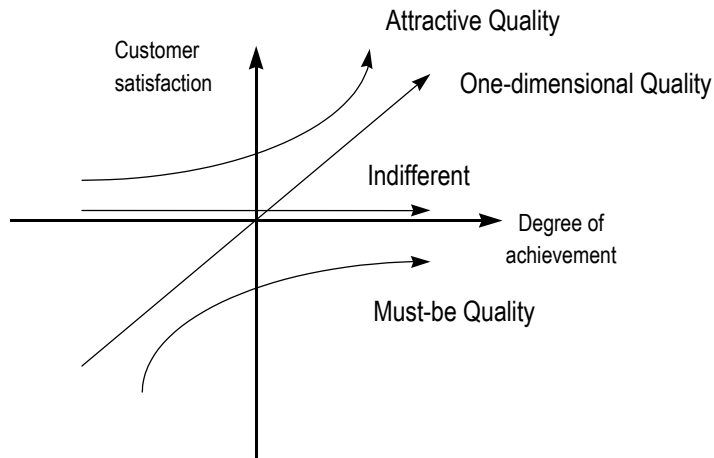


Figure 4: The Kano model (adapted from Kano et al., (1984)).

For example, basic demands like the electrical start motor in cars or windows in houses are considered a *Must-be quality*. Often the customer does not express these demands, since is self-evident to her. Usually a *one-dimensional* quality is expressed, i.e. special light metal rims or CD-player in cars, tiles in the bathroom, etc. The customer is aware that this type of equipment is not standard and expresses a desire for it. Manufacturers try to surprise the customer by adding a feature, which was not expected like a sponge for body gel, electrical heated side windows in a car, etc. This product property might be decisive for the customer buying the product. Particularly common products manufactured by many different companies can be made recognizable in this way. This is called an *attractive quality*.

Kano points out that almost every product property traverses a certain life cycle. When the property is newly introduced to the product the customer considers it an attractive quality. After a certain time the customer gets used to it and expresses it when

purchasing a new product. In the end the feature becomes common and it can be found in almost every product. Then it has become “Must-be quality”. Take the remote control for a TV-set as an example. In 1970 this feature was probably considered very attractive. Several years later practically all manufacturers could offer a remote controlled version of their TV-sets and the remote-control became a desirable feature. Since the number of TV sets sold equipped with remote control was relatively low, it became a kind of status symbol too. Nowadays remote controls are standard. No TV set is sold without them any longer, since it has become an expected minimal quality.

1.3 Ergonomics in products

1.3.1 Definitions of ergonomics

The expression ergonomics comes from the Greek words *ergon*, which means work and *nomos*; (natural) law. However, since the field of ergonomics includes many different branches the definitions of ergonomics vary depending on focus and time.

According to Clark and Corlett, “*ergonomics is the study of human abilities and characteristics which affect the design of equipment, systems and jobs and it aims to improve efficiency, safety and well-being.*” (Clark and Corlett 1984)

Kragt states, that “*product ergonomics, i.e. the usability of things people use* (Kragt 1992),

The Nordic Ergonomic Society defines ergonomics in the following terms:

“Interdisciplinary field of science and application considering integrated knowledge of human requirements and needs in the interaction human - technology - environment in the design of technical components and work systems” (NES/SIS)

Regarding development of new products, the same aspects as in the previous section about quality are of importance. The benefit for the user lies in the affective advantage the product can offer. The difference to the field of quality lies here in the addressee. Whereas quality wants to satisfy the customer, ergonomics focuses on the actual user. Regarding consume products the customer and the user might be the same person, but in the case of investment goods i.e. trucks it can be different persons. This circumstance can lead to different design solutions.

However, the instrument to adapt the product is the same: Designing feeling into product properties by using some kind of method.

1.3.2 The history of ergonomics

The expression ergonomics was introduced by K.F.H Murriel in 1949. But ergonomics as a science is much older. A certain concern about the work force can be found as early as in the 17th and 18th century. The motive for improving the working situation was rational, since there was a shortage of workers (Ruth and Odenrick 1994).

At the same period Ramazzini (Ramazini 1731, 1991) wrote a book about occupational injuries. However, the big break through for ergonomics began first in the middle of the 19th century, at the same time as the industrial revolution. The workers were employed in highly specialized tasks and new production methods were developed requiring new equipment and tools.

Previously the tools had been invented by the users themselves and could be adapted according to their personal preferences, but now the workers had to use tools which were already made. F. W Taylor realized that a non-optimal design of working tools worsened work performance and could cause occupational injuries. As a consequence he conducted several experiments with shovels and integrated the findings as an essential point in his thesis about *Scientific Management* (Taylor 1972). In the 1920's the focus shifted slowly from the rational to a more humanistic perspective. New branches appeared dealing with the psychological effects on work performance (Bridger 1995).

This development was interrupted by the Second World War, which brought in a military approach, dealing mainly with weapon design in multidisciplinary work groups. These tendencies were continued after the Second World War, but in the 60's the focus swung back to industrial ergonomics. Due to the economic crisis in the 70's companies try to orient the products closer to the users and discovered in this context ergonomics as a sales argument.

1990 saw a rapid growth in ergonomic approaches at different levels. The new parts were influences from organisational psychology and sociotechnology, but also quality topics found a home under the umbrella of ergonomics (Ingelgård 1998). The trends point nowadays towards more complex and multidisciplinary methods.

1.4 *Heading towards increased customer orientation*

At the threshold of the new Millennium companies see themselves confronted with new challenges. The trends described above of customer centred product development will continue in a more demanding way.

The demands on user-friendliness, usability and ergonomics will increase (IVA 1999a). Shortened product life cycles are likely to increase development costs. This contributes to making errors very expensive in estimations of market trends (IVA 1999b).

The product itself is changing shape (see Section 1.6.1). Already today trends are visible where products are to a higher degree connected to services, i.e. most of the cellular phones are sold in connection with a operator contract reducing the purchasing cost. Electronic devices like TV-sets, computers and video systems can be rented including a free repair and replacement service.

Rental and service connected products have been common for investment products in industry and are now being spread to consumer products. In turn the above-mentioned trends are likely to go on to investment products like vehicles, control units, etc.

Since the number of manufacturers producing products for the same market segment is rising and the grade of maturity is high, products tend to be equivalent in performance and cost. Hence, manufacturers will be inclined to make their products recognisable by designing brand identity into the products. Hitherto mostly visible and touchable design elements have been used. In car industry even the sound played a role, but now even product properties stimulating smell and taste will be registered trademarks (Wallerius 2002). Already today products like cherry-smelling motor-oil and tennis balls, which smell of grass are available.

Life style products will play an increasing role. Products from different areas of daily life are collected and sold under the same label representing a certain life style. Under the brand name "Will" i.e. companies like Toyota, Panasonic, Asahi sell cars, bicycles, home-computers, refrigerators, ice-cream, etc. Customers will consider the brand name in a wider context than today.

The customer will buy with heart, mind and soul (Axelsson 2001) to suit their feelings, emotions and lifestyle – quality of life and user experience will be the most vital aspects of the future. Expressed in quality terms: Quality is in the eye of the beholder (Garvin 1988).

Companies are currently working with organizational changes in order to be prepared for new challenges.

For example the Japanese Pioneer group started the project “Pioneer Vision 2005” and according to a press release from August 1998 spends about 30 billion yen every year on the project (Martensen and Dahlgaard 1999). Pioneer states in the “Pioneer Vision 2005”, that the collective objective is to be “an innovative company creating network and user friendly entertainment” (Pioneer material). Pioneer follows two philosophies in order to reach this goal:

- Management policy: Customer Satisfaction is the ultimate goal
- Corporate philosophy: Move the heart touch the soul

Referring back to the Kano Model, properties like user friendliness, ergonomics etc. which are nowadays attractive features, will soon become “must-be-quality”. Future products will be designed rooted in earlier periods but possess new properties giving emotional an impact.

1.5 Truck Design

The author has had the opportunity in several cases to carry out studies in cooperation with BT Industries. BT is located in Mjölby, Sweden and is one of the leading manufacturers of warehouse trucks.

1.5.1 Products and Product ranges

BT’s product range stretches from hand pallet trucks, to 5 ton diesel fork trucks. Moreover, it includes applications for horizontal transport, stacking, order picking, very narrow aisle, and combinations of these items.

However, the product program has to be complemented with distinct surround services, which are prophylactic and emergency maintenance in different forms, spare part supply, short- and long time rental, financing and driver education. These parts account for approximately 40% of BT’s turn over, which is typical for this branch. (BT Industries, Annual Report 2000)

Trucks and services can be composed into individual packages adapted to particular purpose. Consequently the product delivered by BT is in most cases not only the truck itself, but the combination of tangible and intangible sub-products.

The studies conducted focused mainly on reach trucks alone. This choice was made, since this type of truck is sold in large quantities and BT had long experience with it.

1.5.2 Market Segmentation

According to BT the market for reach trucks can be divided into three main categories as shown in Table 1.

Table 1: Market segments for Reach Trucks (source: BT Industries).

Group	I	II	III
Frequency of use	Low	Medium/High	High
Ownership	Purchase	Rental	Rental
Lifting Hight	Low/Medium	Medium/High	High
Driver Qualification	Layman/Professional	Professional	Professional
Operating Time	<700 h/Year	1000-3000h/Year	2000-3000h/Year
Sell in %	15%-20%	80-85%	
Tendency	Growing	Stagnating	

Group I is characterized by trucks with low frequency of use, used in small warehouses with a small number of employees working with various tasks. Material handling equipment in this sector must be easy to handle by everybody and universally applicable. Since the majority of these trucks are owned by the company the purchasers are relatively price sensitive. Group II and III are rental trucks with medium to high frequency of use. Those are typically operated in big warehouses under single- or multiple shift conditions. In these cases the operators are professional truck drivers, requiring an adaptability to their personal working situation.

1.5.3 Meeting the customers demands

BT Industries have a genuine experience in designing the customer's demands into their products; i.e. trucks and surrounding services.

Adapting the services to the customer's demands is possible by tailoring the rental- and service contracts individually.

Product development methods like QFD make it possible to collect the voice of the customer regarding the tangible product. Modularization contributes to an easy change of components in order to suit the customer's demands regarding performance values. In addition the prototypes or parts of the new trucks are tested under real conditions, which gives valuable feedback from the actual users.

1.5.4 Earlier cooperation between BT Industries and Linköping University

Together with BT a joint research project in the field around productivity and ergonomics (PRODERGO) was started. This project has three objective targets.

The central pillar is a cooperation between BT and a Ph.D. student, and the cooperation is the basis for this thesis. Kaisa Nolimo-Solman proposed based on results gathered from her studies at BT a framework for analysis of interaction quality in human-machine-systems (Nolimo-Solman 2001)

Another focus lies on a number of different projects, which are related to the fields covered by PRODERGO. In most of the cases these projects are conducted by masters students doing their theses, jointly supervised by persons from BT and Linköpings University. Often the projects are an integral part in the ongoing research work.

As a third objective Linköping University performs learning laboratories in topics related to the ongoing projects at regular intervals. These topics are often collected from the various fields of work and industrial science and quality. BT in turn contributes with their experience on these sectors.

1.6 Definitions

As mentioned BT's product program includes both trucks and surround services. Both are considered as two different types of products and consequently developed in different departments using different product development processes. However, it is known that there are overlaps between the two groups, i.e. the edition of a manual requires co-operation between several departments within BT. The arising questions are, how do the two different types of products relate to each other, what are the overlaps and how can synergy effects be utilized? This requires a proper definition of the expression product and it's contents.

1.6.1 Product

Since this thesis mainly deals with product development the perspective used on products has to be clarified.

The word "product" is derived from the latin word *productum*, which means result, or gain. During the industrial revolution it became synonymous with industrial manufactured artefacts. Nowadays the expression also includes services (Röstlinger and Goldkuhl 1999). Most of the methods for measuring customer needs are originally

designed for development of physical artefacts, but recently several studies were conducted on services proving that the applicability of those tools is much wider.

According to Röstlinger and Goldkuhl artefacts can be connected with certain services e.g. delivery and installation of a washing machine, rental cars or cell phone services (Röstlinger and Goldkuhl 1999). Since the number of these types of combined products will increase in the future (IVA 1999b), a suitable method for determining customer needs has to be designed to conduct examinations of both the intangible and tangible part of the products as well.

Figure 5 portrays the three different types of products, which is a potential method for collecting customer needs has to be able to evaluate in future.

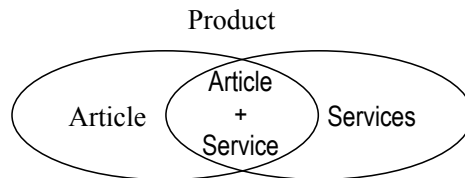


Figure 5: Product Definition used.

1.6.2 Product Properties

Every product possesses a number of properties, which enables it to fulfil the function that it is originally designed for. In this thesis the product properties are subdivided into:

- *design parameters* and
- *product traits*

A product parameter is a intentionally designed property of the product. In contrast, a product trait is a product property which was not intended by the designer but nevertheless a property of the product. An example: When designing a cell phone, the housing is usually made out of plastic, since it is easy and cheap to produce, light, shock-absorbing and it has a smooth surface. These are the intended design parameters. On the other hand the material has a number of unintended traits, like the shock absorption, its thermal conduction etc., which are not originally intended but are now properties of the phone.

All the properties have a potential impact on the user of the product. Unfortunately not all product properties can be treated by methods evaluating customer needs, but a certain selection has to be made. To make this explicit the selected properties are called items (Nishino 2001). An item, in turn, can include several categories, completing the information about the item. The item ‘colour’ can i.e. be completed by the categories “green”, “blue”, etc.

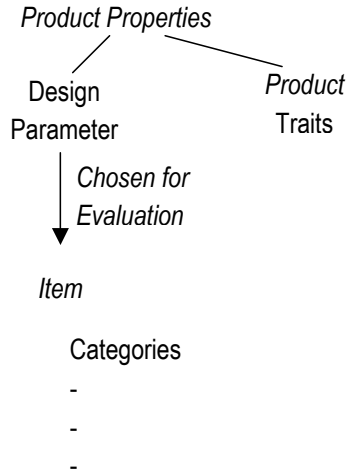


Figure 6: Definition of Product Properties for this thesis inspired by Nagamachi, Ishihara et al. (2001), Nishino (2001) and Eklund (2000-2002).

1.7 Defining the research area

Projecting the above mentioned trends of present and future customer behavior into the Kano model can provide a certain forecast on the way product development can look in the future.

Today’s basic needs will be completed with today’s one-dimensional customer demands, since the users get used to the features and expect them from future products. In turn those product properties, which are considered attractive quality becomes a one-dimensional quality. Consequently, new attractive product properties must be found. Attractive quality can be achieved by adding new services, articles, functions, etc.

However, the company Pioneer might indicate the direction of the new efforts. Customers call for a holistic perspective on product development. Future products are more than the sum of its parts. Emotions, feelings and soul are the required properties.

This thesis will focus only on parts dealing with the emotional impact of products, since, tools in this area are still very rare. Figure 7 displays the demarcation of this thesis visually.

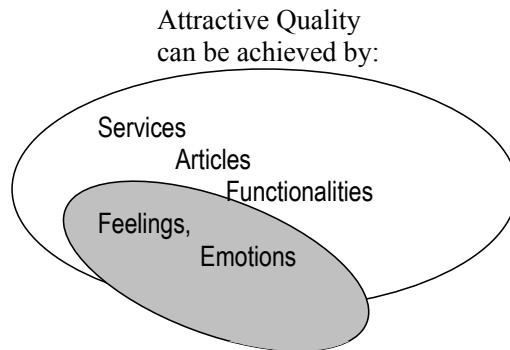


Figure 7: Demarcation of this thesis.

The questions to be answered are:

1. How can feelings and emotions be captured and measured?
2. Which method can be used in order to carry out such studies?

A company's organizational structure is in many cases still influenced by the old paradigms.

3. How can new methods be implemented in a company's development process?

1.8 Scientific approach

1.8.1 Streams in Scientific philosophy

The history of science shows mainly two streams. On one side the rational-empirical approach which refers to the early Greek scientists like Aristotle, on the other side the intuitive-theological approach, which refers to the early forms of biblical studies. During the following centuries the dominance of the two forms shifted, depending on the regime in power and spirit of the age, but both forms existed in parallel and influenced each other. Today these mainstreams are called positivism and hermeneutics.

1.8.1.1 Positivism

The positivism grew based on Aristotle's logic based on empiricism. Around 1930 (Comte 1979) recognized that different scientific methodologies were used in different scientific fields. He plead for a homogenous methodology, "*which could guarantee positive knowledge*". This was the starting point for the positivism.

One of positivism's most essential assumptions is that existence of a *true reality*- a reality, which is independent of the researcher's beliefs and convictions. Knowledge can only be gathered from observations and has to be documented in a logical-analytical or mathematical way in order to give the statements a universal character and make the observations repeatable.

Scientific knowledge is according to Comte, an instrument for predicting future events. These predictions can be based on probability terms, which in turn have to be based on sensory data. Useful scientific data must be measurable and express observable laws.

This make the positivism suitable for natural science.

1.8.1.2 Hermeneutics

Hermeneutics is a Greek expression and refers to Hermes, the messenger of the gods. During the Middle Ages Protestant priests were called Hermeneutics, since they could interpret the Bible. These priests were representatives for the above mentioned intuitive-theological approach.

A Hermeneutic perspective assumes that human expressions follow a universal pattern, which is expressed by actions, language, gestures, etc. Since humans live in the context of the present their actions will be based on history and controlled by previous experience. The Hermeneutics state that no fact is static, but everything can (and has to be) interpreted. This is valid even for material things. Reality is what humans consider to be real and consequently subjective. The basis of human thinking is language, which forms the way of thinking, clarifying standpoints and evaluating as well as understanding and having perspective on life.

Hermeneutics strives after an understanding and an interpretation of the human context rather than "hard" measurements and establishing of laws. Moreover, according to the Hermeneutic perspective it focuses on the overall impression of things. Whereas positivism examines a phenomenon in its parts, hermeneutics considers that the sum of the parts result in a greater meaning. Hence, hermeneutics is especially suitable for human science approaches.

1.8.2 Quantitative vs. qualitative measurements

In recent years much has been written manifesting the distinction between qualitative and quantitative research methods. It appears as if one rules out the other in a research approach. In practice this is not the case. Both methods can be used within the same research problem (Patel and Tebelius 1987). The choice of which method is most suitable depends on what kind of information is required.

If the purpose of a study is to reduce the facts gathered to mathematical figures and formulas to provide a measurability of the investigated phenomenon, a quantitative approach should be chosen. Among practitioners, qualitative measurements are often considered to be more objective (Black 1999). On the other hand qualitative methods suffer from a lack of detail description ability, especially in low researched areas (Strauss and Corbin 1990). Since these are the demands the positivistic view makes on its investigation methods, hermeneutics often rejects the use of this method.

Qualitative measurements are mostly used in hermeneutics. The research question aims of a deeper understanding and interpretation of a phenomenon. With a holistic view upon the settings, and the humans involved the context becomes important (Taylor and Bogdan 1984). The strength of qualitative methods lies in their ability to support understanding of details and set them in correlation to the context. Overlying patterns becomes detectable (Patel and Tebelius 1987). Findings on the other hand are not arrived at by means of statistical procedures or other means of quantification (Strauss and Corbin 1990).

1.8.3 Building a bridge between customers feelings and product measurements

Starting from an easy experiment, Fibonacci developed a series of numbers, nowadays known as Fibonacci-numbers. This series is commonly used in art i.e. for determining the “golden section” and can be seen as a link between mathematics and art and qualitative and quantitative science (Liedman 2001).

Market research utilizes social scientific theories in order to reveal customers’ demands and attitudes; whereas product design is primarily based on natural science’s mathematical terms. Integrating the findings from market research into product design requires a bridging over of the different areas. The main task is to translate feelings, individual experiences and understandings into “hard” measurements and mathematical models which in turn have to be falsifiable using both qualitative and quantitative methods. Figure 8 shows this graphically.

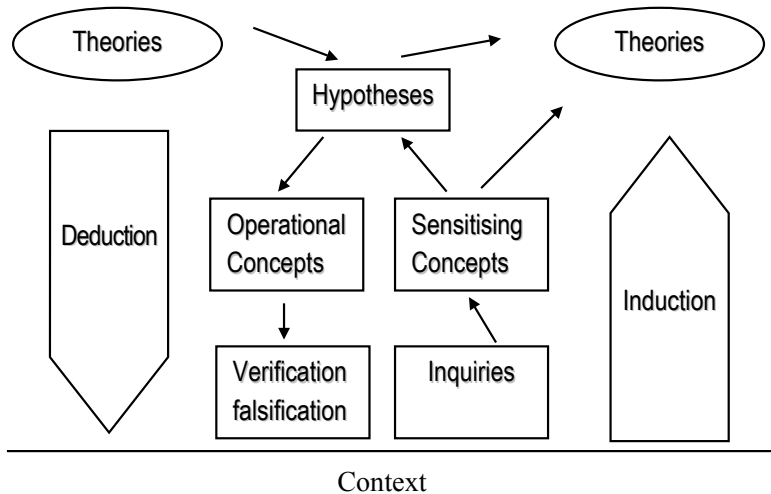


Figure 8: Scientific Context Adapted from Patel and Teblius (1987) and Starin et al (1991).

Starting at a hermeneutics-context data about the emotional impact of products is gathered. Using induction hypotheses and theories are built describing the relations either quantitative or qualitative. The models which had been gathered in that way are a linkage between a certain impression and e.g. a product property which has to be verified using deduction methods. This means that the bridge between customer feelings and product properties has to be double tracked.

1.8.4 Possible methods

Many methods are developed and used. The most common in industry is probably Quality Function Deployment (see Section 2.5.2) using expert knowledge for connecting the voice of the customer to technical responses. A method using the human ability to distinguish between different concepts is Conjoint Analysis (see Section 2.5.3) This method identifies the preferred combinations of product properties to a certain price. A more specific method is Semantic Environment Description (SMB) (see Section 2.5.1). This method has been especially developed for the evaluation of architectural environments.

However, all of the methods mentioned above can be applied to this type of problems, but the customers' wants can only be expressed in technical solutions. This problem was recognized by Professor Mitsuo Nagamachi and he developed a methodology for measuring the impact a certain product has on the customer. He called his invention Kansei Engineering (see Section 2.1).

1.9 Outline

1.9.1 Structure of this thesis

After having read the previous sections the reader is briefly familiar with some relevant parts of the history of economics, ergonomics and quality. Since parts of the research work for thesis had been done in cooperation with BT, the products used and product development processes of this company are presented. A brief picture of the future has been drawn and the reader has been introduced to several aspects of the research area. The scientific approach is illuminated and gives an impression of how the arising research questions arising can be solved from a theoretical point of view.

The frame of reference in the following section introduces the reader into suitable methods for measuring and translating feeling into product design parameters. The presented methods are Kansei Engineering in the first instance, Quality Function Deployment (QFD), Conjoint Analysis and Semantic Environment Description (SMB). Since Kansei Engineering is little known in the West, it is presented in more detail than the other methods.

Chapter 3 contains tools and techniques for carrying out a Kansei Engineering Study. Kansei Engineering utilizes a number of different methods from different fields of science and adapts it for its own purpose. According to the author it is important to document how and in which way these methods are used in Kansei Engineering context.

First at this point the reader is fully introduced to the principles of Kansei Engineering. Starting from the definition of the research area, the purpose of this thesis is stated. Kansei Engineering is chosen as the main study object, but it is always referred to other methods used in product development processes.

In the following text the methodological procedure for conducting this thesis is shown. In contrast to Chapter 3 this chapter contains only those tools, which were really used in practical research work and describes in which way and order they were applied and adapted if necessary.

Chapter 6 illustrates the results from the studies conducted and gives an impression how Kansei Engineering can be integrated into product development. This thesis is finalised with a discussion of the gathered results and a reflection about future research.

1.9.2 Brief overview of the appended papers

The appended papers reflect and stress the progress the author made from August 2000 to Spring 2002.

In cooperation with BT Industries, a project was started dealing with the brand image of different truck types. This study was documented in two steps. Paper I deals with data collected in Swedish companies and was presented at the International Conference of Affective Human Factors Design in Singapore, between 27th and 29th June 2001. Paper II includes this data and data collected in German companies. It is currently being submitted for publication in an international journal.

One goal of the cooperation with BT was to implement Kansei Engineering in their product development processes. Paper III is a step along this way. It describes the role of Kansei Engineering in product development and reveals opportunities to integrate Kansei Engineering with similar methods like QFD. Paper III was presented at the 4th International QMOD Conference in Linköping/Sweden between 12th and 14th September 2001.

During the work with Kansei Engineering it became evident that the total concept of Kansei Engineering has never been documented in English literature. This made it difficult to understand the different types of Kansei Engineering. Hence, the author decided to propose a concept explaining all the existing types of Kansei Engineering and facilitating the development of a new tool within the area. Paper IV is currently a working paper. It is intended to be published in an international journal.

Frame of Reference

The reader is now familiar with the research area and the questions arising. This chapter presents possible methods for answering the research questions. These methods are Quality Function Deployment, Semantic Environment Description, Conjoint Analysis and Kansei Engineering. However, the main focus lies on Kansei Engineering.

2.1 Kansei Engineering

2.1.1 What is the Kansei?

The Butterfly

O wonderful and wingèd flower,
That hoverest in the garden-close,
Finding, in mazes of the rose,
The rapture of a summer hour !

O symbol of Impermanence,
Thou art a word of Beauty's tongue,
A word that in her song is sung,
Appealing to the inner sense.

Of that high mystic harmony
All lovely things are notes and words--
The growth of flowers, the flight of birds,
The figured Signs, the foam-wrought sea,

The whitening gold of sudden dawn,
The sunset's garnet afterglow,
The cumulus, the noonlit snow,
The moon in irised clouds withdrawn.

Lacking (who knows?) a cloud, a tree,
A streamlet's purl, the ocean's roar
From Nature's multitudinous store--
Imperfect were the melody!

By Clark Ashton Smith

Did you feel the sun warming your skin and a slight breeze touching you softly, while reading the poem? Did you see the butterfly dancing in the sunlight coming through the tight leaves of the mighty trees? And did you smell the smell of summer? Didn't you have a taste of fresh strawberries in your mouth?

That is what Kansei is about!

The expression Kansei is difficult to translate. It means approximately "total emotions", but that does not fully explain its meaning - in fact not at all. Kansei is the impression somebody gets from a certain artefact, environment or situation using all their senses of sight, hearing, feeling, smell, taste as well as their recognition (Nagamachi 2001).

An example: Imagine you want to purchase a new car. During a short trip in a vehicle you borrowed at a car-dealer's shop you smell the new material, can touch the surfaces and check the quality of each detail. When you start the engine, it has a unique sound. You feel the pressure on your back when you press the accelerator and feel the car pull forward, see the needle of the speedometer climbing, while you hear the engine-noise becoming more intense. All these highly subjective factors contribute to the way you experience the vehicle and they will decide in the end whether you will buy just this car model or not.

On the other hand, if your job is to design consumer products it is useful to know what Kansei just your customers have of your products and which ones they want to have. Unfortunately, customers cannot always express their impressions about a certain artefact verbally in a proper way. Sometimes they are not even aware of their demands on a product. What is for example the difference between good and bad chocolate?

And if you have a piece of bad chocolate; could you say what should be improved to get a better or rather the best product? The taste? The smell? The form?

As seen it is not easy to decide which property of the product evokes a certain Kansei and how the Kansei is influenced when this property is changed. Moreover, the Kansei depends in many cases not only on one product property, but on the composition and balance between them. The decision process whether a bit of chocolate is good or not or if the new car has good quality is made unconsciously. Only the result of such a thinking process can be expressed in words.

Choosing the relevant traits for physical products can be rather complicated, but in Kansei methodology a product does not necessarily have to be tangible (see Section 1.6.1). In this context, products can also be intangible i.e. services, information, computer programs, etc. The expression “product” used in this context will in the following mean both tangible and intangible products (see Paper IV).

2.1.2 What is Kansei Engineering?

Kansei Engineering is first and foremost a product development methodology, which translates customer’s impressions, feelings and demands on existing products or concepts to design solutions and concrete design parameters. Secondly, it shows how Kansei is translated into design.

According to Nagamachi (2001) there are three focal points of Kansei Engineering:

- How to accurately understand consumer Kansei
- How to reflect and translate Kansei understanding into product design
- How to create a system and organization for Kansei orientated design

Figure 9 shows how Kansei Engineering works in principle.

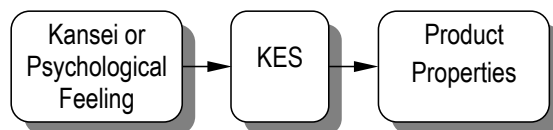


Figure 9: A Kansei Engineering System (KES) adapted from Nagamachi (1995).

The methodology is mainly a facility for the systematic development of new and innovative products, but can also be used as a tool for the improvement of product concepts. As input data the Kansei is measured, conditioned and subsequently processed by a Kansei Engineering System (KES). The resulting information tells how the psychological feeling “Kansei” is related to the product considered, which can be both material or immaterial. The question arising is how the Kansei can be grasped and conditioned. Since Kansei is an internal sensation, it can at present only be measured using external methods. Therefore, a series of measurement method has been developed, interpreting:

- People’s behaviours and actions
- Words (spoken)
- Facial and body expressions
- Physiological responses (e. i. heart rate, EMG, EEG)

(Nagamachi 2001)

Kansei Engineering is limited to the evaluation of words and their emotional impact on a human’s mind. This means consequently that not the whole span of Kansei is quantified; only the part that can be expressed in words is used. Usually these words are adjectives, but also nouns can occur (see even Section 5.3.2). Figure 10 depicts this visually.

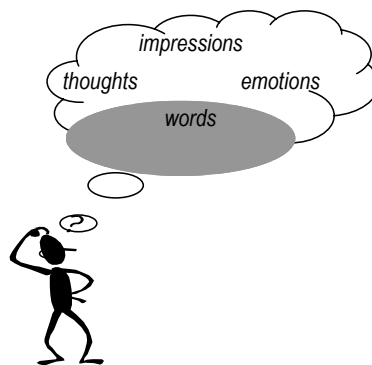


Figure 10: The excerpt from Kansei measured by Kansei Engineering (adapted form Axelsson (2001)).

KE is based on subjective estimations of products and concept properties and helps customers to express their demands on the products, even those which they are not aware of. Therefore, semantic tools i.e. the Semantic Differential Method developed

by (Osgood et al. 1969) are used. In this way it is possible to quantify the emotions such as driver feeling and spatial perception or the impression of the sound of vehicles.

2.2 Kansei Engineering from a historical perspective

Since Kansei Engineering was developed in the early 70's an increasing number of universities and companies have adopted and implemented the method. Nowadays there are about 1000 scientists working with Kansei Engineering in Japan alone; approximately 100 of them professors, and approximately 300 engineers in several companies. One reason for this distribution is the complexity of the methodology, which requires close co-operation between companies and universities.

2.3 Different Types of Kansei Engineering

Kansei Engineering can be carried out in different ways using different types of Kansei Engineering. At the moment six types of Kansei Engineering have been developed, proved and tested.

2.3.1 Kansei Engineering Type I –Category Classification

Applying Kansei Engineering Type I gives the simplest and quickest way of making a Kansei analysis. A certain product strategy and market segment is identified and developed into a tree structure. This tree structure shows similarities with Ishikawa diagrams (Ishikawa 1982) and QFD (see Section 2.5.2).

The decision in favour of a certain market segment implies certain product properties these must be known by the development team and taken in account when designing the new product. Kansei Engineering Type I starts with the so called zero-level concept, which is broken down into several sub concepts. These sub concepts can be evaluated separately at several levels until the product design parameters can be easily determined. In more difficult cases it may be necessary to carry out small surveys to support the decision for one final concept. Figure 11 illustrates this process.

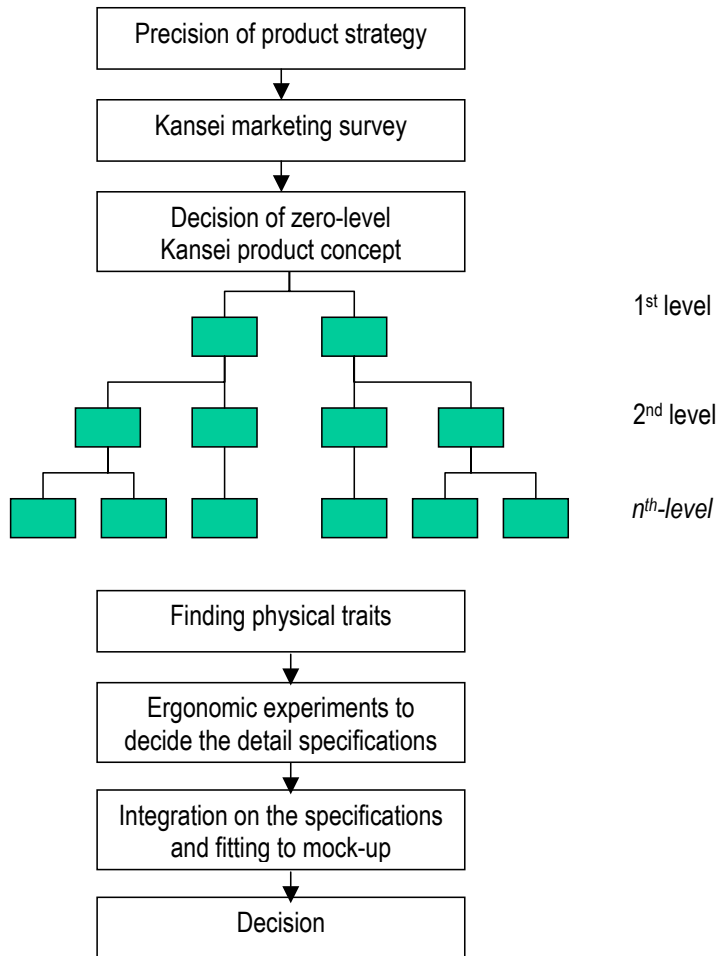


Figure 11: Process Tree for the Kansei Engineering Type I Method (Nagamachi 2001).

As an example an automobile, the Mazda Miata (in Europe MX5), is used. The aim was to build a sporty low-price car for younger male drivers. A product philosophy called zero-level-concept was chosen based on a survey on customer trends. The participants in the survey voted for the concept “Human-Machine Unity” (HMU). Since this concept is very abstract and difficult to interpret it is apparent that a special method is necessary to translate the vision into technical terms. This can be Kansei Engineering Type 1

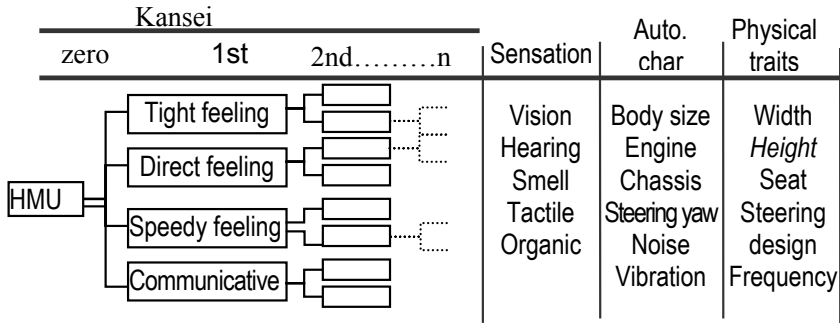


Figure 12: Kansei Type I; HMU concept for Mazda Miata (Nagamachi 1997b).

Figure 12 shows the several levels in this tree. The product philosophy is set as the zero-level and serves as a base for the structure above. The HMU concept at the first level was translated into a combination of tight feeling, direct feeling, speedy feeling and communication between the vehicle and the driver. In principle this method is used in order to create the higher levels until the results can easily be translated into concrete design parameters as is shown in Figure 13.

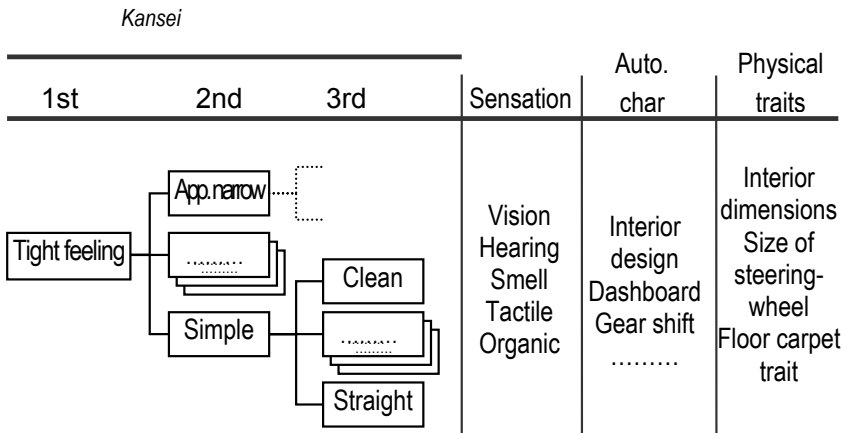


Figure 13: Sub-concept “tight feeling” (Nagamachi 1997b).

In the case of “tight feeling” the tree had to be developed into two levels. From this point the team carried out a small Kansei Engineering experiment where most of the participants voted for a body length around 4m and only two seats. In fact the Miyata has a body length of 3,98 and 2+2 seats. In the same way, the sub concept “direct

feeling” was evaluated. Here the gearshift lever was identified as essential for that part of driving impression. Especially two aspects, the length and the weight of the upper part of the shift lever, were examined by carrying out a similar study.

2.3.2 Kansei Engineering Type II-Kansei Engineering System KES

A Kansei Engineering System is a computer-aided way of connecting the user’s Kansei to the product properties. Kansei Engineering Systems are in many cases expert programs supporting design decisions on different products.

A typical KES consists of four coupled databases for Kansei words, images of the examined products, design and colour and knowledge about how the different data are related to each other. In Figure 14 a scheme of a KES is presented.

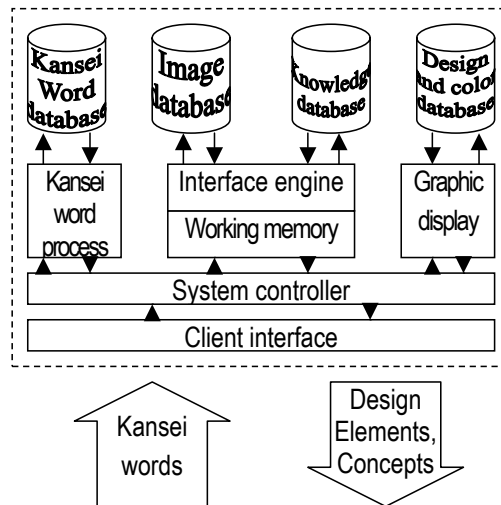


Figure 14: Principle of a Kansei Engineering System (adapted from Nagamachi 1997).

When a certain Kansei word is fed into the system, data from the knowledge database links the Kansei word together with a certain product image using a certain interference engine. Before the design elements matching the Kansei word is presented to the user of the System, the design and colour setting is carried out from data in the corresponding database.

(Imamura et al. 1997) applied this technique to a kitchen design program, where the customers are supposed to describe their dream kitchen in their own words. The KES chooses a kitchen system and design based on the customer's life-style and habits.

Building up such an expert programme requires knowledge about the target group's life style and habits. In some cases even activity studies are conducted (Nagamachi 1997b). Figure 15 portrays the procedure in 11 steps.

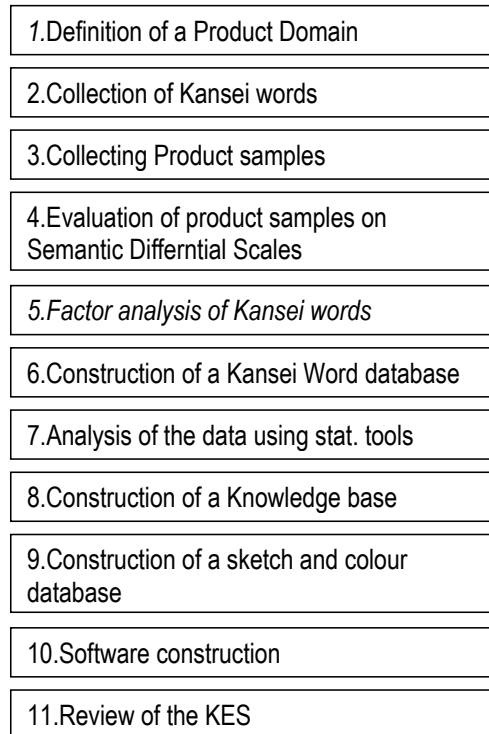


Figure 15: An outline of the procedure of a Kansei Engineering System (Nagamachi 2001).

Firstly a domain is chosen, by defining product groups and potential customer target groups. On the basis of this information the domain is described by Kansei words originating from different sources such as dealers, recorded dialogues between dealers and customers, relevant magazines, pertinent literature, etc. The number of descriptive Kansei words can be up to 600 depending on the product (Nagamachi 1997b). At the same time an Image database is built up, containing images, video-clips, VR-presentations or real product samples. In general it can be said that the more senses are involved, the clearer the Kansei becomes.

After this step volunteer participants evaluate the products on ranking scales (Semantic Differential Scales) (compare Section 3.1). The data gathered from this step is treated by factor analysis in order to reduce the total number of Kansei words. Then representative words for each factor are chosen and the Kansei database is established. Using the new database the product samples are evaluated and treated with Hayashi's Quantification theory Type 1 (QT1) (compare Section 3.2.1). The evaluation using QT1 establishes the connections between the Kansei words database and the Image database. In the following a knowledge database can be built. After the construction of a design and colour database, the software for the interference engine can be established and the system is tested and reviewed in order to spot errors and validate the results.

2.3.3 Kansei Engineering Type III- Hybrid Kansei Engineering System

The Kansei Engineering System presented in the previous section is also called Forward Kansei Engineering, because it can only be used to convert the consumer's Kansei into design parameters. On the other hand there are many applications requiring the analysis of concepts, free drawings or drafts, which are made during the development process. In principle the same process can be used, but the cost and time consumption are excessive in relation to the outcome. Consequently, it would be convenient to set up a database from related products which can be used in reverse order to predict the Kansei that a user will have from a drawing or concept. Consequentially this type of Kansei Engineering is called Backward Kansei Engineering System and can be seen in Figure 16

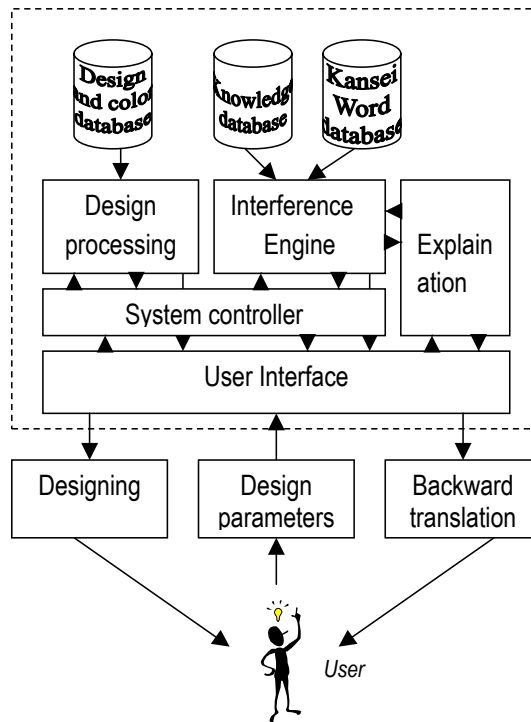


Figure 16: Principle of Backward Kansei Engineering System (adapted from Nagamachi (1997b)).

In spite of the fact that the databases used for Hybrid Kansei Engineering are the same as in the KES, the programme is specially developed for designers use. A designer feeds her/his ideas via the user interface and the system controller into the interference engine, which analyses the product parameters of the incoming data and compares it with the stored data in the knowledge database. These data in turn are linked to the Kansei word database. The related Kansei words are picked and presented to the designer.

Often the Forward and the Backward KES are combined, because they use the same databases. This type is called Hybrid KES and it can be seen in Figure 17.

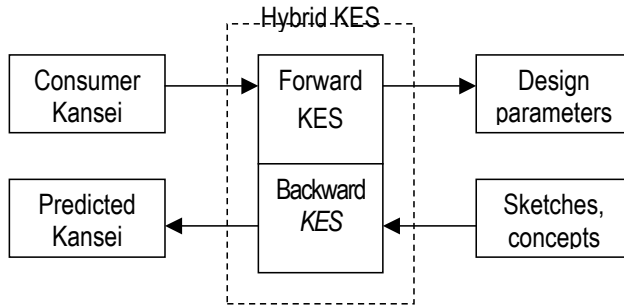


Figure 17: Hybrid Kansei Engineering System (adapted from Nagamachi, (1995)).

Using Hybrid KES offers several advantages:

- Quick estimation of the customers Kansei on the concept
- Not necessary to present concepts or prototypes to potential users
- No expensive market survey necessary

Hybrid Kansei Engineering Systems can be very complex. Usually a number of other functions are implemented. It is e.g. possible to integrate a form and colour recognition system in order to analyse the design traits from rough sketches and free drawings.

2.3.4 Kansei Engineering Type IV-Kansei Engineering Modelling

Kansei Engineering Type IV implements more than just Expert Systems for Kansei Engineering. The implementation of a mathematical model is an example. Sanyo successfully applied such a mathematical model to a colour copy system to reproduce a more desirable Japanese skin tone. The first step to implement the “human sensory perception oriented image processing” (Fukushima et al. 1995) was to understand what colours Japanese feel or sense to be desirable. Therefore, 50 persons were asked to evaluate 24 human faces of slightly different skin tones (done with 3 different colour factors) on a five-point Semantic Differential scale, just as with the procedures of the previous types. The rankings were analysed with the Quantification Theory Type I. The resultant score values were used to define fuzzy sets that express the degree of desirability of the skin tones.

The developed Kansei Fuzzy logic system in the colour printer system can now first analyse the human’s face colour in the three colour factors and process this data by a RGB system and finally print a more desirable face (Nagamachi 1996). Nagamachi

developed a Word Diagnosis System, WIDAS with the help of the Quantification Theory Type I. Utilising Fuzzy Measure and Fuzzy Integrate the system allows the user to assess the human feelings (Kansei) of a word or even of a series of words. The system is used to diagnose the feeling about a brand name (Nagamachi 1996).

2.3.5 Kansei Engineering Type V-Virtual Kansei Engineering

Insufficient understanding of the functionality of more complex products like flats or kitchens when using Kansei Engineering Type II, can lead to erratic results, since only several design elements are gained as an output of KES. Virtual Kansei Engineering is an extended type of the KES-technique. In addition to KES this one uses virtual reality (VR), a powerful technology to place the user in a virtual 3D environment, which can be directly manipulated. The VR Kansei Engineering is a combination of a Kansei Engineering computer system and a virtual reality system to help the user's selection of a product with virtual space experience (Nagamachi et al. 1996).

A joint project of Matsushita works and Hiroshima University applied VR Kansei Engineering technology to kitchen design. The procedure to create such a system is the same as within previous types: adjectives are collected, reduced in number, and evaluated subjectively. With the help of Quantification Theory Type I, the correlation between consumer feelings and design characteristics of the kitchen can be identified. This system was connected to VR, and allows the customer after inputting personal information, to walk through the virtual space, to attempt object operations and if necessary to change detail design elements. The favoured version can directly be transferred to production

2.3.6 Kansei Engineering Type VI-Collaborative Kansei Engineering Designing

Collaborative Kansei Engineering Designing or Internet Kansei Designing System (IKDS) is an Internet supported Kansei Engineering System. Making the KES publicly assessable by using some kind of Group Ware Systems i.e. Internet offers the opportunity to bring the viewpoints of customers and designers together. Doing this, the early development phases can be shortened and simplified. Though it is still in the development phase, IKDS is expected to offer many benefits, e.g. co-operative work of the participants, efficiency of product development speed, effective consumer-producer dialogue or participation of many persons, providing a diversity of ideas (Nishino et al. 1999).

A proposal of how IKDS could appear is shown in Figure 18

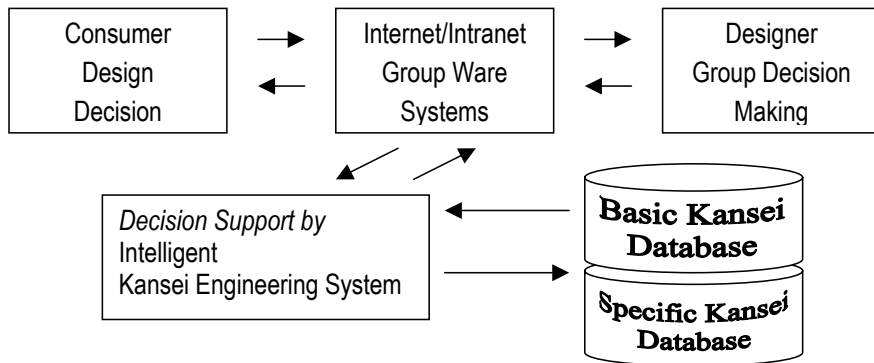


Figure 18: Internet Kansei Designing System (adapted from Nishino et al., (1999)).

One application is the construction of a “roundness” database as a basic design database for IKDS. This system provides on the one hand the customer with the opportunity of input Kansei words into an interface and gain a form-ratio according to the input. On the other hand the designer can draw his or her own square in a drawing box and receive Kansei consultations as an output. This allows the designer to design products suited to the Kansei of the consumer while the consumer can participate in designing their own product, thus get the product designed to their own feelings and taste (Ichitsubo et al. 1998a).

2.4 Applications in Kansei Engineering

Kansei Engineering has a wide area of applications. Several mainly Japanese companies in different business areas used Kansei Engineering for improving their products. The range of industrial business areas stretches from automobile industry via packaging design to cloth and furniture manufacturers, even Kansei Engineering applications in houses and flat conception bolster the record of Kansei Engineering in industry. Most of the scientifically documented Kansei Engineering studies are published in Japanese, but around 30 publications are available in English.

2.4.1 Automotive industry

In the automotive industry, companies like Mazda, Ford, Nissan and Honda have co-operated in projects. Jindo and Hirasago conducted a project on the front-end design of vehicles (Jindo and Hirasago 1997b). Matsubara examined the car exterior (Matsubara et al. 1999) and conducted a comparison between European and Japanese Kansei regarding car exterior design (Matsubara et al. 1998b) in co-operation with the University of Nottingham. The automobile interior was evaluated in a study of Ishihara (Ishihara et al. 2001), who examined, the emotional impact of different instrument panels of passenger cars on the user. Also, Jindo and Hirasago examined in co-operation with Nissan speedometer design and the meter cluster layout on the dashboard of passenger cars (Jindo and Hirasago 1997a).

2.4.2 Electronic devices

One of the great success stories within Kansei Engineering's history is Sharp's video camera with an adjustable external LCD display (Nagamachi 1997c). But also colour copiers were the object of Kansei Engineering examinations (Fukushima et al. 1995). An associated topic is digital image processing where (Takahata 1997) conducted several studies on.

2.4.3 Home equipment

In the home-equipment sector, several studies were carried out in order to build up a KES for kitchen design (Imamura et al. 1997) and (Matsubara and Nagamachi 1996). On a more detailed level, dish washers were examined (Ishihara et al. 1998b). Skogman (2002) made comparisons of different types and brands of vacuum cleaners at Electrolux in Sweden. But also furniture like office chairs underwent a Kansei evaluation (Jindo et al. 1995). Bathroom layout with special regard to comfort and space was examined in a study by Nishikawa et al. (1998). Finally, whole house and flat layouts were examined in co-operation with ECR Consultant (Nagamachi et al. 1998) and (Nagamachi and Nishino 1999). In Sweden, a comparative study on different presentation techniques for flats was carried out in co-operation between Linköping University and Skanska AB (Bergqvist and Domeij 2001).

2.4.4 Architecture

In architecture some more Kansei Engineering applications are documented. A series of different studies deals with bridges and the surrounding landscape. Ichitsubo et al. (1998b) worked out the emotional impact of different bridge shapes and in another study he examines the interrelation between a bridge and the surrounding landscape (Ichitsubo et al. 2001). In another stage the impact of different landscapes per se is examined (Matsubara and Nagamachi 1997) and (Matsubara et al. 1998a).

2.4.5 Everyday things

Everyday things like packaging design are often evaluated. Ishihara made examinations of the exterior design of coffee cans (Ishihara et al. 1997b), beer cans (Ishihara et al. 1998a) as well as of milk cartons (Ishihara et al. 1996). It was intended to express the taste of the contents by colour setting, the shape of the logo and illustration on the outside. Nagamachi conducted a survey on body cosmetics, especially hair treatment (Ishihara et al. 2000).

Since the human body differs in many respects an adaptation to size of wear such as spectacles (Fujie et al. 1997) is necessary. Nagamachi examined skirt design (Nagamachi 2001). In another study the design of shoes was evaluated (Ishihara et al. 1997a). Wacoal, a women's underwear manufacturer conducted a study on attractive form of womens' breast (Maekawa 1997) and developed a new brassiere from this (Nagamachi 1997c).

2.4.6 Work Equipment

However, not only consumer products can undergo a Kansei Engineering treatment. There are some cases reported where industrial products are examined regarding their Kansei. Arnold and Burkhard conducted two studies about welding helmets in comparison to competing products using Kansei Engineering (Arnold 2002), (Burkhardt 2002). Lowlifter truck platforms are the topic of another report made at Linköping University. An approach to driver feeling utilizing Kansei Engineering is made in L. Elsmarks thesis (Elsmark 2000). In a co-operation between BT, Scania and Saab automobile, the Kansei of pushbuttons differing in pushing force and stroke was determined (Rydman and Sandin 2000) and (Axelsson et al. 2001).

2.4.7 Basic research

Kansei Engineering was also used for basic research, such as a cross cultural study of preferences for colors and forms (Ohmi and Lee 1997) and the impact of colour on different human beings (Kitajima and Kim 1997). Moreover a roundness database was established indicating which type of roundings evoke certain Kansei (Ichitsubo et al. 1998a). In the same way a database for form and size ratios of e.g. refrigerators was made (Komatsu et al. 1998).

2.5 Other Methods for capturing the Kansei

To grasp Kansei several optional techniques are available; e.g. Quality function deployment (QFD), Conjoint Analysis, Semantic Environment Description (SMB), Kansei Engineering (KE) etc. In the following the most important methods are presented in brief.

2.5.1 Semantic description of environments

Semantic description of environments (Swedish: semantisk miljöbeskrivning, SMB) is mainly a tool for examining how a single person or a group of persons experience a certain (architectural) environment. This can be both interiors like flats or offices or exteriors like a housing area or a landscape. By presenting images, models or films of the chosen environment, to volunteer participants, the emotional impression of the different environments can be measured using SMB. The results can be used as planning support for new architectural objects (Küller 1975). The SMB method was developed by Rikard Küller at Lund University in Sweden in the early 70's.

Like Kansei Engineering SMB is based on Osgood, Suci and Tannenbaum's theories about the Semantic differentials (see Section 3.1). Since SMB is specially adapted to architectural environment Küller used two more sources dealing with the interdisciplinary area between architecture and psychology (Honikman 1970) and (Cass and R.G. 1973).

In order to get representative words describing architecture more than 1000 words were collected from the National Swedish Dictionary. These words were evaluated on semantic scales and treated with factor analysis. In a first step the number of words was reduced to approximately 200 based on the results from the factor analysis data. New studies were conducted and 36 words were considered as sufficient to describe architectural environment after new factor analyses were deployed.

Küller used two different experimental designs. In the first case he let a group of participants rate different environments on 78 different scales. For every environment

the mean value was calculated and this data underwent correlation calculations and a factor analysis. The determined factors and dimensions reflect the variation between the environments presented. In the second experimental design only one environment was presented to different groups and rated on the same scales. The result from this part presented the variation within the group. Since at least some of the factors were alike, Küller assumed that the factors were valid.

Concluding the results eight factors could be identified

These factors are:

- Pleasantness
- Complexity
- Unity
- Enclosedness
- Powerfulness
- Social status
- Affection
- Originality

(The names of the factors are translated from Swedish, see Küller (1991))

A list of all the word belonging to the factors is given in Appendix A

The first dimension “Pleasantness” corresponds to the “Evaluation” dimension in Osgood’s Semantic Space (see Section 3.1.2) whereas the “Activity” dimension in the Semantic Space is almost identical with the “Complexity” expression in SMB. The “Potency” factor is the same as “Powerfulness” in Küller’s model (Küller 1975).

Based on these facts the SMB technique allows the ranking of every new environment on preprinted forms to make quick and easy evaluations. Figure 19 portrays what a SMB result can look like.

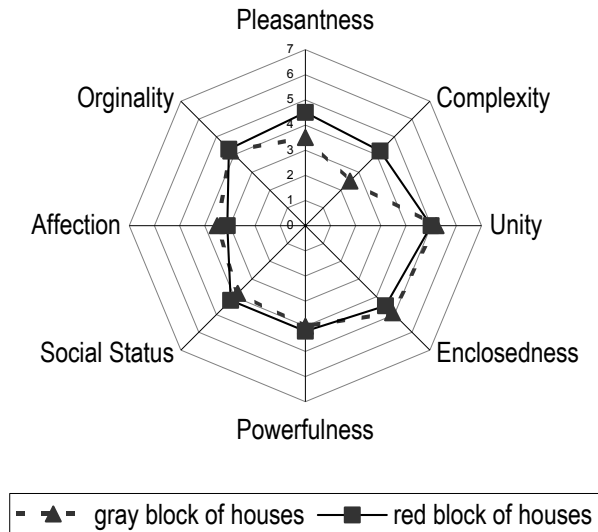


Figure 19: SMB Comparison between a gray and red block of houses (Küller 1975), (Küller 1991).

2.5.1.1 Kansei Engineering and SMB

Kansei Engineering and SMB share the same basis. Choosing and evaluating words in Kansei Engineering can be carried out in the same way as in SMB. However, in contrast to SMB, Kansei Engineering is able to link single properties of the evaluated products (in SMB environments) to certain word or factors (Ishihara 2001). This makes Kansei in some manner more powerful than SMB.

2.5.2 Quality Function Deployment (QFD)

QFD is a method for structured product planning and development that enables a development team to specify the customer’s wants and needs, and then to evaluate each proposed product or service capability systematically in terms of its impact on meeting those needs (Cohen 1995). The history of QFD began in 1950, when Deming traveled to Japan to introduce his work about statistical quality control (SQC). His ideas were taken up by the men who would later become the fathers of QFD: Dr. Ishikawa, Dr. Minzuno and Dr. Nishibori.

According to Akao (1990) two main aspects led to the development of QFD:

- How could the *quality of design* be determined?
- How could the quality in production be assured?

The first documented application of QFD was conducted at the Kobe shipyard in Japan (Akao 1990). Already in this project the correlation matrix, nowadays known as the House of Quality was introduced. A well known QFD application is the Toyota Rust Study from 1975 in which Toyota practically eliminated warranty cost due to corrosion problems with their cars (Sullivan 1986).

Nowadays QFD is a well established product development method in many countries (see Cohen (1995) and Gustafsson (1998)). However, since the cultures are different the mode of usage of QFD varies. According to Mizuno and Akao (1994) QFD generally fulfills two main tasks:

- Quality Deployment
Focus on the product, deployment of customer wants and requirements and other areas that are important for the product, i.e. technology, costs, reliability etc.
- Quality Function Deployment in the narrow sense
Focus on the process, deployment of activities in functional organizations that creates quality in the product.

In contrast to the way QFD is used in Japanese companies, Western companies utilize QFD more as a decision support during the product development process than as a quality assurance tool (Gustafsson 1998). The most famous part of QFD is the above named House of Quality (see Figure 20). It consists of a relationship matrix in the middle and displays the customer's wants along the left and the development's technical response on the top. A group of experienced product designers link the customer's needs to the technical parameters.

Moreover there are several other sections for market research and strategic planning. The "roof" is in fact a half square matrix connecting the different technical solutions to each other. Beyond the matrix the results are presented, giving different information:

- Computed ranking order of the technical responses
- Comparative information on the competitor's technical performance
- Technical performance targets.

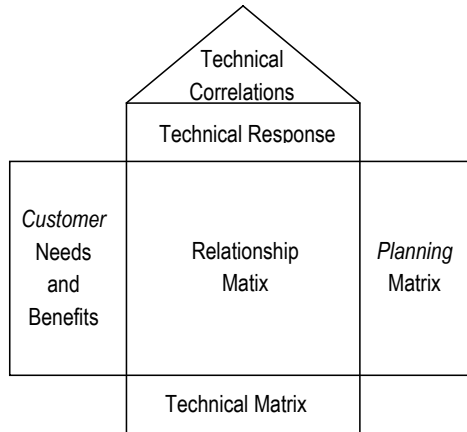


Figure 20: The House of Quality adapted from (Cohen 1995).

In Western countries the QFD model most used is the four phase model of Hausser and Claussing (1988) (see Figure 21 below). The House of Quality (I) is run first, translating customer demands into engineering characteristics and ranks them after their importance. This data is the starting point for the second phase where the critical parts of a new product are identified and ranked according to their importance. In the following step the key processes in the production are reviewed (III) and improved if necessary. Phase four focuses on the role of the production personnel and the impact on product quality.

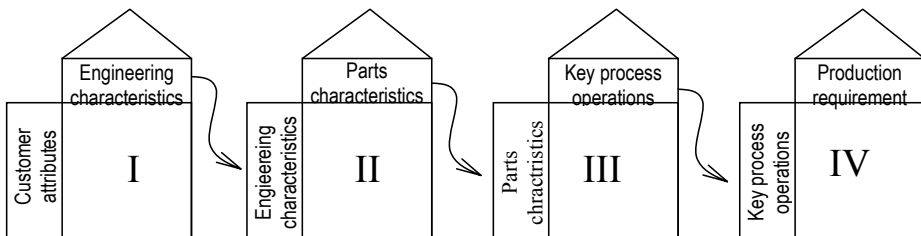


Figure 21: The most wide spread QFD model in the Western- The four phases. (adapted from Hausser and Claussing 1988).

2.5.2.1 Capturing the User’s Kansei using QFD

Information on the customers voice can be collected through interviews, observations, customer’s complaints or internal error statistics (Gustafsson 1998). This data is

usually treated with Voice of Customer Tables (VOCT) in order to extract the customer needs, which are fed into the House of Quality. Customers answer questions on products or interact with a certain artefact based on their earlier experiences. These experiences are probably a result of perceptual input in combination with the human cognition. Nagamachi calls this the Kansei (Nagamachi 2001). So it can be said that the Kansei is implicitly contained in the customers column. However. Since QFD focuses on technical solutions, the Kansei is difficult to extract from the gathered data.

2.5.3 Conjoint Analysis

Conjoint analysis is a method for weighting different product concepts against each other in order to identify which product attributes are preferred by a certain customer group and the price they are willing to pay for it. A major assumption in conjoint analysis is that opinions on products can be broken down into separate attributes (product characteristics) (Green and Srinivasan 1978). This means that the combination of the different attributes like price, colour, mileage, fuel, brand etc. has a joint influence on the consumer decision whether to purchase the product or not (Gustafsson 1996). This means that a consumer would spend more money on a Mercedes than on a Fiat with the same specifications if the brand is seen as a product attribute. Conjoint analysis is based on the human ability to rank concepts with different content in order to make a clear decision on how desirable the concept is.

In 1964 the basic ideas of conjoint analysis were published for the first time by Luce and Tukey (1964). They called their method “Simultaneous Conjoint Measurement” and introduced it as a new mathematical psychological measurement. Later on in the early 70’s the ideas were picked up by the marketing sector and Conjoint Analysis became a tool for market analysis (see Green and Rao (1971) and Johnson (1974)).

According to (Gustafsson 1996) there are three different approaches for conducting a conjoint analysis study: paired comparisons, trade-off and full profile approach.

In the *paired comparisons* approach the participants are asked to compare two simultaneously presented products and indicate which one is the better. Paired comparisons are suitable for complex products when it is hard or time consuming to rate each product separately (Gustafsson 1996).

Choosing the *trade-off* strategy means that the participants are asked to rank their preference for two product attributes at a time, holding all other attributes constant. e.g. a floor –lamp with a 25W bulb or a hanging-lamp with 150W bulb. This is probably unrealistic, but easy to conduct and evaluate.

The third and most frequently used procedure is the *full-profile* approach. In this case the participants rate complete product concepts on 10 step scales from “Would never consider buying this concept” to “Would definitively consider buying this concept”. An example of such a concept is displayed in Figure 22.

Compact Disk
Singer: Shakira
Type: Single
Songs: 2
Cover: Carton
Price: Kr 29

Would never consider buying this concept Would definitively consider buying this concept

1 2 3 4 5 6 7 8 9 10

Figure 22: An example of a full profile experiment.

The concepts mentioned are chosen in a statistically orthogonal way, this means that the impact of every product attribute on the score can be measured independently. The product attributes are not correlated with each other. The surveys are usually planned as fractional factor designs since a full-factor design either increases the evaluation time leading to fatigue in the participants or reduces the number of levels or product attributes to be evaluated. The collected data is treated using multivariate tools like multiple regression with dummy coding (see Section 3.2.1) and the results reveal how the respondents react to a change in a particular attribute.

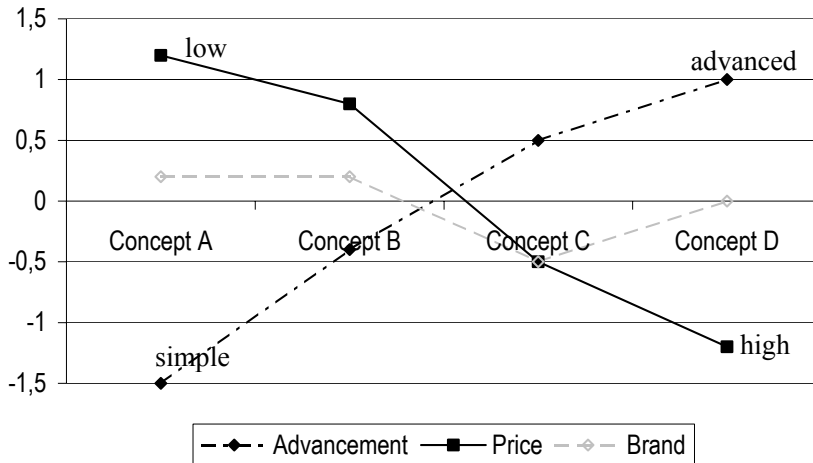


Figure 23 Sample output from a conjoint analysis study (modified from Gustafsson (1996).

Figure 23 shows a typical output from a conjoint analysis study made for new fax machines. The diagram shows four different models (Concept A-D) on the x-axis and the y-axis indicates the relative weight of the chosen attributes (Advancement, Price and Brand). It can be concluded from the diagram above that the customers want to have the most advanced machine to the lowest price. The brand seems to be less important. Focusing on the slope of the curve reveals how sensitive the respondents are regarding a certain attribute. Apparently they are much more sensitive for price changes than for changes of the brand.

2.5.3.1 Capturing the Kansei using Conjoint Analysis

According to Nagamachi, Kansei Engineering is a “consumer orientated ergonomic technique of product development ” (Nagamachi 1997a). He states that, “even though manufacturers provide hundreds (of different concepts) ... customers want only products which fit their needs and feeling” (Nagamachi 1997a). In conjoint analysis the different product alternatives are presented and the customer decides whether the product satisfies her/his needs or not. It can be said that the Kansei is measured by conjoint analysis, but never explicitly expressed. Instead it is directly translated into product design. It is difficult to see how a certain product property affects the score for a certain Kansei word. This means therefore that only existing products or concepts can be evaluated.

Tools and Techniques

Kansei Engineering is built on existing theories and methods. The new aspect with Kansei Engineering is the composition and usage of tools from different areas within engineering, psychology and mathematics. This chapter provides the reader some of the most important tools and techniques.

3.1 Semantic differentials

3.1.1 History and Short Review on Semantic Differentials

In the first half of the 20th century several researchers aimed to analyse the connection between words as such and their meaning and underlying ideas, which in this context can be called Kansei. It became apparent that such studies needed powerful instruments for quantification and measurement. Several researchers conducted studies on this problem and proposed different models. Thorndike and Lorge (1944), Cason and Cason (1925) and Zipf (1949) (Zipf's law) made *similar frequency-of-usage* counts in order to detect laws and relations to its meaning. The underlying theory is that associations on the semantic level appear to be organised in such a way that “few words and expressions have a higher probability of occurrence whereas many have low probabilities of occurrence” (Osgood 1952). Inspired by the different political ideologies, which became evident in World War II and the following Cold War Osgood developed a method to measure the emotional content of a word more objectively. He called this method “semantic differential technique”, which more than 30 years later became one of the foundations of modern Kansei Engineering.

His assumption was to divide any expression into two parts:

- The object, “which is a pattern of stimulation which evokes reactions on the part of an organism”, and
- The sign, “which is any pattern of stimulation which is not the object but yet evokes reactions relevant to “object”-conditions under which this holds lying the problem for theory”

(Osgood 1952)

For example, the spoken word “hammer” is not the same stimulus as the object hammer. The former is a pattern of sound waves and the latter a combination of visual, olfactorical and tactual sensations. The word hammer elicits a type of behaviour, which is in some manner relevant to the object hammer. This means that the spoken or read word “hammer” is the sign for the object “hammer”. Osgood’s approach is expressed in simplest terms by the question: **Under what conditions does something which is not an object become a sign of that object?**”(Osgood 1952)

3.1.2 The Method

To answer the question above, Osgood and his colleagues (Stagner and Osgood 1946) conducted surveys by means of questionnaires. His subjects were supposed to rate signs (words) of objects like Pacifist, Russian, Germans, Dictator or Neutrality (remember that the experiments were conducted during World War II) on bipolar scales. These scales were defined with a number of contrasting adjectives at each end on which the participants checked that position which best represented the direction and intensity according their point of view. An example of the 7-point rating scale type used is shown in Figure 24.

PACIFIST: Kind _____ : : : : : : _____ Cruel

Figure 24: Example of a 7-point rating scale, originally used by Stagner and Osgood (1946).

The data collected can be stacked in a three dimensional raw store data matrix, as it can be seen in Figure 25.

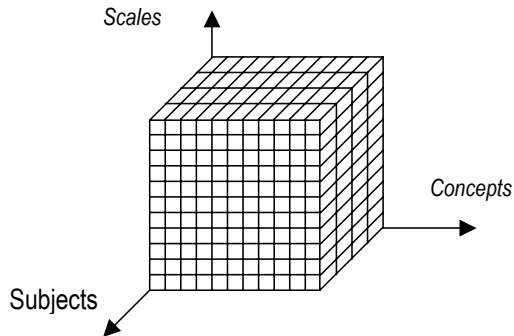


Figure 25:Raw store data matrix, obtained when a group of subjects (x-axle) judges a sample of concepts (y-axle) against a set of semantic scales (z-axle). Each cell contains a number from 1 to 7, representing the judgement of a particular concept on a particular scale by a single subject. (adapted from Osgood and Suci (1969)).

In a following step the 3 dimensional matrix from Figure 25 is converted to a matrix of inter-correlations by summing together both subjects and concepts. This allows an easy comparison of every scale with every other scale to which the total data contribute and also avoid spuriously low variability of judgements on single concepts. In addition a factor analysis can easily be run with the data conditioned in that way .

Together with the interrelation matrix, the factor analyses answer questions of how the different word pairs are related to each other, in which way they affect the understanding of a meaning of a certain word, and how to facilitate upcoming experiments. Furthermore, comparing the rotated matrix of the factor analysis from many different experiments led to the discovery of the existence of a common pattern (Carroll 1959). It could clearly be seen that all examined word pairs span a three dimensional orthogonal vector space as presented in Figure 26. Osgood called this space the semantic space.

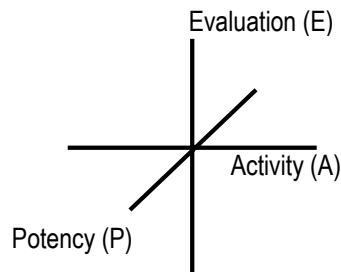


Figure 26 *The Semantic Space.*

Considering the word pairs in the individual factors it was possible to identify a pattern and name these factors.

- Evaluation (E) usually contains word-pairs like: good-bad, timely-untimely, kind-cruel, beautiful-ugly, successful-unsuccessful, important-unimportant, true-false, wise-foolish, etc. All these word-pairs have in common a possibility to evolve into a better or worse stage.
- Potency (P) usually contains word-pairs like: large-small, hard-soft, masculine-feminine, strong-weak, etc. These pairs characterise a potential, a capacity for change.
- Activity (A) is characterised by word pairs like: active-passive, fast-slow, hot-cold, sharp-dull, angular-rounded, etc. This factor indicates the grade and speed of change.

Applying these factors into the semantic space, as is seen in Figure 26 these factor-names become the names of the axis. Now it is possible to project every concept in the semantic space and give it an individual position. E.g. a dictator would score high on the potency axis (hard, strong, etc.), low on the evaluation axis (bad, cruel, ugly, etc.) and receives low positive values on the activity axis (active, fast...)

3.2 Statistical methods and tools used in Kansei Engineering




3.2.1 Quantification Theory Type 1 (QT1)

The quantification of the relationship between Kansei words and design elements can be performed using Hayashi's Quantification Theory Type I. It is a variant of the linear multiple regression analysis, which allows inclusion of independent variables that are categorical and qualitative in nature, such as design elements within Kansei Engineering (Komazawa and Hayashi 1976).

This is possible through dummy variables. Dummy (or indicator) variables are usual in order to reflect qualitative variables. They are a particular class of discrete independent variables, which are limited to two possible realizations, taking the value one whenever it occurs and zero otherwise (Lea 2001).

Introducing dummy variables in Kansei Engineering requires special attention, since design elements are classified into two levels: each element (e.g. the colour of a beer can) corresponds to an item and each variation of an item (e.g. blue, silver, black) corresponds to a category. Table 2, partly taken from a study of Nagamachi (2001), helps to understand this context.

Table 2: Table for beer cans -Dummy coded (Ishihara 2001).

	Item	1			2			3			...	R	Evaluation value
		Can Colour			Can Illustration			Label Shape					
	Category	1	2	3	1	2	3	1	2	3	...	C _j	
	Sample	Blue	Silve	Black	Anim	Symb	Other	Oval	Other	None			
	1	1	0	0	0	1	0	0	0	1			3,2
	2	0	1	0	1	0	0	1	0	0			4,1
	3	0	0	1	0	0	1	1	1	0	0		2,6
⋮													
n													

To include the classified design elements in the regression analysis, dummy variables are introduced as in the following:

$$\delta_{i(jk)} = \begin{cases} 1: & \text{when sample } i \text{ corresponds to item } j \text{ in category } k \\ 0: & \text{otherwise} \end{cases}$$

$$i = 1, \dots, n \quad (n = \text{number of samples})$$

$$j = 1, \dots, R \quad (R = \text{number of items})$$

$$k = 1, \dots, C_j \quad (C_j = \text{number of category for item } j)$$

Consequently, for the item “can colour” in Table 2 the coding would equal:

SAMPLE 1: “100”; **SAMPLE 2: “010”;** **SAMPLE 3: “001”**

This coding was only done for ease of demonstration. Considering the item colour, a third category for cans being black would be redundant, since every can which is neither blue, nor silver has to be black (at least in the above table). Consequently, the correct coding for item colour is “10” for the first sample (William, 2001).

This means if a category variable has k categories, $k-1$ dummy variables are needed to represent that variable. Otherwise a situation of perfect multi-collinearity would be created, as the dummy variables would be linear combinations of each other. The k^{th} category is treated as the base level or reference category.

This reference category should be clearly defined and contain a sufficient number of cases to allow a reasonably precise estimation of its mean. With dummy variables, coefficients are not interpreted in isolation, but in connection to the reference category (SPSS Inc, 2000).

Taking these points into account, the resulting linear regression model for the category variable is:

$$Y_i = \sum_{j=1}^R \sum_{k=1}^{C_j} b_{jk} \delta_{i(jk)} .$$

Y_i is the observed value of the dependent variable. It stands for the semantic differential evaluation value on a Kansei word, which was explained above. The column on the right in Table 2, named “Evaluation value”, indicates the scores of the Kansei word “bitter”, taken from a hypothetical semantic differential analysis.

b_{jk} is called the coefficient of the dummy variable δ , indicating the relation of the dummy variable (design element) and the rated Kansei word Y_i , when all other variables are held constant.

As within all other linear multiple regression models, now, the task is to find a value for b_{jk} such that the difference between actual observation Y_i and prediction Y^* is at a minimum. Or, to express it in the terms of Kansei Engineering, to accurately predict the influence of the items as well as of the categories on the customer feelings, expressed in Kansei words. This is achieved with the help of the least square method, which minimizes the squared prediction error ε (compare Ishihara (2001)). Therefore, the following equations have to be solved:

$$\text{Equation 1: } L = \sum_{i=1}^n \varepsilon_i^2 = \sum_{i=1}^n (Y_i^* - Y_i)^2 = \sum_{i=1}^n \left(\sum_{j=1}^R \sum_{k=1}^{C_j} b_{jk} \delta_{i(jk)} - \sum_{j=1}^R \sum_{k=1}^{C_j} b_{jk} \delta_{i(jk)} \right)^2 \rightarrow \min$$

and consequently $\frac{\partial L}{\partial b_{jk}} = 0$.

This partial differentiation has to be solved for each b_{jk} and for each Kansei word separately. These calculations are performed with the help of standard computer software, hence the details of computing will not be given here. For further details see Matsubara et al. (1999).

A sample of what is received as an output can be seen in Table 3:

Table 3: Hypothetical Output of a Conducted Quantification Theory Type I.

Item	Category	PCC	not bitter ←————→ bitter	
			-2 -1	1 2
Can Colour	1. Blue	0.302		1.1
	2. Silver		-1.4	
	3. Black			1.9

It is, on the one hand, the partial correlation coefficient (PCC) that indicates how much an item, for example the item colour, affects y , the Kansei word. In his beer can study (Ishihara 2001) detected that the item colour has the largest PCC. This means that, in this context, the colour has the strongest relation to the Kansei word “bitter”. On the other hand, the category score corresponds to the coefficient of each category. This figure describes the influence of the categories within the item. A result might be that category black has the largest positive value, indicating a positive relation to the Kansei word “bitter” (Ishihara 2001).

The third output of importance is the multiple correlation coefficient (MCC). It measures the overall accuracy of the equation. It can take values between zero and one. At zero there is no correspondence at all between the predicted and actual variable while at unity the coefficient indicates a perfect correspondence. MCC is written as R^2 and calculated by dividing the explained variation with the total variation. For applications in this context a R^2 value lower than 0.5 was considered as not reliable (Lea 2001).

3.2.2 Non-linear models

The previously introduced mathematical models deliver a linear prediction model for the connection between the user's Kansei and the product properties. Consequently a linear correlation is presumed. However, these methods work well in many cases, but often human senses do not work linear, which can disturb the result. Figure 27 displays the sensitivity of the human skin over the actual temperature exemplarily.

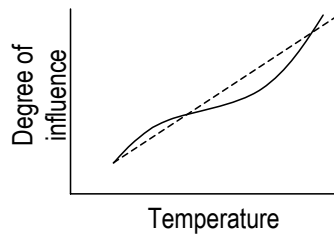


Figure 27: Example of non-linearity of human sensation (full line actual human sensation, dashed line regression line) adapted from (Shimizu and Jindo, 1995).

The dashed line shows a linear regression line deflecting in many points significantly from the actual human sensation. Using e.g. QT 1 based on multiple linear regression analysis leads in this case with strongly varying human sensation to wrong results. It is, therefore, desirable to provide a procedure adapting better to these curves. Currently a number of different tools are developed adapting bended curves in a better way:

- Neural Networks (Ishihara et al. 1996)
- Fuzzy Logics (Shimizu and Jindo 1995)
- Genetic Algorithm (Nishino et al. 1999)
- Rough set analysis (Nishino et al. 2001)

Purpose of this thesis

Omnia mariari etiam tritissima

*(Varthän man än vänder blicken finns det något värd
en avhandling)*

Carl Linné

Based on the definition of the research area in Section 1.7 the purpose of this thesis is defined in this chapter. The knowledge from the previous chapters contributes to a deeper and more fundamental understanding of the research conducted in this thesis..

Industry is presently looking for reliable tools in order to meet increasing customer demands on products and to integrate them into the product and product development processes. A number of tools like QFD, Conjoint Analysis or SEM (see Section 2.5), mainly in the area of Quality Technology can be used, but none of those techniques is especially designed for this purpose. In Japan this problem was observed earlier which resulted in the invention of Kansei Engineering. Kansei Engineering is based upon methods and techniques in other sectors like mathematics, statistics, psychology, marketing and engineering, and combines them in order to achieve a measurability of emotions and feelings. At present Kansei Engineering is spread all over Japan, but in Europe experience with this method is rare. Connections to other methods or disciplines are not documented in the literature available in English. In fact the literature in English deals mainly with experiment design. Publications with an educational background are even fewer.

<p>The aim of this research is to understand and apply a methodology, measuring and translating the Kansei that customers have about a certain product and explore ways of integrating the method into industrial product development processes.</p>
--

This overall aim was divided into three more specific aims:

- To propose an adapted and facilitated version of Kansei Engineering technique for industrial applications.
- To set Kansei Engineering in relation to Total Quality Management (TQM) in product development by identifying interfaces in today's product development procedures.
- Proposing a conceptual framework around Kansei Engineering, contributing to an improved understanding of Kansei Engineering's working principle.

Methodological Procedure

"This all look like "Whats".

It's the "Hows" that I have trouble with."

Winnie the Pooh: (Allen, 1995)

After introducing the research problem and exhibiting Solution methods, this chapter portrays the author's procedure in order to answer the questions asked in the previous chapter. Moreover, the methods used by the author are described.

5.1 An overview

Using Kansei Engineering in an academic context is documented in many Japanese publications. In order to use it for industrial applications the methods had to be abbreviated and adapted. The first steps were to understand the ideas and the basics of Kansei Engineering properly. Based on this knowledge, several small case studies could be evaluated including a few Kansei Words on a limited number of product properties. The author chose watches and soaps for this part. Kansei Engineering recommends a number of different evaluation tools which could be tested in this context.

A number of small projects were carried out by students in co-operation with industrial companies. Together with BT, Saab and Scania the manipulation feeling with switch keys and swing buttons was evaluated (Rydman and Sandin 2000). In addition a number of master theses were supervised by the author. Kansei Engineering studies using different types of evaluation equipment and products were carried out mainly in close cooperation with industry. Some examples are welding helmets of Hörnell (Burkhardt 2002) and (Arnold 2002) and Vacuum cleaners at the Electrolux-group (Skogman 2002).

In parallel and continuously inspired and supported by the findings and procedures used in the latter named studies the author conducted an examination on BT fork-lifter trucks in order to find out how the products are perceived by the actual users in different European countries. At the same time Kansei Engineering could be developed in a way that meets the company's demands and could be carried out in a reasonable time.

The next step was to find support for the gathered result in the company's organisational structure and its development process. In Japanese companies, Kansei Engineering is often run separately from other development procedures and is able to deliver the result independently from the actual company philosophy. However, the author chose to introduce Kansei Engineering as an integrated part in product development. Hence, the approach here was to inspect the different methods used in product development processes and find entry points for Kansei Engineering data. This task was accomplished by an in depth scrutiny of common product development processes and related methods for gathering customer information. Once again BT offered the opportunity to conduct studies and the author joined the pre-planning phase of a new forklift-truck model in order to provide and condition the data gathered from the previous study to the on-going project.

As mentioned above, only a few publications, dealing with Kansei Engineering in an educational context are available in English. Hence, it is difficult to understand the features that all the types of Kansei Engineering have in common. Consequently, the author began to sketch a flowchart for Kansei Engineering Type II, which later developed into the generalized proposed conceptual framework presented in Paper IV.

5.2 The authors contribution

Research on Kansei Engineering at Linköpings University was initialised by Professor Eklund in 1999. The author approached this group in August 2000. At present the group consist of around 5 members from different disciplines, like quality, design, psychology, statistical mathematics and mechanical engineering. Cooperation in many aspects is necessary when working with such a complex and interdisciplinary topic as Kansei Engineering. Table 4 gives an impression about the author's role within the group and his contribution to the work in this thesis.

Table 4: Overview of the author's contribution and work within the Kansei Engineering group at Linköping University.

Stage	Understanding Kansei	Making KE work	KE in full-scale	Integrating KE into Product development	Proposing a conceptual framework
Description	Learning about Kansei Engineering, conducting small case studies	Adapting Kansei Engineering to different industrial products and development strategies.	Applying the experience from the previous work to a development project at BT	<i>Integrating Kansei Engineering into BT's product development process</i>	Grouping and structuring of Kansei Engineering Types.
Case study	Soaps: (Axelsson and Schütte) Watches: (Schütte)	Vacuum cleaners, welding helmets, flats, keys,	Study on brand-image of forklift trucks in different European Countries		
Report, Publication, Thesis	Schütte (2000)	Master thesis: Arnold, K. (2001) Bergquist and Domeij (2001) Burkhardt, D (2001) Skogman (2001)	Conference proceedings: Schütte and Eklund (2001) (Paper I) Paper: Schütte and Eklund (2002) (Paper II) Paper: Axelsson, Eklund and Nagamachi (2001)	Conference proceedings: Kammerlind and Schütte (2001) (Paper III)	Paper: Schütte and Eklund (2002) (Paper IV)
Contribution of the author	Discussion and conducting of case studies	Supervising function together with Eklund and Axelsson	Planning, conducting, analysing and writing	Theoretical part in cooperation with Kammerlind; Practical part complete	Planning, analysing, writing

5.3 Methods used

Kansei Engineering is in this thesis considered to be a methodology linking together a number of methods from different areas. In some cases these methods can be replaced or adapted to the particular purpose. In the following a number of proven methods are presented used for the Kansei Engineering studies in this thesis.

5.3.1 Choice of participant groups

In English literature on Kansei Engineering only a little can be found about how the participants for a Kansei Engineering study are chosen, selected and composed into groups. However, it is very important insure that the interviewed subjects, are representative of a certain customer group with a similar behaviour.

This requires a good knowledge about market segmentation (see Section 1.5.2) and different customer groups. Based on this, the market niche can be identified, before Kansei Engineering can be carried out.

Usually a company has this data and conducts regular market research. The techniques used for this are multi-faceted and not an integral part of Kansei. Nevertheless these examinations important are an input for Kansei Engineering, since a Kansei Engineering study relies on the homogeneity of the subjects examined.

As shown in Section 2.3.2 one task in Kansei Engineering is to collect Kansei words describing the product in a semantic way. In contrast to the Japanese procedure not all the words could be used, since the number of collected words was so big that it is not simply possible to evaluate all the products according to the ranking scales. As a result the number was reduced using a factor analysis on the data from a small pilot study.

According to (Küller 1975) a number of 14-20 participants is sufficient to conduct a factor analysis in a SMB study. As Kansei Engineering and SMB are very similar up to this stage it can be assumed that his statement is also valid for the first steps of Kansei Engineering (reduction of the number of collected Kansei words). In reality, the participants in the study about BT reach trucks in Paper I and Paper II, were parts of the staff at the manufacturer. They had considerable knowledge about the different models and long-term experience with warehouse trucks. The group consisted of 13 persons in total, seven of whom were designers from different departments, two represented the marketing department and one was a manager.

For an actual Kansei Engineering study the subjects must be chosen at random from the target group as described above (Peters and Austin 1994) In these concrete cases the market niche was chosen as Reach trucks in the range between 1400kg and 2500kg. The participants chosen were the users of these truck models manufactured between 1999 and 2002. Moreover, the people selected had experience with at least 2 different truck models with and different usages. On a higher level the participants were chosen from different business areas in order to be able to make comparisons about the groups and different countries.

5.3.2 Collection of Kansei words

A Kansei word is a word describing the product. Often these words are adjectives but other grammatical forms are possible. When e.g. describing a “fork-lift truck”, adjectives like effective, robust, quick, etc. but also verbs and nouns (acceleration) can occur (Schütte and Eklund 2001). In order to get a complete selection of words, all available sources are used, even if the emerging words seem to be similar or the same. Suitable sources can be:

- Magazines
- Pertinent Literature
- Manuals
- Experts
- Experienced Users
- Relating Kansei Studies
- Ideas, visions

An important point is to translate ideas and visions into Kansei words because also non-existing solutions should be considered. Only in this way can Kansei Engineering be used as a creative product development tool, which generates new and revolutionary solutions. The task is to describe the domain, not the existing products.

Depending on the domain considered, the number of existing Kansei word generally varies between 50 and 600 words (Nagamachi 1997b). Since it is of high importance to collect all the existing words, word collection is continued until no new words occur. The gathered data will critically influence the validity of the results if important words are missing.

5.3.3 Data Reduction Methods for Selection of Kansei Words

Generally it is considered advantageous to use the original number of words collected in the previous step for further evaluation, because a selection would mean a loss of information. On the other hand if the number of words collected exceeds a critical size it can be difficult to find volunteer participants to fill in questionnaire forms, due to the amount of time needed. As a consequence that means in that the statistical power may suffer from a low number of participants (Körner and Wahlgren.L. 2000). Besides that the quality of the data gathered will be relatively poor due to effects of fatigue on the participants (Fråga rätt, SCB, 2001).

As the data quality is appreciably affected by the number of Kansei words or the evaluation time of the questionnaire reaches critical dimensions a reasonable data reduction must be carried out. Two empirically tested possibilities are portrayed in Figure 28 (Arnold 2002).

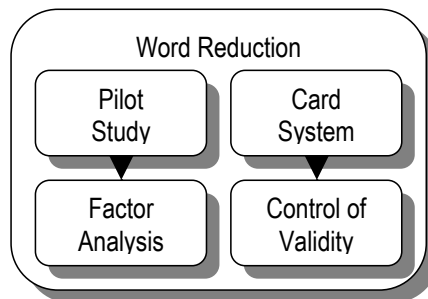


Figure 28: Proven data reduction tools for reducing the number of Kansei Words.

One of the possible word reduction methods presented in the figure above is a pilot study using Osgood's Semantic Differentials and factor analysis for evaluation. The participants are supposed to think about the product per se and answer the question "How do you think this Kansei Word correspond to the product?" Subsequent factor and/or cluster analysis is applied in order to reveal the correlations between the words and allow a choice of representatives for each factor or cluster becoming the new set of Kansei words.

5.3.5 Computerized data collection

Kansei Engineering data is statistical in nature, which requires a large amount of different opinions to get statistically reliable results. Depending on the number of Kansei words, rated products and participants, the number of ratings made can exceed as many as 100,000 data points. This is an enormous amount of data, which is very difficult to handle manually, i.e. on paper forms. Nowadays statistical evaluations are conducted using computerized evaluation systems. As a result the data has to be accessible electronically. The risk of transcription failures from paper to a computer system increases with the number of data points and depending on the type of scale used scale. Moreover, the transcription process is a time consuming act, and as mentioned earlier Kansei Engineering data is perishable, because trends can change. This means that data has to be collected and evaluated quickly.

These reasons speak strongly in favour of a computer-based data collection. Several methods have been used and tested by the author. The most frequently used software was a Windows Excel add-in as displayed in Figure 30. The participants were supposed to rate the product presented above according to a Kansei word on the left on VAS-scales and set an X-mark. This type of data collection can be extended with more products and Kansei words.



Kansei word	Not at all	X	Very much
Kansei word	Not at all	X	Very much
Kansei word	Not at all	X	Very much
Kansei word	Not at all	X	Very much
Kansei word	Not at all	X	Very much
Kansei word	Not at all	X	Very much
Kansei word	Not at all	X	Very much

Figure 30: Data collection program used in the pilot study.

The modified VAS scale, described in Section 5.3.4, was also presented in a computer environment. In contrast to the standard VAS in Figure 30 the Kansei word were presented sequentially with a describing text. This was to facilitate the rating

procedure for those of the participants, who were not familiar with Kansei Engineering nor Microsoft Excel.

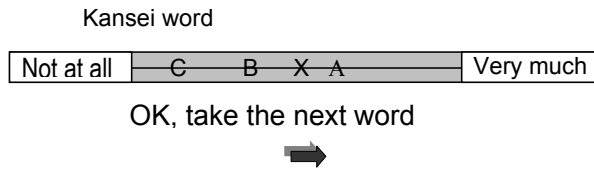


Figure 31: Modified computerized VAS-scale: Products A to C are ranked in a random order. Finally an X marks the ideal value.

5.3.6 Connecting the Kansei words to product properties

For every Kansei Word a number of product properties can be found, affecting the Kansei Word (see Figure 32). Doubtless the most important step in Kansei Engineering is to connect the Kansei words to product properties and estimate to what extent and in which way the Kansei word is affected. Hence, Kansei Engineering can be used as a method predicting customer behaviour from as yet unlaunched products.

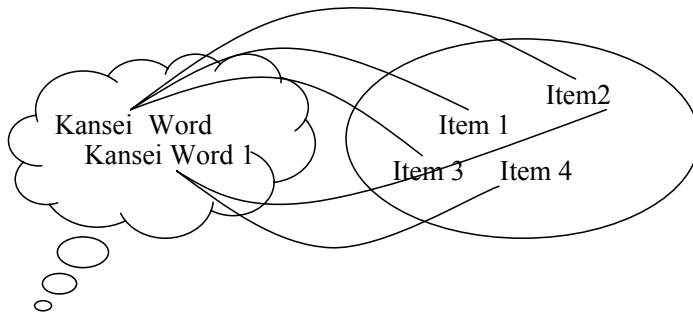


Figure 32: Connecting the User Kansei to Product properties.

Jindo conducted a study on the shape and the evoked impressions of vehicle front-end design. (Jindo and Hirasago 1997b). He assumed that e.g. the impression of boldness is most effected by the bumper-type, the orientation of the headlamp panels the grille pattern and the shape of the headlamps. His results showed that e.g. the Kansei score for the Kansei word bold is positive influenced by a thick bumper upward oriented headlamp panels with round headlamps in combination with a mesh grille pattern.

The research on establishing those links has been one of the core parts in Nagamashi's work with Kansei Engineering over the last years. At present a number of different qualitative and quantitative tools are available. Since the incoming data is stacked in a standardized way every tool can be used. It is even possible to use for different tools and compare the result afterwards in order to reveal the best suitable tool.

5.3.6.1 *Qualitative treatments*

People working with design usually have a certain hunch for the links between peoples' impressions and the product traits. They know the target groups well from different sources and have a "sixth sense" or intuition about how the products should be designed. This latent knowledge cannot be expressed and is very difficult to communicate. By providing the data from the previous steps the experts become able to interconnect their knowledge with their colleagues and in that way create a new consciousness. QFD uses almost the same principles when linking the customers needs to the technical responses in the House of Quality (Nagamachi et al. 2001). In a Kansei Engineering context this procedure is called Kansei Engineering Type I.

5.3.6.2 *Statistical Treatments*

In many cases experts are more aware of the users' demands than the users themselves. On the other hand users can easily assess whether or not a product is suitable in a certain respect or not. Nagamachi has developed a number of different statistical procedures using different mathematical implements to capture the users impression and make the synthesis independent of expert knowledge (Nagamachi 2001).

- Linear regression (Ishihara 2001)
- General Linear Model (GLM) (Arnold 2002)
- QT1 (Quantification Theory Type 1) (Komazawa and Hayashi 1976)
- Neural Networks (Ishihara et al. 1996)
- Fuzzy Logics (Shimizu and Jindo 1995)
- Genetic Algorithm (Nishino et al. 1999)
- Rough set analysis (Nishino et al. 2001)

The use of the different tools depends on the context. Emotions and feelings do not follow mathematical laws. Sometimes it is possible to use linear methods, which are easiest to handle, sometimes more complex models have to be applied. The outcome of all the tools presented describes only in what way the Kansei words are correlated to the product properties.

Findings from Employing Kansei Engineering

If I have seen further is by standing
on the shoulders of giants

Sir Isaac Newton

This chapter presents how Kansei Engineering was used in two studies where opportunities exist to integrate it in product development processes at BT Industries. Framework for Kansei Engineering is developed and proposed fitting all types of Kansei Engineering and opens the methodology for new approaches.

6.1 Kansei Engineering in European industry

As a part of the PRODERGO project, BT Industries offered the opportunity to conduct a Kansei Engineering study on their reach-truck model Reflex. This made it possible for the author to implement experience made in previous small-scale experiments in a full-scale project.

A Kansei Engineering study was conducted in three European countries, Sweden, Germany and France. A following stage is planned while editing this thesis. In total a number of 150 truck drivers were asked about their opinion regarding three different trucks from three manufacturers. The appended Papers I and II portray the study design.

6.1.1 Conducting Kansei Engineering studies on reach trucks

The collected data from all participants can be presented concisely in only one diagram showing kinds of product profiles. Figure 33 presents these profiles by means of three forklift trucks. In addition to the rating of the three competing truck models the respondents were asked to give an opinion about what an ideal truck should look like. This gives on one hand the opportunity to compare the trucks with each other and on the other hand it becomes possible to see what the customer actually wants.

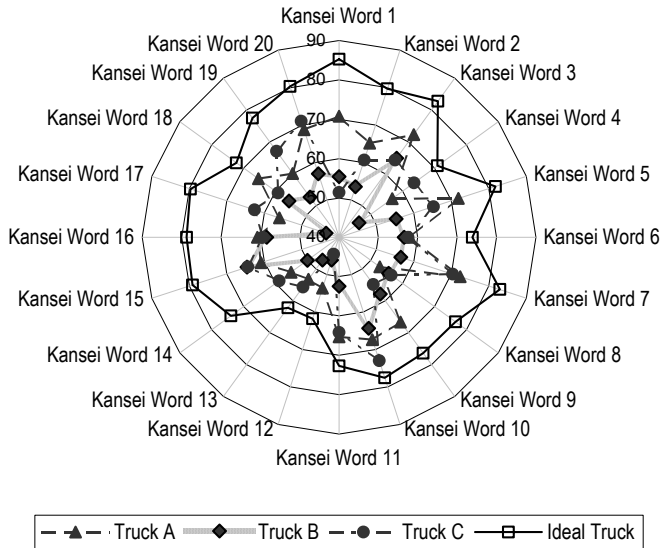


Figure 33: Total data displayed over 20 chosen Kansei words.

Based on these reflections the profile and with it the Kansei for a new product, can be designed. The task is to decide, by which Kansei word(s) the new product should be different. Suitable Kansei words are words where the actual Kansei score can be moved near the ideal value, increasing the gap to the competing products considerably. Finally the product gets its own individual profile, which reasonably correspond to the company’s brand image.

Figure 34 displays an excerpt from the collected data describing how the ideal truck is rated in different countries. In principle this can even be done for the trucks themselves. As a reference the average value for Europe i.e. the entire data from Germany, France and Sweden is added. This graph serves as reference for comparisons within the diagram.

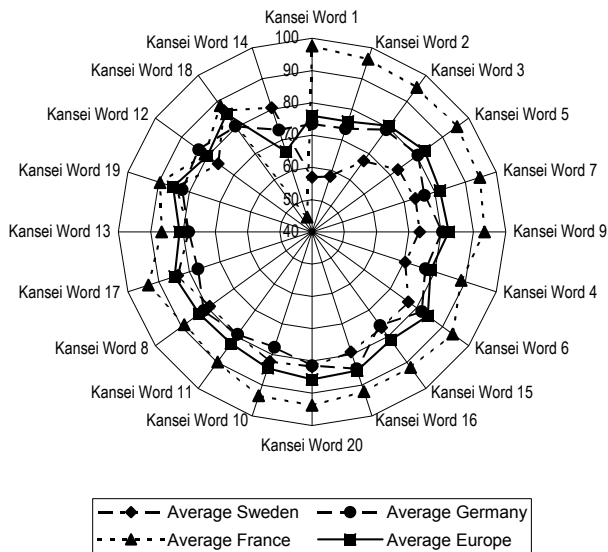


Figure 34: Comparison between the three countries examined for a certain truck model; Reference value. Europe.

BT’s Reflex truck is sold mostly in European countries and is developed in conformity with the European laws, warehouse design and the ergonomic realities in this part of the world. However, the current model was designed by Swedes with particular regard to the Swedish market. As a result models sold e.g. in Germany had to be adapted in some manner in order to meet the German market’s requirements, incurring additional costs.

Thus, it might be better not to specialize the product for only one market, but to develop a model meeting the requirements in all markets as closely as possible and make minor adaptations for the certain country before delivery. Figure 34 can contribute to this, since the diagram indicates the median values “between” the different countries.

For example: One of the studies revealed that the average respondent of the German market wants trucks which are “quicker” than the present (Swedish) model, but were relatively satisfied with the present maximum speed. A solution can be to design the new model in a way that allows individual programmability and deliver it to the German market pre-programmed with a steeper slope in the acceleration characteristics than the Swedish versions.

6.1.2 Experience with the modified rating scale

The modified rating scale seemed to be more logical compared to the original scale, since it allowed rating between the different truck models. In the prevailing context it became easier for the participants to check their rating visually. Setting an 'ideal' value made it possible to determine how the different products were seen in total and in relation to each other. In some cases, participants complained that the 100 mm scale was too narrow for conducting four ratings. They stated that the values of the following ratings were already fixed when rating the first product and an objective rating for each product was not possible.

6.1.3 Computerized data collection in practical use

The data collection was performed using a portable personal computer with special collection and evaluation software. This choice gave many advantages. The data could be collected and stored electronically, which reduced collection time and avoided an additional data transfer from paper to computer. It became easier to transfer the data into other evaluation programs and reduced the risk of errors in data transfer. The time savings allowed collection of more data, improving statistical strength. In order to facilitate the evaluation and to provide better control of tendencies and suitability, the software allowed rapid statistical operations and already sorted the data during the data collection.

The study could potentially be performed in several countries without the presence of a researcher. Therefore the software could transfer the resulting data quickly using e-mail. Using the same software layout for all participants, every participant experienced an almost identical test environment, which reduced nuisances and increased the statistical strength.

6.2 Designing attractive quality into products

Referring back to the Kano model introduced in Figure 4 the different types of quality can be recognized in Figure 33 regarding a certain Kansei word. The customer expects that a product is at least in the range of comparable products (must-be-quality). If the product ranks higher than the competing products for a certain Kansei word, the customer probably becomes aware of this and she will express this at the next occasion she buys this type of product (one-dimensional). However, if the product is ranked close to the ideal value, the customer was certainly surprised and consider this particular impression as attractive quality.

In the case of warehouse trucks performance is a typical must-be-quality. It is represented by Kansei words like fast, agile, acceleration, etc. Vehicles are considered to be unequal, if the performance figures are not in the same range. A mast allowing an increased field of view is often considered to be one-dimensional within the work vehicle sector. Representative words here can be: comfortable, convenient, etc. Attractive quality can be achieved by adding new or unusual features to the product evoking a certain Kansei. An example can be an extraordinary chassis, positioning the Kansei scores for the words stable, predictable, etc. near or above the Kansei score for the ideal truck (compare Axelsson et al. 2001).

Another way of estimating the overall impression of a product relative to competing products is presented in Equation 1. The Kansei score for each Kansei word is added and compared with the ideal values. Multiplying by 100 gives the percentage the certain product ranks against the imaginary ideal product. The application of this procedure to a number of different products allows a comparison of the overall impression.

Equation 2:
$$\frac{\sum_{i=0}^n KS_{Product\ i}}{\sum_{i=0}^n KS_{Ideal\ i}} \cdot 100 = SK [\%]$$

With:

- SKDegree of attractiveness compared to the ideal value
- KS_{Product i}Kansei Score for a certain product regarding a Kansei word
- KS_{ideal i}Kansei Score for the ideal product
- iconsecutive number for Kansei words
- nmaximal number of Kansei words

However, this equation does not completely free the use from their own reflections. It can give only a general impression how the product is related to the ideal. To be significant, must-be quality has to be fulfilled for every Kansei word, otherwise a Kansei word rated below the expected minimum, can affect the overall impression.

6.3 Integrating Kansei Engineering in the product development process

6.3.1 Kansei Engineering in Stage-Gate processes for product development

In Japan Kansei Engineering is used independently of product development methods and in many cases parallel to ongoing projects. However, since the method is practically unknown in Swedish industry the work at BT Industries required the development of a concept of how to integrate the findings from a Kansei Engineering study into the new products. One step was to identify possible entry points in product development processes both from the viewpoint of time and suitable method.

BT uses as many manufacturing companies a kind of Stage-Gate model. Within a working stage an exactly defined part of the product development process is carried out and subsequently reviewed by the project leading group. If the result is sufficient it can pass the gate, otherwise it is sent back for revision. (Cooper 1998) developed a general stage-gate model, which is portrayed in Figure 35.

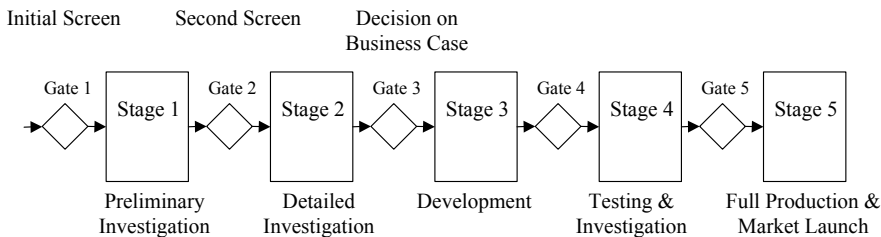


Figure 35: A Stage-Gate process for product development, adapted from Cooper (1998).

The Stage-gate process model allows an identification of time intervals where Kansei Engineering data is most useful for the product development process.

Kansei Engineering can be applied at different levels on the product. A macro-level investigation is often used on whole product concepts or a product family, whereas micro-level examinations are used for detailed studies on product parts after the concept is specified. Moreover, Kansei Engineering can be used as a validation tool too. These three types can be recognized in the stage-gate model in Figure 35.

Preliminary investigations making a quick investigation scoping up a large number of potential projects is conducted. This is based largely on desk research and therefore inexpensive. Kansei Engineering data from rough macro-level examinations on

different competing products can be a valuable information source for the pre-selection of product concepts.

In the second stage a more detailed investigation is carried out. Typically market studies are included and Kansei Engineering can support the forthcoming decisions by focusing on several product parts more carefully (micro-level investigations). After this point the actual development process is conducted. Kansei Engineering data can even support this process by making the designers aware of the Kansei their work may evoke.

In the following testing and investigation phase Kansei Engineering is able to reveal whether the new product fulfil the requirements regarding emotional impact or not. At this point small changes thus like colour setting, tuning parameters or changing minor modules, can still be made.

6.3.2 Integrating Kansei Engineering data in QFD

In product development the setting of the product specifications is of high importance, since the products meet the customers' demands and needs. Many companies use standardized methods for the translation of customer wants and needs to product and process properties, see e.g. (Gustafsson 1998). One of the most common methods is QFD. Since BT Industries uses QFD, especially in the second stage of their development processes (Cooper 1998) a recurring question was if and how Kansei Engineering can contribute or be combined with QFD.

Empirical attempts could spot five potential approaches. Kansei Engineering data can be used in order to identify customer needs and determine their importance, facilitating the setting of target values for technical data and perform benchmarking between different products and brands and quantify the relationships in the relationship matrix in a more exact way (Figure 36).

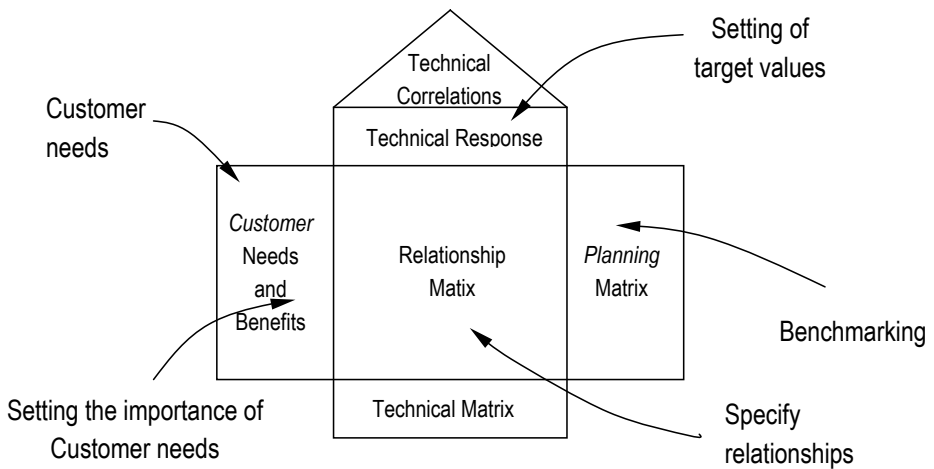


Figure 36: Entry points for Kansei Engineering data in QFD.

In the relationship matrix the customer's needs are linked to the technical responses. The strength of the relationships is determined by more or less qualified guesses of experts distinguishing between strong, medium and weak relationships. Further refinement of the scale complicates the decision process and in consequence increases the evaluation time. However, in some cases more detailed information is desirable. Kansei Engineering can quantify those relationships mathematical exact based on the customer's opinion. Moreover, statistics allows to examined whether different customer group have different opinions which in turn can lead to the development of alternative product concepts.

In QFD the customer needs are collected using focus group interviews, activity analysis etc. The data gathered is evaluated and interpreted by i.e. Voice of customer tables, etc. Those tools try to grasp even implicit needs and wants and link them to product parameters. However, interpreting the customer's statements is very difficult and requires very much experience. Kansei Engineering is designed for evaluating the unconscious wants and needs, and delivers statistical mathematical values for the connection between a need and its technical response. E.g. Regarding furniture the customer may describe her home as "elegant". One way is to treat this statement with VOCT, and feed it into the House of Quality. An alternative way is to make a Kansei Engineering evaluation and get an exact translation into product properties with only minor influence from the researcher.

In the following step within the QFD procedure, customer needs are ranked after their importance. QFD offers a number of different tools, based on (subjective) expert knowledge. Kansei Engineering offers the opportunity to collect the customer's attitude about the particular importance of the different product properties. Paper II in the appendix describes how the type of importance can be valued and ranked by customers (see Section 6.4.4).

A third way Kansei Engineering can be used in QFD process is the setting of the target values for the product properties. For every customer need, a number of product properties can be identified. Collecting additional information about what the ideal product should feel like, gives a clear indication about in which direction the Kansei Score of the certain Kansei word has to be adjusted to suit the customer's needs in a better way. Since it is known how and in which way the product properties are connected to the certain word, it becomes clear how the Kansei can be manipulated. As a result Kansei Engineering can help to set target values for the technical specifications. Assuming that the word "elegant" is connected to such product properties like, dark wood-types and leather trim, it is also known that a certain product scores only low values on this Kansei word, the identified design properties should probably be used more consistently.

Success in international markets does not only require a customer-focused design, but also knowledge about the competition situation in the specific market segment. QFD provides a product comparison where different products within the same segment are compared regarding the degree of fulfillment of a specific customer need. By comparing the results of Kansei Engineering studies made for different competing products, a benchmarking profile can be developed as demonstrated in Figure 33 in Section 6.1.1 and integrated into the House of Quality. Such a combination of the House of Quality and Kansei Engineering allows a special profiling of the products Kansei. The product becomes unique and easy to recognize for the user; it gets its own personality and follows the trends introduced in the beginning.

6.4 Proposing a conceptual framework for Kansei Engineering

6.4.1 Constructing a flowchart on Kansei Engineering Type II

Besides the research on Kansei Engineering the author conducted several small Kansei Engineering studies on soap and watches in order to learn about the functionality of Kansei Engineering. In these cases the mathematic statistical variant Kansei Engineering Type II was used. As a supervisor for a number of master thesis students

it became necessary to communicate how Kansei Engineering works and it was drawn an adapted flowchart was drawn inspired by an earlier flowchart in Kansei Engineering literature, (Nagamachi 1997b). Figure 37 depicts the result from these efforts.

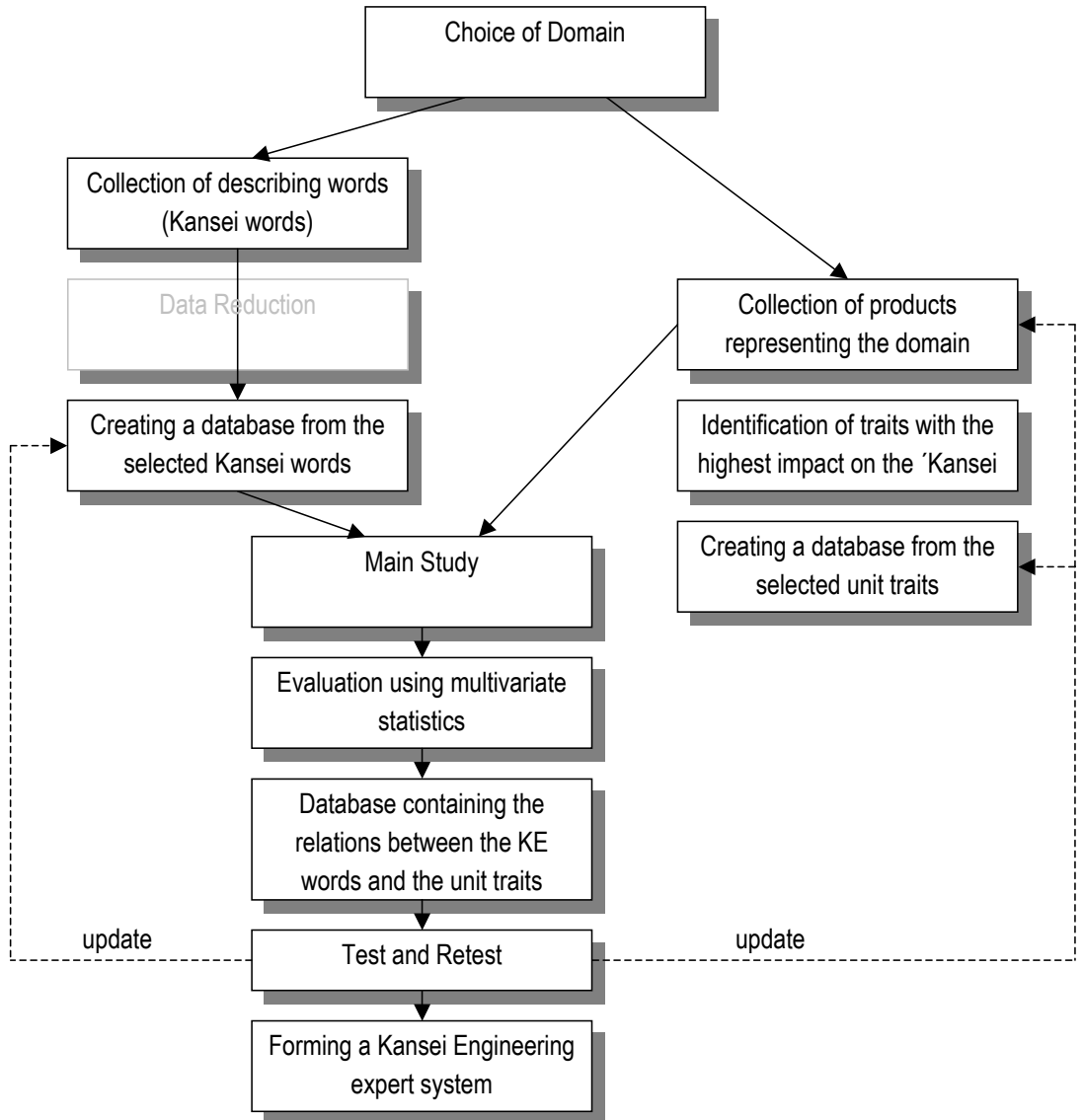


Figure 37: A generalized flowchart for Kansei Engineering Type II.

In contrast to Nagamachi’s flow chart several steps were considered as belonging together and were combined. Nagamachi’s diagram is serial, but it was discovered that

several steps could be carried out simultaneously giving the chart a parallel structure. Based on the experiences in previous studies, several points were added or modified. These were:

Data reduction after collection of Kansei Words

In the Japanese Kansei Method all the collected words are evaluated by participants. This procedure was not possible in the documented studies, since it was very difficult to gather volunteers together. Moreover, the data quality suffered from the problems of fatigue and boredom in the participants (see appended Papers I and II). Hence it was decided to reduce the number of words before the main study was carried out using mathematical and manual clustering tools.

Identification of product traits with the highest impact on a customer's Kansei

Often the important product traits are already chosen before the study design is finished, but no method is described in English Kansei Engineering Literature, which could give a technique to accomplish this. Since this was considered to be a critical factor for the result, an extra step was added in the flowchart, standardizing this step.

Other steps in Nagamachi's flowchart were modified and enhanced in order to give a wider meaning and make it possible to open Kansei Engineering for more and other methods from different fields of science. Those steps were:

Validity test

The "review" of the KES in Nagamachi's papers was replaced by a "validity test". Instead of testing the newly build KES, the validity test allows the testing of different intermediary results, which makes it easier to detect errors in the system. Since new tools (e.g. data reduction and affinity diagrams) were added, it became necessary to introduce more review methods for testing the results of the new methods. All the testing methods could be collected under the umbrella of validity test.

Forming the Kansei Engineering expert system

Nagamachi's describes the forming of the KES in four steps. In Figure 37 this is summarized in a single step.

6.4.2 Proposing a General Framework for Kansei Engineering

An analysis of the structure in Figure 37 reveals an underlying more general structure, consisting of four main parts. The simultaneous steps can be put into groups, whereas the lower part can be grouped and put together in a new way. The question arises whether a general pattern exists, which covers all types of Kansei Engineering and allowing the introduction of new tools. A review of the available literature in English gave the below presented abstracted structural model for Kansei Engineering.

In Figure 38 the General Kansei Engineering Method is portrayed. The basic idea is to describe –based on an domain chosen earlier - the idea behind the product from two different perspectives:

- The semantic description
- The description of product properties

These two descriptions span a vector space each. Subsequently these spaces are merged in with each other the synthesis phase indicating which of the product properties evokes which semantic impact. First after these steps have been carried out, is it possible to conduct a validity test, including several types of Post-Hoc analyses. As a result from this step the two vector spaces are updated and the synthesis step is run again. When the results from this iteration process are acceptable, a model can be built describing how the semantic and the space of application are associated.

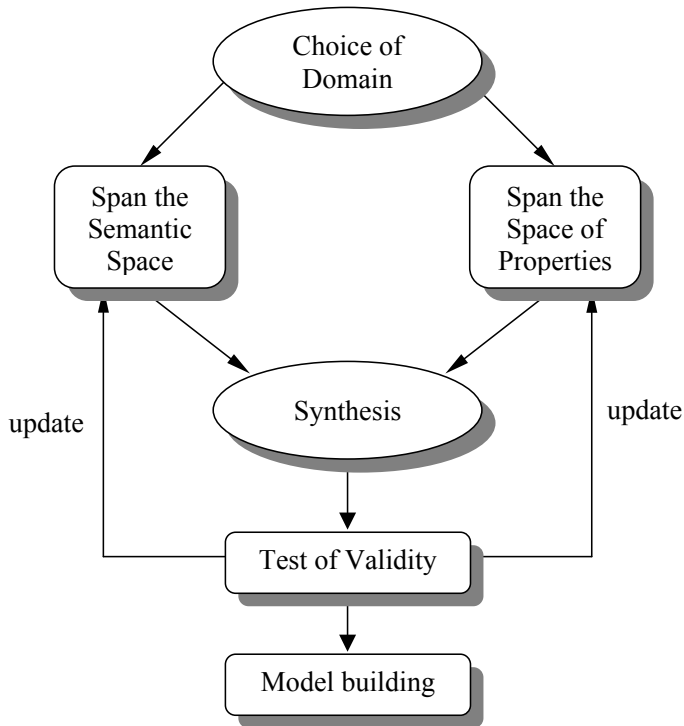


Figure 38. Abstracted model of Kansei Engineering.

6.4.3 Selecting the Domain

Selecting the domain includes the selection of a target group and market-niche and specification of the new product. Based on this information, product samples are collected, representing the domain. The Kansei Domain can be understood as the ideal concept behind a certain product.

Despite the fact that a circle can never be drawn perfectly round, everybody knows what the perfect idea of a circle is. The Kansei domain is dealt with in the same way. It is an abstract super-ordinated mind structure while the representative products are either tangibles or intangible samples from this domain. As a result, a domain includes both existing products, concepts and even still unknown design solutions.

The task in this first step is to define the domain and find representatives (products, drawings, samples, etc) covering an as big as possible part of the domain.

6.4.4 Spanning the Semantic Space

For the spanning of the Semantic Space Osgood's theories about the Semantic Differential are applied (see Section 3.1). As a first step the domain is described by Kansei words. If the number of the words collected exceeds a critical limit, the data quantity is reduced. Subsequently an rating of the chosen domain representatives against the selected words is conducted and evaluated. The result can be understood as a Semantic Space, according to (Osgood et al. 1957).

6.4.5 Spanning the Space of Product Properties

In parallel to the data collection and evaluation of the Semantic Space the relevant and most important product properties are selected for further evaluation. These activities are rarely described in Kansei Engineering literature. The author tried to identify several techniques like, affinity diagrams, pareto diagrams, etc., but it is desirable to test more solutions.

The data gathered from this step describe the product physically. Since there are several dimensions visible it is assumed to be a similar space as the Semantic Space.

6.4.6 Synthesis

The synthesis step is the mostly well-known and best explored step. Nagamachi and his colleagues mainly work in this area. Here the two spaces are linked together as shown in Figure 10. Depending on which mathematical context is expected, different statistical methods can be used in order to describe the connection (see Sections 3.2 and 5.3.6)

6.4.7 Model building and test of validity

Finally a mathematical or non-mathematical model can be built depending on the synthesis method chosen. However, before using the model as a prediction model for future products it has to be validated. At present not only are validation methods for the Semantic differentials available, but there is a need for a more integrative validation concept.

Discussion and Conclusions

En slutsats är någonting man drar
När man inte orkar tänka längre

Martin H. Fischer

This chapter provides reflections about the approach and methods used. Kansei Engineering as a method is discussed and experience with the underlying structures is described.

7.1 Kansei Engineering - a methodology?

Kansei Engineering was invented around 1970, when Professor Nagamachi recognized the necessity for a methodology capturing hidden feelings and emotions about products. Kansei Engineering is based on the semantic differentials of Osgood, enhanced by adding different mathematical tools from other applications. These tools needed to be adapted for this purpose within Kansei Engineering, but it still remained an external tool, independent from the other tools in Kansei Engineering.

One of the questions arising during the research on Kansei Engineering was whether the method of Kansei Engineering could be considered as an independent methodology or only as a collection of different tools adapted for a common aim.

Answering this question based on the available English literature, one might tend to overlook the underlying thoughts, since this kind of literature mainly deals with the tools mentioned instead of the underlying superstructure. No paper described the purpose and limitations of Kansei Engineering with the tools used.

However, a deeper look Kansei Engineering reveals that the Kansei is a very complex formation alluding to many different scientific fields. It can be observed from different scientific perspectives but measuring it requires an interdisciplinary method utilizing specific tools from the fields involved. The role of Kansei in this context is rather to tunnel through the borders between the different fields, creating an interface and setting the rules for an interaction between the tools. Seen from this angle, Kansei Engineering becomes more than the sum of its parts.

In fact my research showed that many tools are not fully suitable for use in Kansei Engineering. A task for the future would be to make Kansei Engineering a transparent structure bonding together recent and future tools. The proposed framework in Figure 38 is one step on this path.

7.2 Kansei Engineering as a tool for innovation

Reading about Kansei Engineering, one is reminded in many cases to the great success stories like the Mazda Miata, Sharp's camcorder with an extern LCD-display or Wacoal's brassiere. According to pertinent literature, these are the proof of Kansei Engineering's innovative ability.

However, when conducting a Kansei Engineering study, only existing products are evaluated. These products do not possess any new property. Consequently the result can only show how the already existing properties could be combined in order to evoke a certain Kansei. Conclusions about new properties can not be drawn from this data.

However, Kansei Engineering analyses the feelings of products and presents them in a way that it can be communicated and discussed by the designers. This way of presenting data facilitates the understanding of the product's emotional impact and contributes to the development of new combinations and ideas. Hybrid Kansei Engineering (see Section 2.3.3) in turn makes it possible to process the new product concepts with new properties and captures the Kansei of the new property as a result.

Maybe Kansei Engineering should also be combined with a kind of creativity tool in order to ensure innovation ability?

7.3 Influence of cultural differences

The limited information available in English also decided the approach chosen. One way of gathering additional information was to conduct a Kansei Engineering study of our own. As previously mentioned several small studies were conducted before it was decided to translate the experimental design into a bigger scale and apply it to Reach trucks at BT (see also Paper I and II).

From the word collection and the pilot study, it was learned that Kansei Engineering could not be applied in the same way as documented in Japanese Papers. It can be speculated that the cultures may be too different, but the proof for this is still missing. Hence, the tools and methods used had to be adapted and new ones were introduced. E.g. the number of words were reduced in order to conduct the evaluations in reasonable time and factor and cluster analyses were applied. The theories around the SMB and the Semantic differentials (Küller 1991), Osgood, Suci et al. 1969) provided enough information that this procedure can be considered as giving valid results.

7.4 Integration of Kansei Engineering in European companies

Since Kansei Engineering is a relatively unknown method in many European companies, the author had to explain its contents and advantages in order to initiate co-operations. Based on the experience with the different companies the author was in contact with, it can be concluded, that Kansei Engineering was seen with a certain skepticism and reservation in the beginning which has to be dispelled.

According to the author this may depend on a lack of transparency in the method itself and the fact that Kansei Engineering procedure cannot be as easily understood as e.g. QFD, due to its heavy mathematical statistical part. Another problem might be the fact that it is so different in comparison to other common product development methods, as it is practiced in Japan.

As a researcher is it not the author's task to market Kansei Engineering, but it is in the author's best interest to create a positive environment for future research. A side effect might be to facilitate the further spread of Kansei Engineering.

Two different strategies can be identified:

- Kansei Engineering should be connected to commonly used methods in product development. Hence, one aim was to integrate Kansei Engineering using existing entry

points and connect it more closely to product development processes as documented before. Even this required adaptations of the tools used, (see Section 6.3 and Paper III)

- Kansei Engineering should be easier to understand, even by non-experts. This required the development of a new framework and the integration of new tools (see Section 6.4 and Paper IV).

Today Kansei Engineering requires a lot expert knowledge for the evaluation steps. Opening the framework to new tools as done in the framework proposed in this thesis, allows the development of a “Kansei Engineering Light”-version, using mostly non-mathematical and non-statistical tools for the different stages within the Kansei Engineering procedure. Such a type of Kansei Engineering could be learned and applied quickly and make the method more independent of academic support than today’s types.

7.5 The proposed framework

The proposed framework is primarily based on empirical data from the research conducted for this thesis. Hence, it can not be considered as a fully validated model, but a support for building a mental model within Kansei Engineering and show the borders between the superstructure of Kansei Engineering and the tools used more distinctly. This facilitates the development or adaptation of other tools.

The proposed framework portrayed in Figure 38 has many unexplored fields, since it was developed based on the assumption, that Kansei Engineering is still advancing. Future research will hopefully fill today’s gaps (see Chapter 8).

7.5.1 Validity of the proposed concept

According to the literature used the model fits all currently existing types of Kansei Engineering. Moreover it allows the addition of new tools and steps as seen in the Swedish variant. The Kansei Engineering concept has been tested in several respects at Linköping University. On the other hand only future will show to what extent it will manage to explain future developments in the field of Kansei Engineering.

7.6 Generalisability

When starting the research on Kansei Engineering the author did not have any previous experience with its methodology. The studies conducted contributed in many respects to a growth of knowledge and the experimental design was changed several

times in order to include the knowledge gathered. Hence, it took a relatively long time to finish the study and evaluate the results.

Bearing this context in mind it is necessary to ask if the results would be the same if the study was repeated and how far the results can be generalized. Since it took a relatively long time to collect the data, there is a risk that the trends changed in the meantime, but on the other hand, Reach trucks usually have a lifetime of about 5-8 years which makes it relatively insensitive to short term trends. The strategy in the study design was changed within given limits several times. This disturbed a smooth evaluation and caused trouble and doubts in several cases. This probably affected the result, but in which way and how strongly could not be estimated. However, since the results sounded logical for BT staff dealing with these tasks, it can be assumed that the error is minor.

In the studies Reach trucks were the object of research. Even in other studies work vehicles were the research object. From this point of view the result could probably be transferred even to similar products. On the other hand the study conducted dealt only with the tangible parts of the truck. During the examinations it became clear that the product also has an important intangible part, which was not evaluated. Therefore the author recommends an enhanced perspective on the product (see Section 1.6.1). Since the study had progressed so far at this time, it was not possible to integrate this dimension in the ongoing study. Consequently the result is only valid for the tangible part. Future studies may take those parts in consideration too.

Subsequently Kansei Engineering was applied to BT's product development process. As described in Section 1.5.3 BT uses a number of common techniques within its development processes. Entry points for integrating Kansei Engineering and feeding the result into the process could be identified. Despite the fact that those solutions were developed individually for BT Industries, the outcome has a certain general character, since it shows that it is possible to combine Kansei Engineering with existing systems. Moreover, even some part solutions may work independently from the BT structure.

Future Research

This chapter gives a summary of the research initiated and portrays the adopted strategy. Using this as a starting point from the trends become visible and future research frontiers can be identified.

At the time of editing this thesis several projects were in progress. The intentions were, partly to prove the results found and improve the Kansei Engineering methodology and partly to explore new areas. On the basis of Figure 38 several new research frontiers can be identified.

Beginning at the top of the figure it can be remarked that only a little work has been done on giving criteria about how to choose the product domain. Currently the most difficult tasks in this sector are the definition of focus groups, market niche and proper establishment of a product specification. There are several techniques available from other scientific fields, but none is reported as being used in a Kansei Engineering context. According to the author the domain has to be specified as a base for the following product development process.

Further down in Figure 38 the domain is described in two different ways, semantically by spanning the Semantic Space, using Osgood's theory about the Semantic differentials and physically by spanning the Space of Product properties. Specifically, a procedure for filling out this space is still absent. The main tasks are actually to identify the relative importance of product properties and the selection of those which represent the product best and therefore span thence an imaginary space.

Proceeding downward the spaces are merged in the synthesis. Nagamachi and his colleagues have done much research around this area. The main research problem here is to find mathematical models which accommodate the non-linearity of human emotions better than other existing methods.

After a mathematical model is proposed, the validity has to be checked. Currently this can be done by using Osgood criteria for the Semantic Differential, but it can not be proven that the selected product properties are correct. Future research should be devoted to this area in order to allow recommendations on how to design the experiments.

As mentioned earlier Kansei Engineering was mainly used for evaluation of tangible products. In the recent years it was also used in order to evaluate intangible products like Internet services. However, products become more and more complex and are in many cases a combination of tangible and intangible parts, which become obvious in the presented BT-cases. For these purposes the author proposes to expand the perspective on products to the version presented in Figure 5. More studies about this type of products should be conducted in order to underpin the validity of this proposition.

One trend the author followed in the recent research was to find Kansei Engineering's role in product development processes. There are several models for product design available like the Beitz-model (Pahl et al. 1996) or Hubka and Eder's design model (Hubka and Eder 1992). A future research approach could be to integrate Kansei Engineering into these processes.

Another research direction the author explored was to integrate Kansei Engineering under the roof of TQM and set it in relation to existing methods in quality. This was only done peripherally but should be continued. Moreover even other scientific fields should be investigated looking for more suitable methods for the different steps within a Kansei Engineering procedure.

Using Kansei Engineering presumes that the participants in a design process have understood the basic ideas and are convinced of its advantages. Moreover the role of Kansei Engineering in the company has to be properly defined and understood, in order to achieve the necessary commitment of the users. In the case of BT the author and some employees of the company initialized the embedding of the new method in the companies structure, but yet it is not concluded. Further affords must be taken to tighten the acceptance. This is one task for the future.

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Appendixes

Appendix A

The Semantic Environment Description factors and the included words in each factor (Küller 1991)

Factor	Description	Adjective included in each factor	
		<i>Positively correlated to the factor</i>	<i>Negatively correlated to the factor</i>
Pleasantness	The degree of pleasantness, beauty and security which individual experiences in the environment.	Stimulating Secure Idyllic Good Pleasantness	Ugly Boring Brutal
Complexity	The environments liveliness and complexity.	Motley Lively Composite	Subdued
Unity	How well the various components in the environment seem to fit and function together.	Functional Pure style Consistent Whole	
Enclosedness	The closedness and degree of demarcation of the space.	Closed Demarcated	Open Airy
Potency	The expression of strength and force.	Masculine Potent	Fragile Feminine
Social Status	Economic and social evaluation of the environment.	Expensive Well kept Lavish	Simple
Affection	An age aspect as well as a feeling of the old and genuine.	Modern New	Timeless Aged
Originality	The unusual and surprising in the environment.	Curious Surprising Special	Ordinary