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Design and Evaluation of Affective Features in Automobiles

PENG HONG

School of Mechanical and Aerospace Engineering

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LIST OF ABBREVIATIONS

Abbreviation	Definition
ARH	Affective Requirements Hierarchy
CARE	Car Evaluation
CATER	Computerised Automotive Technology Reconfiguration System for Mass Customization
CDM	Critical Decision Method
DECA	Design Equations for Citarasa Analysis
DESA	Design Equations for System Analysis
ECU	Engine Control Unit
NPD	New Product Development
ProEmo	Product Emotions
QFD	Quality Function Deployment
R&D	Research & Development
SME	Subject Matter Expert
TNT	Truck Needs Tracker

ABSTRACT

Traditional product designers assume that the most effective strategy to enhance customer satisfaction is to improve design performance. However, today functionality is more and more taken for granted recently. Customers are looking for fulfillment of various perspectives of appreciation. Products are expected to generate pleasurable experiences. This phenomenon also applies to the automotive industry. Most automobiles are produced with excellent quality and functionality. But affect and emotion play essential roles in customer evaluation. Therefore we need to investigate affective factors, which include: individual preferences, status, life styles and values.

In this study, our objective is to provide a framework for affective design and evaluation, which can assist designers in utilizing affect and emotions in the automobile design process. In design planning, affective design can be decomposed into three distinct levels: visceral, behavioral and reflective.

A Product Planning study was conducted to validate and evaluate the effectiveness of the proposed affective design evaluation framework. Moreover, a customer Affective Requirements Hierarchy (ARH) was proposed to study the customer evaluation process top-down, from overall evaluation associate to detailed design features. An evaluation method called: Design Equations for Citarasa Analysis method (DECA) was developed to support the design process. A series of case studies of automobile parts design were performed to investigate the applicability and effectiveness of proposed DECA method.

Chapter 1– Introduction

This chapter gives an overview of the background of this research. After analyzing the background, objectives for the research are presented. The research problem is then identified as the integration and analysis of affect in the design process, and how to evaluate customer affective needs.

1.1 Background

Abraham Maslow's hierarchy of human needs describes human needs from lowest level to highest as: physiological, safety, belonging and love, self-esteem and self-actualization needs (Maslow, 1943), as shown in Figure 1-1.

Figure 1-1 A Hierarchy of consumer needs (Jordan, 2000)

Based on Maslow's hierarchy, Jordan (2000) proposed a hierarchy of customer needs, with functionality at the low level, and pleasure at the top, as illustrated in Figure 1-1. When needs on the lower levels are fulfilled, meeting needs on the higher level can provide competitive advantages. Desmet and Hekkert (2002) referred "product pleasure" as a product benefit that exceeds just basic functioning, more explicitly, pleasure is an emotional benefit of owning a product.

The term *emotion* is derived from Latin "emovere", which means to set in motion. It initially referred to an idea of physical movement and then a figurative implication of mental movement was associated with it. The term *affect* is derived from German "affekt" and refers to a variety of psychological states such as emotions, feelings, moods, sentiments and passions. These states vary in extent, impact and eliciting situation (Frijda, 1986). Aboulafia and Bannon (2004) referred to *affect* as an intense and relatively short emotional state brought about by a sudden change in circumstances, a short-term and direct response to the situation; while *emotions* go beyond the specific situation and lasts for several days. Moreover, Masters (2000) defined: "affect is an innately structured, non-cognitive evaluative sensation that may or may not register in consciousness; feeling is affect made conscious, and emotion is psychosocially constructed, dramatized feeling." Before proceeding, it is helpful to clarify the terms used in this report; emotion and affect, and emotional and affective refer to the same concept and will be used interchangeably.

1.1.1 Affective Product Design

Conventionally, designers believe that the most effective way to enhance customer satisfaction is to improve the design performance and technical aspects (Jiao & Zhang, 2005). The increasing competition in consumer product markets and growing awareness of importance of design has led to a new insight of successful product design. Hekkert (2002), the chairman of Design and Emotion Society, declared: "It is no longer sufficient to design good product or service; we all want to design experience and

generate pleasurable or exciting sensations.” This is also true for the automotive industry. As Welch (2007) from Business Week noted:

As if the automaker doesn't have enough troubles, its accelerated efforts to design cars that people actually want, comes at a moment when competition is the fiercest ever... Plus, most car feature are acceptable to excellent quality these days, so finding a way to differentiate yourself becomes all the more important.

In this development, product quality shifts from functionality and usability to satisfaction of affective needs. For example, a truck has to meet different types of requirements. Functional requirements such as fuel economy, power, service and maintenance, are important to the driver as well as fleet owner. But there are bonus factors that influence customers' decisions. These refer to affective and emotional aspects. Frog Design, a creative global design company, has the motto: “Form follows emotion”. Customers do not just buy a product, they also buy value in terms of entertainment, experience and self-identity (Sweet, 1999). Affect and emotion play crucial roles in customer's evaluation. Therefore, the research must consider how to design product which appeal emotionally, affectively, socially and cognitively.

Customers evaluate products holistically, and they face difficulty to express their feeling. For example, in the car showroom, they would say: “I like it!” This is not an instructive statement, and for the designers, it is hard elaborate what they mean by that. Why do they like it? Which specific parts or features excite them? There are lower abstraction levels in design, which is necessary to break down.

Another issue in affective product design is the domain of application. Usually designers focus on a handful of products for affective design. These are typically expensive and expressive products, such as automobiles, computers, perfume, mobile phones, and so forth.

1.1.2 Customization and Personalization

No single product is capable in satisfying the needs and preferences of all customers, and hence it is recommended to provide a variety of products (Norman, 2004). Customer's attitudes and preferences differ. Most products are designed and distributed differently for different countries, such as magazines, automobiles, electronics appliances, and so forth. They vary in design according to the regional customers' needs.

With personalization and mass customization, customers can select product attributes, and the product is assembled based on individual preference (Moon et al.2006).

Dell computers noted that: "Designing for all is designing for no one" (Supian, 2007). It is important to design products for a broad market. While enabling customization and personalization are added bonuses. A wide range of consumer products allow customization, including: computers, shoes, clothing, automobiles, and so forth. Many great automobile companies offer various configurations, for example: Mini Cooper, BMW, Smart, Audi, and Fiat.

It is possible to build a product which fits everybody's needs and is also mass-produced. Customers can then configure the product according to their taste. This is the concept of mass-customization, meaning mass production with customization. The choice of components, accessories, material, colors, textures are all restricted, hence it is quite different from personalization (Jiao & Zhang2005).

1.1.3 The Four Phases

Figure 1-2 Four phases of affective design

Affective design is the focus of this research. It is associated with four phases as shown in Figure 1-2:

- Elicit and understand customer's needs and constraints from the data collected
- Analyze the data collected
- Transform customer expectations into detailed design specifications
- Evaluate and refine product design process

1.1.4 Holistic View of Product Development Process

To understand the fundamental issues in this research, a holistic view of the product development process is helpful. Figure 1-3 shows the product design process which enables the transformation process from customer needs to configurations of product fulfillment. This process renders in the context of mapping relationships between the customer domain and design domain. Basically, the process involves three stages, namely: acquire, analyze and fulfill.

Figure 1-3 Overall Process of product design and development (CATER, 2008)

Acquisition of Customer Needs

This stage deals with the understanding of latent customer needs and developing customer requirements to denote these needs. Survey methods are considered to be a most effective means, which may be carried out in various ways, such as Critical Decision Method (CDM) interviews, online survey, and knowledge audits. At this stage, we proposed the use of an Affective Requirements Hierarchy (ARH) to figure out how customers evaluate a product and which parts they are looking at when appreciate a product.

Analysis of Customer Needs

The purpose of customer needs analysis is to identify and put in design features that satisfy the customer affective needs. A proposed method, Design Equations for Citarasa Analysis (DECA), will be use. This expresses the mapping relations between customer needs and design parameters. Such a mapping relationship be formed in

various ways and be represented in different forms, such as association rules (Jiao, et al.2006).

Fulfillment of customer needs is the next step. This phase is important but not included in the scope of this research.

1.2 Objectives

Considering the challenges of satisfying fast changing customer's needs and markets, the primary objective of this research is to provide a framework for affective design and evaluation, which can assist designers in utilizing affect and emotion in the design process.

Conventional product design specifies requirements through functional and technical attributes; in this research, affective requirements are also considered important.

In this research, three case studies were conducted to study the proposed framework in Chapter 3. Firstly, in order to elicit detailed customer needs, a field study was conducted to provide sufficient data for later studies. Secondly, another study was conducted to extract domain expertise of product planning team. While the result of customer needs interview and findings of the domain expert study were used to evaluate and validate the effectiveness of the proposed framework in the third case study.

1.3 Research Motivation

The main challenge in this research is to elicit and identify customer's affective needs, and subsequently propose a method to apply these findings in automotive design. The data collection is difficult. Due to the difficulties of customers to express affect in

preferences and find matching design parameters. Similar problem exists in finding design solutions for functional requirements.

Figure 1-4 Activities between designer and customer (Jiao & Zhang, 2005)

There are basically two domains: the customer domain and the designer domain. A customer perceives, responds, and evaluates a product. And a designer achieves a design solution by satisfying the customer's affective and functional needs, see Figure 1-4. Designer needs to communicate and negotiate with customers effectively.

Designers need to understand the customer needs, and how they can be implemented in design parameters. At the same time, there may be a need to negotiate with the customer and prepare alternative design. The customer needs to evaluate the designer's intent and consider how alternative suggestion will satisfy his/her own intent.

1.4 Organization of Report

The following is a summary of the contents of each chapter presented in this report:

- Chapter 1 begins with a discussion of the background for the research and provides an overview of key issues, including: affective customer's needs, affective product design, customization, and so forth. The research objectives are then presented;
- Chapter 2 reviews the literature and provides a theoretical foundation of this research;
- Chapter 3 discusses the research methodology. Through development of a theoretical framework we introduce a systematic approach and explain the various terms;
- Chapter 4 reports a field study to collect data needed to provide input for the studies;
- Chapter 5 reports a study aimed to understand the domain expertise of product planners in conducting automotive product planning activity. The study involved interviews of automotive designers. The designers then collaborated in proposing novel automotive design solutions based on affective design. The findings of this study, provides a basis for validation of the effectiveness of the proposed framework;
- Chapter 6 presents three case studies on automobile parts to validate the application of proposed method in Chapter 3; and
- Chapter 7 summarizes the achievements, along with recommendations for future research.

Chapter 2 – Literature Review

Recently customer seems to prefer products which bring pleasure and happiness. Hence, product designer must consider affect and emotions when designing product. The goal of design is not just functionality, but how to maximize customer value including affect and emotions associate with products. Solvic et al. (2002) claimed that affect plays a central role in dual-process theories of thinking, information processing and decision making. When making decisions, feelings are consciously or unconsciously associated with cognitive representations of the decisions.

In this chapter, the literature is reviewed to provide a foundation for developing a theoretical framework, which is presented in the following chapter. This chapter begins with an analysis of emotions and products. We then examine how product can elicit or induce positive or negative affect. Current processes for automobile design and frameworks for Affective Evaluation, Axiomatic design and Design Equations for System Analysis are reviewed.

2.1 Emotions and Products

2.1.1 Emotional Roles of Consumer Product

There is a need to analyze the relationship between product and emotion. Not every consumer product is able to invoke emotions. Holman (1986) identified five roles that product can play in consumers' lives. The roles vary in importance to the consumer, and the associated emotions typically increase with product price. The five roles that product can have in consumer's life are:

- Background
- Mediator to interactions
- Enhancement
- Expression of identity
- Object of emotions

Table 2-1 Holman's (1986) five emotional roles of consumer products

Role of Product	Product involvement	Source of emotional association	Examples
Background	Extremely low	Product as part of scene in which important emotional events occurs	Grooming product, furniture
Mediator to interactions	Moderate low	Quality of the interactions occurs because of product	Communication items, collections, souvenirs
Enhancement	Moderate high	Success or failure at the role performance using product	Food, cosmetics, music
Expression of identity	High	Degree of self-esteem	Cars, house decoration
Object of emotions	Extremely high	Pleasure at sensory/aesthetic dimensions	Cars, collections

Table 2-1 shows the Holman's five roles. This classification might not be complete. However as it analyzes the emotional roles of products, it can serve as a base for affective product evaluation. In this classification, cars are identified as symbols of identity and objectives of emotions, and the product involvement is very high.

2.1.2 Affect and Cognition in Product Design

Endowment Effect

Thaler (1980) referred to the "Endowment effect", which means that once people possess an object, they tend to value it more than before they possessed it. There is a certain degree of inertia introduced into consumer choice, since goods that are included in endowment, are highly valued.

For example, a person bought a bottle of wine in late 80's for about \$5, but he refused to sell it for \$100 per bottle after a few years. The endowment effect can explain this behavior. Over time, there is an emotional attachment to the product, which makes it more valuable.

Brand Effect

The brand also affects consumers preference (Mahajan & Wind, 2002). Certain brands of cars have good reputation as reliable cars, such as Honda and Lexus. For customers who are strongly influenced by reliability; these brands would be preferred in choosing a car. Brands like BMW and Mercedes are viewed as symbols of status and success. They have higher price, quality and prestige, and would be preferred by customers who seek status. Moreover, Fiat 500 cars are seen as cute symbols.

Marketers have realized that emotions play a key part when a customer makes a purchase decision (McEwen, 2004). For products that are frequently updated, such as mobile phones, and automobiles, each new generation brings different features which appeal to cognitive evaluation, but affect is also embedded in the product choice. People endowed with a certain brand would continuously upgrade to a product of the same brand. For example, Apple Macintosh adopts an affective strategy to create an emotional link with customers. Here affect produces a positive evaluation of the brand, and the induced affect results in a continuous commitment (Evanschitzky et al.2006).

Mahajan and Wind (2002) pointed out that customers who are emotionally connected to a product are less price sensitive, as long as their emotional needs are satisfied. They proposed the combination of affective and cognitive perspectives, where the cognition depends on the logical evaluation. Affect provides a motivation to purchase without being confused by complicated cognitive arguments, even when purchasing expensive products such as cars. It is better to capture customers by affect than by detailed information. However, both perspectives are important to the success of a product, and in this dissertation the focus has shifted to the affective side.

Mahajan and Wind (2002) noted that affective design features can help the product to look outstanding, and increase customer satisfaction. This is illustrated by Kano's model.

Kano's Model

Several important methods relate to customer-oriented design, such as Kano's model (Kano et al.1984) and Quality function deployment (QFD) (Akao, 2003).

In Kano's model, customer satisfaction and dissatisfaction are two independent variables. The objective is to support product design that can enhance customer satisfaction. The product attributes can be divided into categories, as defined in Figure 2-1.

Figure 2-1 Kano's model of customer satisfaction (Kano et al., 1984)

1. As shown in Figure 2-1, the horizontal axis represents product functionality, and the vertical axis represents satisfaction/dissatisfaction. The 45 degree line in Kano's diagram marked "One-dimensional" indicates customer satisfaction as a function of functional features.

2. The upper curve in the diagram refers to “delighter” or “attractive factor”. These are features which the customer did not expect, but that he/she finds delightful. It could refer to visual attributes are some functionality features that are not really necessary, but are appreciated – such as a GPS navigation system of a car. These features increase customer satisfaction.
3. The lower curve marked “must haves” reduce “dissatisfactions”, but don’t increase “customer satisfaction”. These are expected functional features. For a car, a well-designed dashboard is expected.

Considering automobiles, the three types of product attributes are explained as follows: gas mileage is likely to be a one-dimensional customer requirement, better gas mileage provides more customer satisfaction and worse gas mileage is a source of dissatisfaction. Automobile customers may not be dissatisfied if there is no retracting radio antenna. However, if having more special features which excite the customers would quickly increase the satisfaction level. Good brakes are expected and do not raise customer satisfaction, as they are must have requirements (Walden et al.1993).

We noted that Kano’s model emerged from a model of job satisfaction/ dissatisfaction, namely Hertzberg’s two factor theory of job satisfaction (Hertzberg, 1966). The motivational structure of product satisfaction is very different from job satisfaction. Hence, Kano’s model needs to be validated.

Quality Function Deployment (QFD)

QFD is a work template that can be used to derive product design parameters and customer needs (Akao, 2003). QFD provides an opportunity to conceptualize a product before design and implementation. QFD can identify customer priorities. However, QFD focuses more on functional requirements than affective requirements.

The intent of QFD is to incorporate the customer needs into all the phases of product development cycle, through production and into the market (Cristiano et al.2000). House of Quality (See Figure 2-2) is a tool for translating qualitative customer requirements into design characteristics, which based on customer's perspective and values (Hauser & Clausing, 1988).

Figure 2-2 Examples of “House of Quality” (Hauser & Clausing, 1988)

Affect versus Cognition

Products are often quite similar with a list of technical specification, functionality and quality. It is difficult to predict customer's purchasing behavior in such competitive situations. The final decision may, however, be triggered by emotional response. Hence, it is important to study emotions in customer's choice.

Affect and cognition are both vital in designing products. Affect is used to evaluate and judge, while cognition is used to interpret and make sense of the world, the objects, and understand the user (Norman et al.2003).

Cognition refers to “the head”, while affect often refers to the “heart”. Table 2-3 summarizes the distinctions between them:

Table 2-2 Distinctions between affect and cognition (Norman et al., 2003; Plassmann et al., 2005; Khalid, 2006)

Affect and Emotions	Cognition
Judge the preferences	Evaluate the correctness
Instigation to action	Less linked to behavior
Expression are fairly universal across cultures	Restrict to certain language, not cross-culture
Reactions are primary and could happen without cognition awareness	Required sufficient and subjective information input, and accompanied by affect
Affective evaluation of a product involves a low level of arousal	Cognitive interpretation involves a deeper understanding of a product and human behavior

Recent research indicates that emotions play a role in rational decision making, perception, and various cognitive functions, such as how you feel, how you behave,

and how you evaluate objects. Without affect and emotions, people are unable to consider and make decision between alternatives. According to Damasio's (1996) study on affective heuristic, positive and negative feelings are linked either directly or indirectly to the somatic states, which are used to predict the future outcomes. When the affect heuristic is employed positive feeling, namely "somatic marker", it becomes an incentive, and vice versa. The presence of such somatic marker could aid the decision making process, which increases in accuracy and efficiency. On the other hand, absence of such somatic marker could degrade decision performance.

Plassmann et al. (2005) investigated how affect and cognition influence customer decision making. Their results suggested that the choice of customer lead to a specific modulation of neural brain activity, and could be explained as neural correlate of affect heuristic concept. They found that a famous brand could induce a positive influence of emotion on the decision making during the evaluation process.

Integrate Affect with Cognition

Figure 2-3 explains the relationship between affect and cognition, cognition must consider affect, while affect and emotions guide the analytical cognitive system. Affect is used to make feeling responses; cognition is used to understand the user experience, which may include a deeper, rational understanding of product and behavior (Khalid, 2006) .

Figure 2-3 Coupling of affect and cognition (Khalid, 2006)

When humans are exposed to the outside stimulus, both the affective and the cognitive systems respond, but they process the information separately. In another words, both cognition and affect take part in information processing. The affective system is fast and intuitive, sometimes even subconscious. On the other hand, the cognitive system is slow. It uses analytical and rational thinking in interpreting and making sense of the world (Norman et al., 2003). As proposed Figure 2-3, customer integrates both aspects in evaluation at production design – and so should the designer.

2.1.3 Theory of Reasoned Action

The theory of reasoned action was developed by Fishbein and Ajzen (1975). They explored how beliefs, attitudes, intentions and behaviors develop over time, see Figure 2-4. The objective of this theory is to analyze underlying reasons for behavioral intentions, which are then the precursor of a person's behavior.

figure 2-4 Theory of Reasoned Action (Fishbein & Ajzen, 1975)

However, the main factors which influence intention are the attitude toward the behavior and subjective norms (SN). Attitude towards the behavior involves the beliefs about the particular object, which are the perceived outcome of the behavior, and evaluation of possible outcome, which might be positive, negative or neutral evaluation. For example, in buying a car, the possible beliefs could be enhancement of personal image, utility, performance of the car, etc. The subjective norm refers to an individual perception of the beliefs around the person, like parents, friends, partners, etc. and how the perception influences whether or not to perform the behavior. The general subjective norm could be measured by normative beliefs and motivation to comply.

The theory of reasoned action explains how belief, attitudes, intentions and behaviors are developed and changed over time, which is helpful to understand customer's preference in product evaluation.

2.1.4 Positive Affect in Decision Making

Creativity is crucial to the success in designing product (Picard, 1998). Positive affect may promote creativity and flexibility in problem solving, and efficiency in decision making (Lee & Sternthal, 1999). Creativity is the ability to create, and it is associated with the ability to combine ideas and elements together. Research has found that positive affect improves the ability for problem solving, creativity, selection of appropriate strategies, and effective decision making (Norman, 2004).

Positive affect has a significant impact on creativity in design activities, such as problem solving, recognizing and understanding relationships between design features, and integrating information (Picard, 1998).

Positive affect is likewise important in decision making, motivation and social activities (Mäkelä, 1999). Swinyard (1993) cited the role of involvement in product evaluation. He affirmed that when customers are engrossed with the product, they likely give a positive evaluation. Mano & Oliver (1993) stressed that involvement is important, because customers who have high involvement in the product experience high levels of arousal and stronger reactions.

To further elaborate this point, it is needed to investigate the role of positive affect and emotion in design. Norman (2004) addressed that with positive affect, neurotransmitter broaden the brain processing. Hence, positive affect arouses curiosity, creativity and lead the brain into a more effective and active working state. Positive affect such as pleasure or happiness could be induced in many different ways, such as aesthetic

pleasing visual appearance, the joy of using the product like the sense of control, or the enjoyable and memorable experiences; or the combinations of them.

2.1.5 Summary

In this section, we have reviewed several theories for affect, cognition and product design. The following table (See Table 2-3) summarizes each theory dedicates in which aspect and how to associate with this research.

Table 2-3 Summary of theories

Methods	Affective	Cognitive
Basic Emotions (Ekman, 1999)	Y	
Emotional roles of consumer product (Holman, 1986)	Y	
Endowment effect (Thaler, 1980)	Y	
Brand effect (Mahajan & Wind, 2002)	Y	
Kano's model (Kano, 1984)	Y	Y
Quality Function Deployment (QFD) (Akao, 2003)		Y

From this summary we find that except Kano's model, the other methods address reflect either affective or cognitive aspect. Basic Emotions (Ekman, 1999) and Emotional roles of consumer product (Holman, 1986) discuss about the relationship between product and emotion. While Endowment effect (Thaler, 1980) and Brand effect (Mahajan & Wind, 2002) basically explain the construction of emotional attachment and connection between customer and product. Kano's model (Kano, 1984) is used to uncover the characteristic of customer requirements, but it is not used for transforming the design of a product. At last, QFD (Akao, 2003; Hauser & Clausing, 1988) is used to derive and prioritize customer's needs and design parameters, but focus on functional rather than affective aspects. Among all the methods presented, only Kano's model has cover both affective and cognitive, while it is not used to transform the customer needs to actual design of a product.

Hence in later part of this report, we will propose a new framework which could integrate and utilize affective and cognitive aspects of customer requirements, while it can also be used for inspiring detailed design.

2.2 Design Planning

Products are designed to appeal to customers' needs and preferences. The appeal of products depends on the level of processing employed in a situation. How could aesthetic affect the ease of use? Norman (2004) investigated the interaction of affect, behavior and cognition.

2.2.1 Norman's Three Levels of Design

Norman (2004) mapped three levels of processing into different design characteristics, see Table 2-4.

Table 2-4 Three levels of processing associate with brain mechanisms and design characteristics (Norman, 2004a)

Level of Processing	Brain mechanisms	Design characteristics
Visceral	automatic, pre-wired layer, the most primitive part of brain	Appearance, look
Behavioral	brain processes that control everyday behavior	the pleasure and effectiveness of use
Reflective	contemplative part of the brain	self image, personal satisfaction, memories

This processing structure functions top-down driven by cognition; as well as bottom-up, driven by perception. We note that for reflective level, there is no direct access from

sensory input or to control behavior. The vertical arrows indicate the effects and interactions within each level.

It is important to explore the differences and implications of visceral, behavioral and reflective design. This can be explained by looking at different consumer product.

First, the visceral level of processing sends appropriate signals to muscles and brain. For example, Apple Macintosh is a typical product with visceral design; it is appealing mostly due to its appearance, unique and simple look. Here affective processing is directing the purchase decision. There are several product forms that designers use, including shape, color, ornamentation, and texture (Lewalski, 1988). Color, can elicit tension, calmness, and arousal (Bellizzi & Hite, 1992). Round shapes connote softness and continuity while angular and sharp shapes are perceived as abrupt (Fagerberg et al.2004).

The behavioral level of processing is subconscious and the basis of skill development. Products should be designed for ease of use and manipulation. Products may be chosen solely because of functionality and ease of use, which enhance user satisfaction. This level is vital, because poor behavioral design can lead to negative emotions such as anxiety, frustration and even stress.

The visceral and behavioral levels are often subconscious and represent automatic behavior. The reflective level is conscious; the user reflects about the design. Designers should therefore firsthand consider the conscious needs of customers such as to enhance an image, or comply with the current design trends.

Reflective processing is accessible through memory. This has to do with culture and experience which have made an expression. In the reflective mode, we think about these and then guide our task and decision to particular experience. Reflective

processing can enhance or inhibit behavioral processing, but has no direct access to visceral reactions.

Czicksentmihalyi (1992) also addressed the behavioral level. He noted that a task can sometimes become very engaging, because the user is fully immersed and forgets about time and place. This is for example the situation with many computer games – but also activities such playing in an orchestra and solving math problems. Czicksentmihalyi referred too this as a *flow state*. It can lead to increased motivation and addiction. The common obsession with games is also generated by a need for “virtuosity” – a proven need in the human need structure (Kubovy, 1999). The flow state may be achieved by a thoughtful design of controls. In the case of games the question is if the controls are compatible with user movements, and if they afford smooth actuation and are easy to handle. Hence issues of usability must be considered.

We can conclude that designing for each of the three levels requires different strategies:

- Design at the visceral level may seem straight forward. For example, many users would prefer cars that offer visual appeal – they are cute, sporty or prestigious, and so forth.
- Design at the behavioral level often entails a usability and functionality evaluation.
- For design at the reflective level, one would rely on the customer’s taste, which has developed over the years. It based on life-long experience, which forms the basis for a person’s taste and preferences.

2.2.2 Examples of Automotive Design at Each Level

In this section, several examples are presented to further demonstrate how designs can play a role at the three levels. Some may focus on only one level, and some designs play at combinations of different levels. A few automotive designs have been discussed in relation to Norman’s three level of design.

1. Toyota CS&S

Figure 2-5 Toyota CS&S 2006 (Gordon, 2006)

Toyota CS & S (Compact Sports & Specialty), is a 2+2 convertible sports car (Gordon, 2006), see Figure 2-5. This is an example of design which is fulfilled at all three levels, but visceral and reflective designs have probably greater influence compare to behavioral design.

- Visceral: sleek, timeless, clear contrasts, between sharp, angular lines and fluid curves and arches, visually pleasing. Front car body looks like human face, unique design.
- Behavioral: Toyota's advanced Hybrid Synergy Drive system (HSD).
- Reflective: a design that is in agreement with one's taste. Perhaps it also increases prestige and one's self image.

2. Honda Civic EK9 Civic Type R

Figure 2-6 Honda Civic EK9 Civic Type R 1997

(http://images.businessweek.com/ss/06/03/honda_civic/source/4.htm)

- Visceral: not very exciting.
- Behavioral: great handling, great gas mileage, ease of use, safe, practical, outstanding reliability and durability.
- Reflective: Not a car to reflect status.

Figure 2-6 shows Honda Civic, which is well known for its great performance, reliability and affordable price. Though the appearance is not so interesting, it is a good example of automobile design that focuses on behavioral design, the function, utility, and physical feel.

3. Bugatti Veyron 16.4

Figure 2-7 Bugatti Veyron 16.4 2006 (Wikipedia Foundation, 2007)

The Bugatti Veyron 16.4 (see Figure 2-7), is currently the fastest, most powerful, and most expensive street-legal full production car in the world, with a proven top speed of 253 mph (407.5 km/h) (Wikipedia Foundation, 2007). According to Forbes magazine, Bugatti Veyron was the most expensive car in 2006 (Lienert, 2006). Although visceral and behavioral designs are great, reflective design plays a major role here.

- Visceral: very fast, thrilling, attractive, etc.
- Behavioral: great performer, not very easy to handle, not very comfortable.
- Reflective: status symbol, limited, exclusive, self-image, show off.

2.2.3 Culture and Social Issues in Emotions

Customer expectations and requirements depend on culture characteristic and social circumstances (Demirbilek & Sener, 2003). Individuals in Europe and USA are more likely to feel engaged compared to individuals in Asia (Scollon et al.2004). The pursuit of happiness is written into the American culture, and is an important element that guides behavior. While the Asian culture does not seem to favor the positive; pleasant and unpleasant feelings are fairly equal (Mesquita & Walker, 2003). Hence, cross-cultural differences in affect should be taken into account in this research.

Figure 2-8 Truck Painting in Pakistan (www.moleskinerie.com/travel/index.html)

Figure 2-10 shows a truck in Pakistan. These trims from shining metal, shimmering rosettes, wood carvings, colorful chains and calligraphies decorate the trucks. The decorations reflect of Pakistani's culture and popular personality (www.moleskinerie.com/travel/index.html).

Cultural differences are also noted in Norman's three levels of design (2004). The visceral level is not very much affected by culture. In contrast, the behavioral and reflective levels are very sensitive to experience, and the cultural impact is much larger. Trends and demographics issues such as age, gender, living arrangements, need to be considered in design.

2.3 Current Process for Automobile Design

Vehicle design refers to automobiles as well as to cars, trucks, motorcycles, trucks, and buses. The design and development of a modern motor vehicle is typically done by a cross-functional team which incorporates many different disciplines. Figure 2-9 shows a design development process in the automotive manufacturing company (CRF et al.2007).

Figure 2-9 Design process of automotive company (CRF et al., 2007)

The three major design stages documented by the company as described by subjects were:

- 1) Conceptual development
- 2) Design development
- 3) Engineering and testing development

Conceptual Development

The conceptual development stage starts with concept formulation. Various units contribute in this phase; the main drivers are marketing, product planning, styling and engineering departments. Important factors are decided, such as forecasting future customer demands and determining the target customer segment for the vehicle.. This affects the goals and constraints of subsequent design issues. The management will then decide upon the feasibility and grant approval to promising concepts.

Design Development

Design development commences with digitizing designs and creating clay models. Until this stage is finished, the exterior styling of the car is of primary consideration. Upon clay model approval, a technical feasibility study is conducted to look into the rationality of the body engineering issues and interior systems set up. After these stages, the model will be fixed.

Engineering and Testing Development

This portion is similar to the detailed design phase. The interior architecture and part selection are done by the styling and engineering design divisions. Individual part drawings are produced. A complete vehicle prototype will then be built and tested by the product testing department in various areas including safety and material quality. Preparation work will then be carried out for mass production purposes.

Due to the different emphasis placed as the design develops the composition of teams may vary slightly throughout the design phases. It is observed that most of the details spelt out contain technicalities in terms of model making and engineering related work.

Above is a simple illustration of current process for automobile design; however, it should be noted that, each company is adopting its unique design process and method.

2.4 Theoretical Framework for Affective Evaluation

We would like to discuss a framework of affective design evaluation proposed by Helander & Khalid (2006) as shown in Figure 2-10. The framework is divided into two parts: the designer's environment and the affective user experience. The framework is divided into two parts: the designer's environment and affective users experience. The designer's environment shows the designer's considerations in incorporating affect into the design of the product, while the affective user experience explains how affect is elicited in the process of product inspection and evaluation.

Figure 2-10 Framework for Affective Design Evaluation (Helander & Khalid, 2006)

We note that some concepts need to be explained in the framework. Hence, we need to develop a new framework to address the following issues:

- To transfer from designer's environment into user evaluation, we added the central "box" in the proposed framework.
- Additional factors need to be considered to illustrate designer's consideration or constraints.
- In the affective evaluation phase, customer information processing needs to be analyzed.

2.5 Design Methods

2.5.1 Axiomatic Design

The purpose of Axiomatic Design is to reduce complexity in design, it used matrices to analyze the transformation of customer needs into functional requirements, and further transform the functional requirements into design parameters and eventually process variables for manufacturing (Suh, 1990). Design problems can be divided into four domains: customer domain, functional domain, physical domain and process domain. This systematizes complexity analysis and hence facilitates complexity reduction. The principal concepts of axiomatic design can be summarized as follows:

- Design domains are used to group similar types of attributes in design.
- In a domain, the attributes form a hierarchical structure.
- Decision making in design is perceived as a mapping process between attributes that belong to two adjacent domains, such as between functional requirements and design parameters.
- Design equations are used to represent the mapping between domains.

According to Suh (1990; 2001), a design equation is written as:

$$\{FR\} = [A]\{DP\}$$

Where: $\{FR\}$: A vector of functional requirements

$\{DP\}$: A vector of design parameters

$[A]$: Design matrix

Functional requirements $\{FRs\}$ represent design goals, or what a designer wants to achieve. Design parameters $\{DPs\}$ represent design solutions, or how the designer plans to achieve the design goals. In other words, there is a means-ends relationship between FRs and DPs.

The design matrix of a design with three FRs and three DPs is of the following form, shown below:

$$[A] = \begin{bmatrix} A_{11} & A_{12} & A_{13} \\ A_{21} & A_{22} & A_{23} \\ A_{31} & A_{32} & A_{33} \end{bmatrix}$$

Conventionally the values of A_{xx} in a design matrix will be either 'X' or '0', where 'X' represents a mapping between the corresponding vector components while '0' signifies no mapping.

This methodology can be used to reduce the information (complexity) in design by minimizing couplings between the domains and information in design. Decision making in design is thereby described as a mapping process between two adjacent domains, such as between functional requirements and design parameters.

2.5.2 Design Equations for System Analysis (DESA)

Design Equations for System Analysis (DESA) is a formal design method, which can minimize functional dependencies in human-machine system. DESA builds on Axiomatic design, but is different (Lo & Helander, 2007).

Figure 2-11 Design Equations for System Analysis (DESA) Framework (Lo & Helander, 2007)

DESA framework consists of four design domains (Figure 2-11). Each domain consists of a number of design attributes. DESA framework makes use of Axiomatic Design's functional and physical domains.

The functional domain contains a set of functional requirements, which characterize the function of a system, and used to achieve the user goals. The physical domain contains design parameters, which are physical variables that are selected by designers to satisfy functional requirements, and also controlled by the user actions. User goals are formulated in terms of the user's desired state of the system, such as "desired amount of light in the room". Functional requirements are formulated in terms of engineering functions of the design artifacts, such as "provide a range of illumination". Design parameters are formulated in terms of engineering parameters of the machine or device, such as "electrical resistance". User actions are formulated in terms of user operations, such as "rotate light switch" (Lo & Helander, 2007).

Design equations are used to represent the mappings between four design domains:

$$\{UG\} = [A]\{FR\}$$

$$\{FR\} = [B]\{DP\}$$

$$\{DP\} = [C]\{UA\}$$

Hence, $\{UG\} = [U]\{UA\}$

And, $[U] = [A][B][C]$

Where: $\{UG\}$: A vector of user goals

$\{UA\}$: A vector of user actions

$\{FR\}$: A vector of functional requirements

$\{DP\}$: A vector of design parameters

$[A]$ or $[B]$ or $[C]$: Design matrix

DESA makes a system less complex by identifying the couplings in the system, and then proposing new design solutions that will de-couple the system. Subsequently, human performance will improve while decision time and human errors will be reduced.

However Axiomatic Design and DESA address only the functional needs and functional requirements, in this research, we are going to involve the affective needs and affective requirements in the design matrix in later chapters.

Chapter 3 – Research Methodology for Affective Design and Evaluation

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This chapter reports on the development of a theoretical framework and method for affective design. They are based on Norman's three levels of design, Axiomatic Design (Suh, 1990), Design Equation for System Analysis (DESA) (Lo & Helander, 2007), and other relevant models and theories. We also proposed customer's Affective Requirement Hierarchy (ARH) to study and understand customer's evaluation process top-down, from overall evaluation associate to detailed design features. Axiomatic Design and DESA are both systems design method which can be used to analyze the transformation process of customer needs into functional requirement. In this research, Design Equations for Citarasa Analysis (DECA) is developed, which adopts the DESA model while incorporating information regarding affective requirements. Hence Axiomatic Design and DESA are used as foundations of development of DECA. At the end of this chapter, customer interview are performed for collecting data needed.

3.1 Proposed Framework for Affective Design and Evaluation

We adopted the Helander and Khalid's framework (2006) and developed a framework for Affective Design and Evaluation, which fits fit the CATER project context, see Figure 3-1.

Figure 3-1 Revised framework for affective design evaluation (Adapted from Helander & Khalid, 2006)

Here are some important issues we would like to address in the proposed framework, which are essential for the success of the design:

- How the three levels of design influence the design planning phase?
- How to transform customer's affective and functional requirements into specific design features?
- How to evaluate and validate those design features for both the designers and customers?

The proposed framework in Figure 3-1 is divided into three parts, namely the Product Development Environment, Formulation of Design Equations for Citarasa Analysis (DECA), and Summative Evaluation of Design. The product development box shows the designer's considerations in incorporating affect into the design process. The formulation of the DECA method demonstrates how the designer transform customer affective and functional requirements into corresponding detailed design parameters by using a specific design matrix. The summative evaluation of design explains customers' evaluation of the product in both the cognitive and the affective systems.

This proposed framework is intended as a design aid for designers. In the proposed framework, the left box illustrates the methods, considerations and constraints that a designer can used in proposing a new design. One of the methods is Norman's three levels of design. Constraints are formulated and they may come from Marketing and Context of use/activities, as well as current Trends. All these have been included in the proposed framework.

The second box simply illustrates that design parameters can fulfill both affective and functional requirements. Alessi lemon squeezer (Figure 3-2) provides an illustration. (<http://www.foodprocessors.org.uk/juicers.htm>) Most other lemon squeezers have not been designed with affect in mind.

Figure 3-2 Alessi lemon squeezer (FoodProcessors.org.uk, 2007)

The third box illustrates two important issues:

- The variability in customer needs and attitudes
- The joint decision process incorporating affect as well as cognition

This part is included to make designers reflect on the affective-cognition shift in customer appreciation.

In reviewing literature, it was noticed that expensive and expressive products usually involve high emotion. In the affective evaluation system, the theory of reasoned action developed by Fishbein and Azjen (1975) clarifies how Believes, Attitudes, Intentions and Behaviors form over time. These are useful to understand and predict the customer's behavior. It often takes a year to decide what car to buy, and during this time, there is a progression from Believe car to Intention and Behavior (the purchase) (Khoo, 2007).

On the other hand, in the cognitive evaluation system, the customer employs previous experience and knowledge to deliberate whether a product fulfills his/her functional needs. The reliance on past experience is also reflected in the Human Information

Processing model (Wickens & Hollands, 1999). Affect and cognition interplay with each other in influencing decision making and evaluation. In addition, the each individual's needs may further affect the person's overall evaluation of the product.

Citarasa Concept

Designer needs to understand user requirements prior to product conceptualization. These requirements may be classified as functional or affective. In this framework, the basis of customer needs is the customer's *Citarasa*. *Citarasa* is a Malay term that refers to emotional intent and aspirations (Khalid, 2006). To investigate intent, we assume that there is an explicit identification of the user's functional and affective requirements when buying a car or truck. *Citarasa* is generated from the visceral, behavioral and reflective needs of the customer or the search for pleasure of the mind.

Citarasa is different from the rather passive emotions that may be experienced during or after a purchase of a product. There is a strong intentional component of *Citarasa*, which has the implication that customers are actively seeking design features that they believe are important for their satisfaction. The customer's *Citarasa* is an expression of need and taste. In terms of a car, one *Citarasa* might be "elegant". The descriptor can be related to numerous characteristics such as color, shape, size and capacity that designers can manipulate to satisfy customer needs. The nature of these needs is discussed in the following sections. Gathering relevant *Citarasa* of automobiles buyers can therefore enable designers to comply with functional requirements and affective requirements of the customer.

Affective Design – the Three Levels

We can conclude that designing for each of the three levels requires different strategies:

1. Design at the visceral level seems straight forward. At this level, physical features dominate, such as appearance, sound, touch, feel and smell. Design concern here is

related to the customer's initial sense that perceives the product, before the customer goes to a deeper evaluation stage.

Effective visceral design requires a good combination of industrial design skills. For example, many customers prefer cars that are cute, powerful and sporty. These requirements can be specified and associated with several design features. Take "Pleasant" for example, which can be decomposed into lower attributes like color, sound, feel, and so on, and subsequently be associated with specific design features, as illustrated in Figure 3-3.

Figure 3-3 Example of breakdown affective requirements into lower levels

2. Design at behavioral level often entails an evaluation of usability, performance and functionality. It is not about abundant features, and sophisticated technologies. Generally it is about the ease-of-use and a sense of command and virtually in control.

Examples of behavioral design issues in automotive design are: designing seat controls to allow easy seat adjustments; achieving long-term comfortable and seat ergonomics etc. At this level, the designer needs to observe and communicate with end-users who are using the product. To understand their real needs and thoughts, the product needs to be tested by the end-user and improved iteratively in order to achieve the required functionality and usability. This can be done by employing contextual inquiry (Beyer & Holtzblatt, 1998) or CDM, but not through questionnaire and focus group.

Good behavioral design is customer-centered; the idea is to offer pleasure and fun of using and manipulating the product, and eventually, sense of control and error prevention. Behavioral design should be an iterative process, from simple pictorial representations like drawings, mockups and sketches, to the prototype and finally the product.

3. For design at the reflective level, it may require developing an image that reflects upon the customer's sense, status, or value. This is the most challenging part. It has nothing to do with the appearance or the performance; it is all about the semantics of the product – the meaning and image that is presented to customers (Krippendorff, 2006).

In the literature review, we referred to Holman's (1986) five roles that product could play in consumer's emotional life. Obviously, different types of consumer products elicit different levels of affect and emotions, either positive or negative. Automobiles are considered as high emotion involvement products. Other than their functional use, cars can also help people establish a cultural identity, social status and image. For example, Mercedes Benz can reflect elegance: the owner is perceived to belong to a higher social or economic class. However, to some academics driving in around in a Mercedes Benz would be outright embarrassing. A Mini-Cooper, on the other hand, may be associated with young, energetic, and

fun-seeking people. Ferrari sports cars almost always serve as status symbols for the young, upper class, wealthy.

Clothing is another example of how designers can utilize the reflective level, especially the social status. An exclusive and elegant style can suggest the wealth and taste of the owner. Satisfying visceral and behavioral levels are sufficient but not necessary conditions for a perfect design. In other words, unattractive or impractical products can also bring pleasure, which is the positive affect from conscious reflection, such as memorable experiences, cultural associations or brand images. Unattractive products can thus subsequently become attractive. Hence, effective reflective design is vital to the success of product design.

3.2 Proposed Customer Affective Requirements Hierarchy (ARH)

The approach to affect and emotions can be deliberated on many different levels, each of which suggests different insights (Demirbilek & Sener, 2003). When customers were asked to evaluate the product, they may just say something as simple as: “I like it. What a nice design!” However, the statement has little meanings for designer. In product design, designers need to visualize and elaborate the words into actual requirements and design features. They need to be creative to design something that is “nice” to the customers. The problem here is twofold: 1. how can designers understand and interpret a customer’s statement like this; 2. how to achieve a “nice” design?

The proposed customer affective requirements hierarchy

Products affect is an important factor to success in launching a new product. Thus, it is necessary to emphasis the affective evaluation criteria at the same importance as cognitive evaluation, particular in the early design stage (Lee et al.2004).

In this research, it is vital to find out how customers evaluate a product and what the evaluation criteria are. Affective and emotional needs such as styling and user-friendliness, which is difficult to quantify, have been important factors with multitude of products having similar performance. Hence, we have developed an affective hierarchy of customer's affective requirements to better understand customer's evaluation process.

Figure 3-4 Mechanism of Affective Requirements Hierarchy

Figure 3-4 above illustrates the internal mechanism of proposed Affective Requirements Hierarchy (ARH). The general ARH proposed employs a hierarchical structure with top-down customer-oriented architecture, represents the general transition from customer's evaluation to designer's consideration is shown. This structure can be understood as an association process of customer's selection/perception of specific product to detailed design parameters. This proposed

ARH can help the product designer conceptualize the complex relationship between customer subjective evaluation and design element/design parameters. However, the evaluation process is complicated which varied with different evaluation (in terms of descriptors), due to the cross-feature relationship within design. Some design elements may influence a few subjective evaluations at the same time, which probably increase the complexity of the whole model.

In this five-level ARH (see Figure 3-5) the highest level is customer selection; follow by the general perception of the car, which is represented as a simple sentence. Further exploring on what are/is the imposed customer requirement(s) embedded on the evaluation. At this stage, it would be good to restrain a small number of customer requirements to reduce the complexity of ARH. It is noted that customer usually uses either descriptors (adjectives) or specific design feature (such as headlight, car body, etc.) to describe their requirements.

Figure 3-5 Abstraction Requirements Hierarchy (ARH)

To elicit customer's evaluation and detailed requirement, we need to understand customer's words/voice first. Questions such as "what parts/features motivate you to buy the car?" should be ask in this case. Additional probes like "Why?" and "How to achieve this feature?" can enable a deeper understanding of customer behavior.

Figure 3-6 illustrates an example of how customer's overall evaluation can be broken down into lower levels of affective requirements, and classified into different levels of affective design. The process starts from the customer and flows on to the designer.

Figure 3-6 Example of customer Affective Requirements Hierarchy (ARH)

Customer's Core Evaluation - Laddering Technique

The laddering technique has been used to identify key linkages between customer's core evaluation into product attributes and further design elements (Rugg & McGeorge1995). Many methods in knowledge acquisition can be used, such as interview, protocol, ethnographic study, and observation.

Future Work

Due to the limitation of resources of current study, further research in this framework will not be pursued at this time. This proposed ARH framework serves as a fundamental guideline as how customer needs are understand and classified. Hence this could serve as ground for future work, but nonetheless it is worthy of mentioning to understand customer's holistic evaluation.

3.3 Design Equations for Citarasa Analysis (DECA)

3.3.1 Overview

Figure 3-1 gives an overview of what the proposed framework; the box in the middle (see Figure 3-1) illustrates how Design Equations for Citarasa Analysis (DECA) can be used to transform functional and affective requirements into design solutions. This DECA method is adapted from DESA proposed by Lo and Helander (2007). Axiomatic Design is a well-developed method used in design, while DESA has been demonstrated to reduce the complexity effectively. In this research, DECA is developed by adopting DESA and at the same time involve affective requirements. Hence Axiomatic Design and DESA described in literature review section are used as theoretical foundation of development of DECA.

The major difference between DECA and DESA is that DECA considers customer's affective needs and corresponding affective requirements as well as functional aspects. This can assist the designer to consider both affective and functional design at the same time. In this research, we will use design matrix to structure this design process and try to reduce the complexity of design.

Figure 3-7 Formulation of DECA

Figure 3-7 below illustrates the data flow process of DECA. Customer's needs are considered from the beginning of the product development cycle, which coincides with the objective mentioned-above to actively and effectively involve and consider the true needs. The inputs can be the results from customer survey after data analysis, and they can be classified as functional needs and affective needs. For example, considering a car dashboard, customer functional needs can be active night use, while affective needs can be induce sporty feeling. Functional and affective requirements can be extracted accordingly and mapped into design parameters, followed by an evaluation of users, and feedback to the designers. The feedback loop shown below is essential, as it provides important information about what actions have actually been accomplished, what results are actually achieved, and indicate what parts need to be redesigned or refined.

3.3.2 Linkage between DECA Mapping and Citarasa Database

Where: FR: Functional requirement
 AR: Affective requirement
 DP: Design parameter
 $[A]$: Design matrix

Figure 3-8 Linkage between DECA mapping to Citarasa Database

Figure 3-8 demonstrates the underlined linkages between mapping results of DECA and Citarasa Database in the CATER system. During development of Citarasa database,

several different pictures of car body/car parts are first shown to automotive customers. Then detailed customer requirements (CRs), including functional requirements (FRs) and affective requirements (ARs), are then extracted through means of survey or interview. Data gathered is transformed into a “Customer Requirements” matrix, which is stored in the Citarasa database.

Similarly, the same set of pictures (i.e. customization options) is shown to product designers/product planners from product planning and development team, who generate a corresponding set of design parameters (DPs). This information is represented in a DP matrix, which is also part of the database. Thereby it was possible to relate the CRs to the DPs by using an integrated design matrix. This is called “DECA mapping”, which illustrates in the figure above. As explained previously data mining can be used to extract relationships between a set of ARs and DPs.

Product design will always benefit from inspiration and creativity. Axiomatic Design can enhance creativity of designer by clear establishment of functional requirements and constraints (Suh, 2001). Likewise proposed DECA method can enhance creativity of designer by introducing and utilizing affective needs and requirements.

3.3.3 Definition of Terms

The following definitions are adapted and modified from DESA (Lim, 2006), and DECA adds affective components:

Customers: There are existing or future end users of a product; in the context of this research, automobile drivers.

User: User of design matrix are design team members.

Functional Needs (FNs): objectives and needs of customers obtained by interviewing them, for example, this can be obtained from cognitive walkthrough, which also represent users' thoughts. Here functional FNs focus on functional requirements of the product. This is related to the customers' behavioral needs regarding the three levels of design.

Functional Requirements (FRs): Product requirements which are associated with the functionality of products. Here it used in a "verb-noun" structure, such as change speed, control direction, etc. These actions show what the exact form of things are and what is happening, and what the designers want to achieve.

Affective Needs (ANs): customer's needs that are related to affective requirements of the product. These are very different from functional needs, for example, a usable product does not mean a pleasurable-to-use product. Hence, ANs focus on how to derive pleasure in using the product. Normally ANs could be represented as descriptors or simple statement, in terms of customers' emotional needs.

Affective Requirements (ARs): affective appraisals which are judgments concerning the product. Here could follow "adjective-noun" structure. Such as cute headlight, sporty shape, sexy color, etc. These could be elicited through interviewing a customer.

Design Parameters (DPs): detailed physical restrictions imposed on all possible solutions to satisfy FRs and ARs, and design solutions with which designers plan to achieve their design goals.

Mapping: mapping refers to the relationship between two objects, or translation from one set of parameters to another set of parameters.

3.3.4 Procedure

The procedure to employ DECA in the design process can be summarized into the following steps:

1. State product's domain and list target customers, both existing and potential ones.
2. Classify and prioritize functional user needs (FNs) and affective user needs (ANs) from Citarasa ontology and Citarasa database. The purpose of this step is to ensure that the most important needs are satisfied.
3. Define functional requirements (FRs) and affective requirements (ARs) related to functional user needs (FNs) or affective user needs (ANs), and suggest their corresponding functional / affective design parameters (DPs).

Sometimes all FNs and ANs can be satisfied by the selected DPs. Sometimes there may be trade-offs between alternative DPs. In this case the most important DP should, be selected. This implies that some FNs and ANs may have to be sacrificed.

4. Decompose ARs, FRs, and DPs into reasonable lower levels of responding hierarchy and arrange them in a design matrix.
5. Specify user scenarios.
6. Analyze the mapping and coupling between ARs, FRs and DPs. Conventionally, the values in a design matrix will be either 'x' or '0', where 'x' represents a mapping between the corresponding vector components while '0' signifies no mapping. However, as noted above, coupled designs are not desirable for FRs, but coupled designs are allowable for ARs.

Note that the mappings do not necessarily have to be uncoupled; Figure 3-9 illustrates the flow of DECA procedure.

Figure 3-9 DECA procedures

Understanding the customer's true needs is vital to the success of the whole process; hence Cooper's (1996) Goal-Directed Design can be adapted to understand the customer's needs in three levels. It emphasizes identifying user goals precisely before stepping into any formal design. He stated that: "To maximize the quality and effectiveness and make customer happy is to bring goal-directed design earlier in the design process." Questions like "Who is really using this product? What do you want to accomplish or achieve by using the product?" would be asked. Here the end-user of the product is the customer who purchases the automobiles, the drivers. Moreover, the customer's motivations, constraints and context can also be understood through this method.

Additionally, in this study, user needs included both affective and functional needs. Goal directed design combines techniques of ethnography, stakeholder interviews, market research, product/literature reviews, detailed user models, scenario-based design, and a core set of interaction principles and patterns.

Design Matrix

$$\begin{bmatrix} FR_1 \\ FR_2 \\ \vdots \\ FR_i \\ AR_1 \\ AR_2 \\ \vdots \\ AR_j \end{bmatrix} = \begin{bmatrix} x & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & x & 0 & 0 & 0 & 0 & 0 & 0 \\ & & \ddots & & & & & \\ & & & \ddots & & & & \\ x & x & 0 & 0 & \ddots & 0 & 0 & 0 \\ 0 & x & x & 0 & 0 & \ddots & 0 & 0 \\ & & & & & & x & \\ & & & & & & & x \end{bmatrix} \times \begin{bmatrix} DP_1 \\ DP_2 \\ \vdots \\ \vdots \\ \vdots \\ \vdots \\ \vdots \\ DP_k \end{bmatrix}$$

Figure 3-10 Design matrix involves affective requirements

Where FR: Functional requirement

AR: Affective requirement

DP: Design parameter includes design restrictions imposed on possible solutions

The design matrix in Figure 3-10, FR_1 is fulfilled by one DP_1 , FR_2 is fulfilled by DP_2 . However AR_1 also is fulfilled by DP_1 and DP_2 , while AR_2 is fulfilled by DP_2 and DP_3 . Therefore some design parameters can fulfill both the functional and affective requirements. This would be a successful design element since it combines “Form and Function”.

A tool such as axiomatic design will help to structure the design process, and prompt the designer to consider both affective and functional design. It will also make the designer aware of the importance of affective design and instruct him/her to make decisions that can promote affective design. It is therefore considered a helpful tool to designers. Future validations will test the validity of this hypothesis.

These mappings are based on the designers’ considerations and thoughts, but they may not be consistent with the customers’ thoughts, hence further validation by the customers is needed. During the user experience and evaluation, the differences between the designers and customers can be found and relevant modifications can be

made, which forms the feedback loop. The customers are unaware of what exactly prompts their preferences, and the preferences of a product depends on a holistic assessment of product attributes (Khalid & Helander, 2004), such as aesthetics design, functional design, ergonomics design, personal preference, experiences, etc. These could also be related to Norman's (2004) three levels of design (visceral, behavioral, and reflective) that have been identified in the proposed Citarasa Engineering Framework.

Chapter 4 – Field Data: Customer Interview

This Chapter documents the results of customer interview on customer needs for cars, which is conducted in selected countries of Europe and Asia. Car Evaluation (CARE) survey is developed to elicit customer needs of cars. The questionnaire is designed to fit and reflect each element of proposed framework in Chapter 3. Findings are presented and briefly discussed. The outcomes of this survey indicate the importance of understanding customer affective and functional needs, and then provide key input for studies in later chapter.

4.1 Purpose

The purpose of the customer interview is to elicit the customer's needs in buying a car, including both the affective and the functional needs. The results of the survey can be analyzed and used as input for DECA method and also supplementary material for product planning study, furthermore data collected is used in documenting customer needs database.

4.2 Experimental Setting

4.2.1 Method

The CARE survey (see Appendix A) was designed by DAMAI Sciences, and reviewed by Nanyang Technological University and CATER Partners. The survey was conducted in 10 different countries. Eight countries were from Europe (Finland, France, Germany, Greece, Italy, Sweden, Switzerland, and UK) and 2 countries were from Asia (Singapore and Malaysia). A group of customers that were representative of the target market were selected.

4.2.2 Subjects

In total 179 respondents were interviewed, of which 137 subjects were from Europe and 42 subjects were from Asia. Ninety-nine subjects were male and 80 were female. Subjects were categorized into three different age groups: 37 subjects were from the age group of 18 to 24 years, 106 subjects were from the age group of 25 to 55 years and 34 subjects were from the age group of 55 to 65 years old while two subjects were of unknown ages. Subjects were divided into three different car groups, 80 subjects drove small/compact car, 78 subjects drove family/mid-sized car and 19 subjects drove luxury/sporty car and two subjects drove unknown car types.

Region

Table 4-1 shows the majority of the respondents were from Europe, while the rest were from Asia.

Table 4-1 Subject region data summary

		Frequency	Percent
Region	Europe	137	76.5
	Asia	42	23.5
Total		179	100.0

Gender

Both European and Asian respondents were slightly having more male compared to female (see Table 4-2).

Table 4-2 Subject gender summary

		Region		Total
		Europe	Asia	
Gender	Male	74	25	99
	Female	63	17	80
Total		137	42	179

Age Group

Both Europe and Asia respondents are mostly aged between 25 and 54 years old (see Table 4-3).

Table 4-3 Subject age group summary

		Region		Total
		Europe	Asia	
Age_group	18-24	24	13	37
	25-54	87	19	106
	55-65	24	10	34
Total		135	42	177*

*Note: 2 were excluded due to missing data.

Twenty-one respondents from Singapore participated in the study. There were 13 male and 8 female respondents, age varying from 18-65. All of them owned cars and possessed valid driving licenses. Types of car included: compact, family/sedan, sports car and luxury car. Brands of car included: Toyota, Honda, Mitsubishi, Hyundai, Nissan, BMW, Ford, and Chevrolet.

4.2.3 Procedure

Appointments were made with the respondents prior to the interview. During the interview, the respondents were first briefed about the objective and abstract of the interview. The interviews were then conducted using probing interview. In case the respondents had difficulty in answering a question, they were given a hint or the question was re-phrased in a different way to help them answer the question.

The interviews took place at the various locations, in the laboratory, shopping complex, café, etc. Each interview took about 90 to 160 min, and they were conducted in English. Two interviewers were present; one was responsible for conducting the interview, and the other was responsible for recording the answers. All respondents completed the questionnaires.

4.3 Associating the Framework with the Survey

Understanding customer needs is the first step in the product development life cycle. Hence the customer data collection is vital. This survey was designed to collect information from customers, i.e. the car owners and drivers. The data collected was then used in documenting customer affective needs.

In the questionnaire, questions were designed to reflect components in the proposed theoretical framework. The general structure of Survey is shown below:

➤ Part I - Customer experience and general needs

- Customer experience – to elicit customer experience with the car, such as years of driving experience, previous experience with different cars, expected criteria of good car, and so forth. This part can be used to extract information needed for “**Marketing**” in the framework, which focused factors such as price, customer segments, and so forth (see Figure 3-1).

1. What car do you drive currently? Brand, model, version, year, price?
2. Is your current car a good buy?
3. What other cars have you owned/ driven previously?

- **“Affective design”** deals with visceral, behavioral and reflective needs see box in Figure 3-1. In this section, questions were designed to measure sensory characteristics in terms of touch, visual, smell and auditory, functional requirements and needs for trends, status and style.

Visceral needs:

1. Describe your feelings associated with these colors. (A set of colors was given) What paint type (plain, metallic, etc.) is good for each color?
2. Describe your favorite car shape.

Behavioral needs (Also address context of use in this section):

1. What do you use your current car for mostly?
2. What are your functional requirements of a car? How important are these requirements in considering your next purchase? How can the requirement be met in design?

Reflective needs:

1. Why do you like the design?
2. Marketing advertisement usually describe a car using words like cute, cool, sexy, and so forth, what do these word mean to you in term of feeling? How are these words related to car design features?

➤ **Part II - Specific requirements for design**

This part was intended to measure affective and functional requirements of existing or shown cars. The purpose was to generate a large set of Citarasa descriptors for further analysis, especially for the **“Design Matrix”** box, to assist the formulation of DECA, see Figure 3-1.

- *In car devices* – Car devices/equipment, radio, CD player, navigation/GPS system, and so forth.
- *Exterior* – body, front, headlights, wheel rims. The Aim was to measure the affective and functional needs of shown car image. The gathered descriptors were used to develop Citarasa engineering method and Citarasa database. Questions asked here included:
  1. Describe your impressions for each car part (body, front, headlights, wheel rims)? What physical elements (design, shape, size color, material) contribute to your feeling?
  2. Rank and rate car part using 5-point Likert scale.
- *Interior* – seating, dashboard, controls, active safety, and so forth. The purpose was the same as exterior part; further probes were used to elicit detailed requirements.
  1. Describe your impressions for each car part? What physical elements (design, shape, size color, material) contribute to your feeling?
  2. Rank and rate car parts using a five-point scale.
  3. Tell us what feelings are created by material for car seating and what functional requirements related.

➤ **Part III - Customer Expertise**

This part was to evaluate customer knowledge, expertise, goals and affordance, which relate to “**Design goals and constraints**” and “**Marketing**” box in Figure 3-1.

- *Knowledge*
  1. How do you obtain information on cars?
  2. Have you modified your current car? Or any car?
  3. How would you decide what is a good car?

- *Goals and affordance* – purchase budget and motivation
  1. What is your budget for next purchase?
- *Psychographic* – personality and lifestyle
  1. Would you buy a car that reflects your personality?

➤ **Part IV - Customer Demographics**

This part was to extract customer personal data, such as handedness, living arrangement, and education living area, income, and so forth. The data collected in this part could be used to analyze and reflect on the content in the “**Social and culture constraints**”, see Figure 3-1. The data can also be used to document the diversity of customers.

4.4 Results and Discussion

The findings referred to the question in the CARE questionnaire (see Appendix A). Emphasis was on responses that relate to customer’s functional and affective requirements, and customization of car parts/components. We briefly discussed some findings here; for example, color – certain color can be linked with specific emotions.

Color

Color samples were given to identify feelings. Table 4-4 summarizes customer feelings towards different colors used for car body.

Table 4-4 Feelings associated with specific colors

Color	Europe	Asia
Maroon red	Happy/Cheerful, Sporty	Happy/Cheerful
Navy Blue	Calm/Sober/Peaceful, Boring	Calm/Sober/Peaceful, Boring
Lime Green	Happy/Cheerful, Modern	Young
Black	Elegant, Executive, Cool	Elegant, Executive, Boring

Dove Grey	Boring/Dull, Calm Sober	Boring/Dull, Common/Ordinary
Beige	Boring/Dull, Old; Calm	Boring/Dull, Modern, Disgusting

Take “maroon red” for example, both European and Asian customers agreed on “happy” or “cheerful” feelings. In second place in Europe was “sporty”. Similarly for “black” – “elegant” was the first feeling that came to all customers’ mind, followed by “executive”.

Affective Descriptors versus Design Features

Subjects were asked to describe the design implications of words that were often found in automobile advertisements such as: cute, cool, sporty, and so on. The results were summarized in Table 4-5. Several anthropomorphized design features mentioned in Europe were italicized. The corresponding design features listed were according to response frequency.

Table 4-5 Evaluation of common affective car descriptors

Affective Descriptors	Corresponding design features in Europe	Corresponding design features in Asia
Cute	Small, Compact, <i>Feminine</i> , Sweet, Attractive,	Small, Compact, Round, Bright
Cool	Trendy, Modern, Sporty, <i>Youthful</i>	Sporty, Modern
Sexy	Attractive, <i>Girly</i> , <i>Feminine</i> , Desirable, No Feeling, Sporty,	Red, Sporty, No Feeling
Trendy	Fashionable, Modern, <i>Young</i> , New	Modern, New, Popular
Elegant	Luxurious, Classic, Sophisticated, <i>Old</i> , Timeless,	Upper Class, Executive, Luxurious
Sporty	Fast, Speedy, Aggressive, <i>Young</i> , Active,	Powerful, <i>Young</i> , Small, Low
Rugged	<i>Old</i> , Positive, Robust, Solid, Big Reliable	Big, Jeep like, Boxy, Durable, High
Aggressive	Angry, Fast, Powerful, Sporty	Sporty, Powerful, Load

Several of the car descriptors gave similar emotional associations in Europe and in Asia. However some differences still existed. One example is “cute”, was in Europe linked to small and feminine; while in Asia it referred to small and compact. Similarly, “sexy” in Europe referred to attractive and feminine, while in Asia it was associated with red color and sporty design. Note also the response “No Feeling” was mentioned from some of the respondents as if they did not see a possibility of using the descriptor in car advertisement, such as “sexy”.

From the above, we note that a few descriptors conveyed the same meanings to Europeans and Asians, such as “small” for cute, “modern” and “sporty” for cool, and “powerful” for aggressive. Although the terms used in Europe were comparatively similar to Asia, there was one significant difference exist in affective evaluations. In interpreting the car descriptors, respondents in Europe often anthropomorphized the design features by referring to the characteristics of human, such as: feminine, girly, youthful and old. Asians, however, gave a more neutral evaluation referring to the design features of the vehicle.

Further investigation on distinction between six design elements (shape, color, design, material, sound and size) of the car and asked to what extent these related to the various descriptors: cool, trendy, sexy and so forth. The results are shown in Table 4-6. The numbers refer to the association strength. For example, cute was associated with shape in 66% of the cases.

Table 4-6 Strength of associations between affective descriptors and design elements

Affective Descriptors \ Design Elements	Shape	Color	Design	Material	Sound	Size
Cute	.66	.30	.45	.09	.03	.42
Cool	.50	.46	.59	.23	.20	.11
Sexy	.45	.35	.52	.13	.15	.08
Trendy	.41	.48	.65	.22	.08	.08
Elegant	.57	.41	.64	.36	.11	.28
Sporty	.54	.25	.62	.15	.33	.19
Rugged	.41	.13	.41	.27	.22	.31
Aggressive	.42	.30	.48	.10	.40	.23

The numbers in bold showed the strongest associations between each affective descriptors. We found that each affective descriptor had greatest association with “Design”, except for “Cute” and “Rugged”, which was mostly associated with “Shape”. Design was considered a more general and broad term, which explained why participants could easily refer to this term. To get a better understanding of the association, we eliminated the “Design” column from the original table; see Table 4-7. The two highest values in each row appear in bold.

Table 4-7 Associations between affective car descriptors and car design elements

Affective Descriptors	Shape	Color	Material	Sound	Size
Cute	.66	.30	.09	.03	.42
Cool	.50	.46	.23	.20	.11
Sexy	.45	.35	.13	.15	.08
Trendy	.41	.48	.22	.08	.08
Elegant	.57	.41	.36	.11	.28
Sporty	.54	.25	.15	.33	.19
Rugged	.41	.13	.27	.22	.31
Aggressive	.42	.30	.10	.40	.23

From Table 4-7, it can be seen that the strongest association is with the shape of the car as following:

- Shape of a car can be many things: cute, cool, sexy, trendy, elegant, sporty, rugged or aggressive
- Colors can be selected to be: cool, sexy, trendy, or elegant
- Sound of a car mostly induced feeling: sporty or aggressive
- Material of a car can be selected to be elegant
- Size of a car often referred to cute or rugged.

4.5 List of Design Features that possibly be Customized

Not every design feature can be customized using automobile configurators. Hence a list of design features was a list of components for car and truck interiors that are possible to customize was compiled (see Table 4-8).

For cars, the list was generated by reviewing and summarizing several online car configurators, including: Citroën (2007), Smart (2007), Alfa Romeo (2007), and Mini Cooper (2007).

In addition, a list of components of truck interiors that are possible to customize was provided by Volvo Technology Corporation (VTEC), which is one of CATER partners, see Appendix B.

Findings and Discussion

In this case, a list of components for car and truck interiors that are possible to be customized has been compiled (see Table 4-8).

Table 4-8 Example of customizable components for a car

Model	Car shape	
	Body style	-
	Color	Body panel
	Trim	
Exterior		Tridion cell / texture
	Paint type	Metallic/ non-metallic
	Roof	Sliding / solid
	Headlamp	Shape Accessories, e.g. eyebrows
	Accessories	Rack unit
	Color	Main theme
Interior	Texture	-
	Holders	cup holder Disc holder Mobile phone Holder, etc.
	Steering wheel	Shape Material
	Drawer	Under driver seat lockable
	Lights	Color Intensity of illumination
	Accessories	CD/ cassette organizer Boot tray Divider
	Seat	Material / trim Shape Color Texture backrest headrest armrest height adjustability

		covers others
	Audio	Bose sound system CD auto changer
	Carpet	Color Material
	Foot pedals	Shape Design Colors
	Gear knob	Design material
	Rims	Texture Material
Wheel	-	-

From Table 4-8, we noted that the interior design of a car is of utmost importance and thus many components are available to customize a car interior. But there was limited selection with respect to the exterior and models. For example, there was a large variety in the interior design features of a car seat, such as the shape, material, color, texture, functionality, etc for the customer to choose from. To associate personal preference with automobiles, accessories could be an effective component for customization of automobiles.

These findings can facilitate us to understand feasibility of customization and specific parts which need to be studied. Moreover, in future study, we may use interior design parts such as dashboard or car seat in actual design task and case studies.

4.6 Problems Encountered

- During the interview, some respondents had difficulties finding suitable words to describe their feelings. Hence, some hints were provided to help the respondents answer the question at that time.

- Sometimes we needed to rephrase a question in a different way to help the respondents get a better understanding of the question.
- Some respondents could not express their feelings well, and this became more problematic when they encountered some English words that did not correspond directly to words in the local language.

Chapter 5 – Study 1: Product Planning Study

The intention of this study was to investigate how product planning team undertakes planning activity in normal practice. A study was performed to elicit domain expertise from product planners. The results of pre-task and post-task interviews are documented and discussed. The findings of design task and relevant discussion were used to evaluate the effectiveness of the proposed framework. Limitations of this study are also explained at the end of this chapter.

5.1 Introduction

Dieter (2000) defined product planning as a problem definition activity, which includes an initial screening of a concept, preliminary market assessment, market research, preliminary technical assessment, and a business and financial review. For most product development processes, product planning is the first phase. This activity centers on collecting customer needs, but also formulates concepts and defines benchmarks.

The purpose of this study was to investigate how product planning activity is carried out in automotive company, and thereby understand their domain expertise, procedures and concern. Furthermore it was important to understand whether the proposed framework can help the product planning team to achieve affective design. Interviews and design tasks were carried out with members of design teams from different

departments. The objective of the study was to validate the effectiveness of proposed method.

The detailed study plan and interview questionnaires are given in Appendix C1 and C2 (Chinese translation of interview questions).

5.2 Method

5.2.1 Subjects

There is no automotive company in Singapore that deals with the entire product development process from product planning to mass production stage. Due to the difficulty finding experts in Singapore with relevant automotive industry experience, arrangements were made to conduct the study in the premises of an automotive manufacturing company in China.

Two teams of automotive product planning teams were supposed to participate in this study. Each team consisted of four persons representing: product styling, engineering design, product planning, and marketing. However, due to the unforeseen circumstances, one product marketer was unable to attend the experiment. Hence, there was one team of three and one team of four. Some of the participants shared some group history working in previous projects. Each participant was paid S\$100 for the 4-hour participation in the study.

5.2.2 Procedure

This study was carried out in the automotive industry in Chongqing China, by the author and one research assistant from Center of Human Factors and Ergonomics Laboratory at Nanyang Technological University. The participants were first briefed about the CATER project and procedures of the study to ensure a common understanding. The study was an intensive interview and product planning and design

task. To ensure efficiency and smoothness in completing the study, questions were organized in a systematic order (See Appendix C1).

The study was broken down into four sections:

1. Background information introduction – sharing of subjects' job information within the group, such as job responsibilities, working experiences, and so forth.
2. Pre-task Interview – group interview to identify the current product planning processes, domain expertise, and so on.
3. Product planning and design task – engaging in a design & planning task on a automobile dashboard.
4. Post-task Interview – feedback from participants on the study.

The third section (product planning and design task) was further divided into two phases:

- Phase One: design without considering affective design or affective requirements.

This means that the participants were not informed that one important objective of this study was to consider affective design. Phase one therefore documented the typical design behavior in this automobile company.

- Phase Two: design considering affective design and affective requirements. In this phase, the two teams were given the results from the CARE survey (See Appendix A) and related data/pictures for car dashboard design.

Considering both efficiency and feasibility, the study was conducted over a weekend. Appointments were made with the subjects prior to the actual experiment. Emails and phone calls were the major communication tools.

Data Collection Method

Experimenters took notes throughout the observation study. While video and audio recordings have obvious advantages in terms of data capture and review purpose, they increase the richness of data captured. However, they also increase the intrusiveness of in the experiment. In particular, these methods raise issues regarding confidentiality and security pertaining to company intellectual property (Crandall, Klein, & Hoffman, 2006). Moreover, the transcription process is tedious and time-consuming. With sufficient notes taking skills, it would be able to provide a complete set of cognitive perspectives and capture the important elements of the interview effectively.

“Verbal protocol” is another popular task interviewing method, and it was used in this study to collect information on participants’ thoughts during various cognitive tasks. It either concurrent or immediate after completion of the task (Ericsson & Simon, 1993; Ryan & Haslegrave, 2007). Although verbal protocol analysis is tedious and time consuming, it can produce interesting and essential insights.

Considering the advantages/disadvantages of each method, we used the combination of video recording and extensive note taking for data collection in this experiment. The video recording data was used as source of reviewing and the notes taken.

Interview

A well-prepared interview can be used to collect people’s opinions and understand facts. In this study, interviews were conducted to elicit automotive product planning team member’s opinions, attitudes, beliefs and behaviors. The interviews conducted in this study consisted of both open-ended and close-ended questions. Group interview can be used to collect information about a particular topic. We used group interview for both Pre-task and Post-task interview to gain a quicker and deeper insight from diverse sources, i.e. different departments and domain expertise. On the other hand, it can also gain consensus from diverse ideas.

5.3 Result

Throughout the interviews, the interviewers took thorough notes, and the whole session was video recorded. The results from each of the four sections are described below. Except for the Product Design and Planning Task (third section), all the data from all the participants between the two groups were consolidated and discussed together.

5.3.1 Subject Background Analysis

Table 5-1 Summary of subject background information

No	Function	Job Title	Age	Yrs of Experience	Education	Gender	Project Duration (yrs)
1	Product styling	Stylist	27	3	Bachelor (Industrial Design)	F	3
2	Engineering design	Manager - Engineering Design	27	4	Bachelor (Mechanical Engineering)	M	2-3
3	Product planning	Product planner	28	2	Bachelor (Business & Marketing)	M	1
4	Product stylist	Manager - Lead Stylist	37	>10	Bachelor (Industrial Design)	M	1-3
5	Engineering design	Engineering designer	33	5	Bachelor (Mechanical Engineering)	F	3
6	Product planning and marketing	Manager - Product planner and marketer	40	8	Bachelor (Business & Marketing)	M	1
7	Product marketing	Product marketer	28	3	Bachelor (Business & Marketing)	M	2

Subjects Background Information

As shown in Table 5-1, seven participants from one automotive company in China, with age ranging from 27 to 40 years ($Mean = 31.43$, $SD = 5.32$) participated in this study. There were 5 males and 2 females. In this study, we wanted to capture the domain expertise of Subject Matter Experts (SMEs) in conducting product planning activity, and how they make trade-off decisions among the various areas of design. All participants were experts and with an experience ranging from 2 to more than 10 years ($Mean = 5$, $SD = 2.94$). They worked in different automotive fields: product planning, product marketing, engineering design, and product styling. They obtained their expertise from various field such as relevant academia background and industries experiences. They were judged to be experts because they could reason about design and they were also aware of trade-offs in design (Ahmed, Wallace, & Blessing, 2003).

5.3.2 Pre-task Interview Result

The Pre-task and Post-task interviews were conducted. Since they were experienced with the product design process, they could provide valuable perspectives on product development.

Detailed pre-task and post-task results can be found in Appendix D.

Typical Product Development Process

The SMEs described and elaborated on a typical four-stage product development process that they used at work, see Figure 5-1.

Figure 5-1 Typical four-stage product development process

Stage 1: Product planning and market analysis: cross functional teams work together in meetings with the management team to discuss decision parameters, and formulate a concrete plan. This includes several important components:

- Market research involves the process of systematically gathering information, and record and analyzes information about customers, competitors and markets. It is essential to discover what customer want or believe before going into detailed planning or design.
- A feasibility study of a new product development considers:
  - Marketing feasibility evaluation: marketing objectives, target market, potential competition, market constraints/opportunities and similar factors which affect the market and profit.
  - Technical feasibility evaluation: the capability of engineering and manufacturing possibilities in achieving a design. Questions involve

documenting the technology needed for the product development, how it can be achieved, and adaptation problems and reliability of new technologies.

- Identify potential development projects, and deliver the optimal product proposals in accordance with projected market.
- Sketching and creative design. This is an idea generation, and includes sketching (manual to digital) – justification and evaluation – refinement – approval – and clay modeling.

Stage 2: Engineering design:

- Engineering product development and analysis
- Research and Development (R&D) preparation
- Testing preparation
- Include Technical Parameters, such as detailed specification, dimensions, and so forth.

Stage 3: Production stage:

- Production preparation
- Testing and Refinement
- Final Production

Stage 4: Products launch and transfer to sales department

- Launch the product
- Produce advertisement and promotion plan
- Sales distribution pipeline

Product planning is a key activity within the product development process. It mainly deals with the elicitation and identification of customer needs. Product planning meetings are usually conducted at the early stage of the product development process. Participants formed a cross-functional team, consisting of participants from Marketing

and Product Planning Department, Financial Department, Development and Product Planning Department, Automotive Engineering Department, Sales Department and Management Team.

It was important to ensure success in the PP activity, particularly crucial were domain expertise of each SME in: market or customer segmentation, requirements acquisition and categorization, and include automotive technology knowledge, discussion of technical prospects, feasibility of proposed design; and product planning and market planning skills.

Customer Segmentation

Customer segments were defined based on: age, occupation, income, preferences, family, and context of use, attitude, purchasing capability, interest, personality, and similar variables. This information is used to tailor the design to meet customer requirements. There are many combinations of segments, and product planners must select the most useful and profitable combinations.

It is useful if one can understand and breakdown the target market and position products properly to meet the requirements of different customer sub-group. This stage was done before going into a detailed design stage.

Customer Requirement and Knowledge

Effective and early product planning is essential. Customer requirement and knowledge were gathered during the early marketing analysis phase. Data on customer's requirements was usually gathered through outsourcing using market research firms, or by engaging internal staff in the product planning department.

Data analysis consisted of activities such as: analysis of customer satisfaction of existing products and requirements for an ideal product. The results of the data analysis

can help to understand detailed customer requirements for functionality, performance, style, and so on. The analysis results would then be used to identify and associate with design features.

In our case of designing a dashboard for a car, the main design issues would be: form, style, function, layout, material, and color. There are many specific requirements, Singapore or Malaysia position the driver's seat to the right, which affects the layout design. Due to the variance in customer's perception, expectation, budget and taste, the design, in terms of configuration and style, varies much for different customer segments.

The SMEs used their domain knowledge from previous experience and prevalence of requirement to deliberate on the importance of customer requirements. The discussion also depended on the sources of information and the comprehensiveness of the analysis. Trade-offs in customer requirements mainly depended on the significance of customer's requirement on such function/feature. The feasibility of such requirements, and the effects on satisfaction and cost of implementation were also taken into account in the trade-offs analysis.

Customization in Practice

SMEs noted that with the rapid development of economy, product customization is an important, especially for the younger generation, although customization was not yet a very important issue in China.

The following parts can be taken into consideration for mass customization: interior, exterior, electric equipment, accessories, colors, materials, and configuration.

In the future, the SMEs from product planning teams would like to support customization through the following approaches:

- Series of modular design
- More universal/consistent design
- Consider more configuration alternatives to ensure that the parts of the product can be exchangeable
- Provide various decorative options

5.3.3 Design Task Result

5.3.3.1 Discussion of Affective Requirements

This section documents the design requirements gathered from both groups. During the design task, group 1 discussed in detail the differences between design with and without affective requirements. Group 2 discussed in a more general way. The following information is given below:

- How each team gathered the required design considerations
- Phase 1: How to performed the design task without considering affective design
- Phase 2: How to performed the design task after being introduced to affective design

Group 1 - Phase 1:

Design Requirements (DRs)

Table 5-2 below provides design requirements identified by product planning teams for four customer groups.

Table 5-2 Design requirements (DRs) identified by design team for four different customer groups

	Customer Segment			
	Group 1	Group 2	Group 3	Group 4
Name	Economical practical	User-friendly control	Performance and fashionable	Brand and luxury
DR1: styling	simple	technological	fashionable	luxury
DR2: airbag	Single airbag	Dual airbag	Dual airbag	Dual airbag
DR3:centre console	CD/MP3 player	Multi-CD/ MP3 player	USB connection for MP3 compatible CD/DVD player	USB connection for MP3 compatible CD/DVD player Bluetooth
DR4:air-condition	Normal	Automatic	Automatic	Automatic/ Uniform distribution/ constant temperature
DR5: engine control	Nil	ECU (Engine Control Unit)	ECU	ECU
DR6: steering wheel	Normal	With entertainment system button	With entertainment system button	With entertainment system button/ Bluetooth communication
DR7: material of dashboard	Plastic	PVC	PVC	PVC/ ThermoPlastic Olefin (TPO)
DR8: theme	Original color	Silver color theme	Silver color theme	Wooden laminate
DR9:ash receiver	Manual	Semi-automatic	Semi-automatic	Semi-automatic
DR10: tool box	Normal plastic	Light With damping	Light With damping	Light With damping cooler
DR11: dashboard theme	Single color theme	Two color theme	Two color theme	Two color theme
DR12: others	Nil	Nil	Nil	Sunlight sensor with the climate control system

Group 1 - Phase 2:

In general, affective design can influence many aspects including: style, user interface, control, color, layout, material, and so on.

Four affective design categories were considered in this task were these terms generated by the groups: simplicity, high-tech, fashionable, and luxury.

- Simplicity: no direct relationship with price, luxury car design can be very simple.
  - i. Line of dashboard is a major aspects of shape: smooth and streamlined design
  - ii. Easy to control, user friendly design
  - iii. Simple and elegant color
  - iv. Simple and tidy layout
- High-tech: mainly reflected by color, design, function, and layout.
  - i. Black, grey or silver color, with metallic trim
  - ii. Rounded shaped air-con vent
  - iii. Layout of controls or buttons is complicated
- Fashionable
  - i. Trendy design which reflects mainstreamed needs
- Luxury
  - i. Classic and elegant design
  - ii. High quality material: genuine leather, wooden trims, metal accents, polished, and so on
  - iii. High performance, spacious

The teams were asked about affective requirements in dashboard design. How can affective requirement in dashboard design are specified in different groups. The results are shown in Table 5-3.

Table 5-3 Design requirements with affective requirements identified by design team for four different customer groups

	Customer segment			
	Group 1	Group 2	Group 3	Group 4
Name	Economical practical	User-friendly control	Performance and fashionable	Brand and luxury
Steering wheel	Four-spoke	Four-spoke Metallic Integrated cruise control buttons	Four-spoke Metallic Integrated cruise control buttons	Four-spoke Metallic Integrated cruise control buttons High quality leather
Instrument panel	simple	technological	fashionable	luxury
Air-con vent	Square	Rounded cylindrical	Rounded	Square
Color theme	Original color	Silver color theme, with metallic texture	Silver color theme	Wooden texture theme
Centre console	CD player	DVD player A few control buttons	DVD player More control buttons	DVD player More control buttons GPS Touch-screen
Control type	Knob dial	Knob dial	Press button	Press-button

Group 2 - Phase 1:

Table 5-4 below provides design requirements identified by product planning team for three customer groups.

Table 5-4 Design requirements (DRs) identified by design team for three different customer groups

	Customer segment		
	Group 1	Group 2	Group 3
Name	Fashionable	Practical	Middle-class
DR1: styling	Trendy, cool design	Traditional	quality
DR2: location of instrument panel	Centre	Centre	--
DR3: display	Digital meter	Analogue meter	Analogue meter
DR4: theme color	Colorful	---	--
DR5: audio device	CD/MP3 player	CD player	CD/DVD player High quality
DR5: air-con	Simple, basic	Mainstream	High quality
DR1: material of dashboard	--	Durable	High quality
others	--	Spacious	Spacious
DR3: accessories	N. A	N. A	GPS

5.3.3.2 Design Sketch Results

This section shows the design sketches from phase one and two of both groups. Design sketches before and after taking affective requirements into consideration are presented. Changes in sketches will be discussed later.

Group 1:

Design characteristic:

Style: performance and fashionable

Instrument panel layout: in front of steering wheel, with ECU (Engine Control Unit) functional design

Backlight of instrument panel: purplish blue

audio: DVD player.

Audio system: high quality

Steering wheel: four-spoke, cruise control and radio controls built into the steering wheel to minimize the extent to which the driver must take his hands off the wheel.

Control button: knob dial

Glove box: Yes

Umbrella box: No

Material: leather

Color: upper part - black, lower part- light color

Gear shift: metal knob, location: traditional place

Ash receiver: traditional location, semi-automatic, silver color

Steering wheel material: leather

Design Sketch - Phase One (without affective requirements):

Figure 5-2 Design sketch of Group 1 in Phase 1

Phase Two (with affective requirement):

Assumptions: Design for same customer group and maintain the same budget.

Figure 5-3 Design sketch of Group 1 in Phase 2

Changes in Affective Design (as illustrated Figure 5-3):

- Point 1: Shape of air-condition vent – from square to rounded, square vent shape gives the feeling of practical, simple and classic, while rounded shape is more sporty and trendy;
- Point 2: Control type – from knob to button. – standardized control;
- Point 3: Steering wheel style – from four-spoke to two spoke, trendy design;
- Point 4: Dashboard shape – more solid feel.

Group 2:

Design characteristic:

Style: Fashion, advanced

Instrument panel layout: in front of steering wheel

DVD screens: No, just need CD player

Audio system: good quality

Control button: big size

Glove box: Yes

Umbrella box: No

Color: Dark, single color (black with metallic luster)

Gear shift: metal knob, location: traditional place

Ash receiver: traditional location, semi-automatic

Design Sketch - Phase One (without affective requirement):

Figure 5-4 Design sketch of Group 2 in Phase 1

Phase Two (with affective requirement):

Assumption: Design for same customer group and maintain the same budget.

Figure 5-5 Design sketch of Group 2 in Phase 2

Changes in Affective Design (as illustrated in Figure 5-5):

- Point 1: Overall shape of dashboard – extended dashboard to side doors;
- Point 2: Air-condition – change to invisible/hidden air-condition vent, with constant temperature control;
- Point 3: Touch-screen LCD Display at centre console – to control and monitor air-condition, temperature inside/outside car, calendar, etc.;
- Point 4: Add a dashtop on passenger's dashboard – for working, resting, eating in the car;
- Point 5: Steering wheel style – change from four-spoke to three-spoke.

To understand how 'fashion' can be represented in design features, SMEs stated it is necessary to gather designers and customers together to build a common image or concept. The definition of fashion did not come from either side. Designers should guide the customers in the sense of what is a fashionable design, by introducing a series of design that are claimed to be fashionable. This would allow customers to understand, accept and generate a more clear idea of what exactly is a fashionable design to them. The SMEs used this strategy in launching their products. They introduced a series of mini cars which claimed to be "sporty", "cute" and "for lady". This series had been voted as one of the greatest mini-cars in the Chinese market.

At the time of the interview, the trend for dashboard design was dark color (especially black) or a single color theme. Black color gives a "cool" impression; and it has recently become more popular in car interior design. Color is composed of several attributes, such as saturation and value (Fehrman & Fehrman, 1999). The purity and representation of the latest dark color were different from the traditional dull dark color. For example, a popular black color has metallic luster.

5.3.4 Post-task Interview Result

Opinions toward the Use of Proposed Framework

SMEs mentioned that including customer's affective and emotional requirements into product planning and development process was definitely an innovative and promising trend in product design. To a certain extent, customers are becoming more and more demanding and complicated, and they prefer a customized or even personalized product. Understand and utilizing customers affective needs can enhance customers satisfaction, which is essential in product development. In addition, understanding affective design was important and helpful for designers. But it is also of vital interest to explore and understand the customers' mental models in how they evaluate and analyze their affective and emotional needs.

Some SMEs, however, thought that this method might not be very practical to use at this stage for the China market. The Product Planners claimed that they already consider some aspects in current process. Due to the diversity and difficulty in understanding customer affective requirements, it is difficult to implement. The stylists and engineers' lack of acceptance would create another problem.

Despite this criticism, SMEs acknowledged that the proposed affective design and evaluation framework should retain novelty and effectiveness. They would definitely consider it in future development process.

Affective Requirement in Design

To include customer affective requirements in design, the product planning team mainly considered the following four perspectives:

- Customer's aesthetic perception
- Functional needs
- User-centered design need
- Trade-offs in design

SMEs felt it was obvious that by adding more affective design features, the price would definitely increase the cost and effort. A more personalized product usually carries a higher price. However, product personalization is not meant for the majority of customers. Hence, the SMEs would sometimes consider affective/emotional needs. Trade-off decisions are always a product of compromise, it is impossible to satisfy the requirements. The SMEs need to analyze and prioritize customer requirements, and decide whether requirements were achievable.

5.4 Discussion

5.4.1 Effectiveness of Proposed Framework

The purpose of this study was to illustrate the effectiveness of proposed affective design evaluation framework. Based on the changes made in designs without affective element, to consider affective design, it was observed that the new designs were more affective in terms of visceral, behavioral and reflective design. We will discuss these issues below.

Visceral Design

At the visceral level design, both groups made changes to make design more aesthetic appealing and attractive. In Group 2, the overall extended shape of the dashboard design was curvier and more streamlined, which fit the fashionable design requirements. Group 1 modified their dashboard to a more three-dimensional and solid design, which according to our evaluation improved the aesthetics quality.

Both groups changed the design of air-condition vent. Group 1 redesigned the shape of the vent from original square and flat to rounded form with depth, which created a feeling of sporty, stylish, and more affective. Instead of changing the shape, group 2 embedded and hid the vent, to make it invisible. This amendment was definitely more

innovative and special, and provided a seamless aesthetic finish. It also affected reflective design, which will be discussed later. However, in terms of behavioral design, this invisible design may not provide direct feedback.

Physical features dominated at the visceral level design included look, feel, and sound (Norman, 2004). Touch and feel quality of automotive interior is a crucial element of customer's perception of overall product quality (Yun et al.2004). For both groups' designs, the SMEs changed the steering wheel style from traditional four-spoke to either three-spoke or two-spoke. Four-spoke was considered a conventional and common design by SMEs, while a three-spoke steering wheel was fashionable and had a better touch feeling. Similarly, a two-spoke steering wheel induced a sporty feeling. Surface materials leather provided great touch sensation and comfort. It was found that both the style of steering wheel and the surface material contributed to the overall perceived impression of the car.

In addition, both groups used dark color for their designs. Color was categorized as an important product design element that affects the overall product aesthetics. SMEs from Group 1 used a two-tone theme – black color for the upper part of the dashboard and light color for the lower part of dashboard. This provided a strong contrast that was likely to be seen as a fashionable design. On the other hand, SMEs from Group 2 used a monotone theme – black color for whole dashboard. They thought that black color would be perceived as “cool”, and would be fashionable. Color seems to have fairly strong association with emotion and affect in automobile design, and it is also one of the easiest design element to change in customization. From a practical perspective, color also plays an important role in automobile design. Dark color dashboard is not only an account of fashion, but also a concern of safety (Dewey et al.2007), the best design for a dashboard is a non-reflecting dark color surface.

Behavioral Design

Considering the context of use, Group 2 added a so-call “dashtop” to the passenger’s dashboard, which can be used by passengers to rest, work, or eat in the car. The flat surface board was considered a good approach to behavioral design, and an enhancement of product development. By considering affective design, the SMEs tried to adjust their approach from a “designer’s mental model” to a “customer’s mental model”. Hence, The SMEs considered the customer’s needs of using a flat surface, such as for children to study in the car, and for taking a nap. SMEs also considered social norms, such as children who under high pressure have to study in the car.

From an error prevention point of view, group 1 decided to locate the cruise control and entertainment control on the steering wheel to minimize the effort in reaching. This arrangement increased safety, since the driver does not need to take his/her hands off the wheel while using the control buttons. They also standardized all controls and used only buttons, which increased the consistency of the whole design. However, the appropriateness of using buttons instead of knobs, need to be further investigated. One design issue is the effect of using a heavy and “expensive feeling” stereo volume control knob, which induces affective responses from customers (Swindells et al.2007).

Group 2 replaced the original center console with a touch-screen LCD display, which the driver can monitor and control more directly and easily. The integrated display can provide much information at a glance, including: temperature inside/outside the car, calendar, radio channel, and so on. The calendar was also programmed and customized to fit the cultural/social norm. The driver can also change settings by a simple touch of the screen. The levels of informative and simplicity increased, hence this human centered approach reflects good behavioral design.

Reflective Design

Status is how people are perceived by others , which refers to socio-economic status, self-image, and culture (Jordan, 2000). In this study, SMEs from both groups designed

a car dashboard with fashionable and functional characteristic, which portrays the social characteristic such as background, age group, lifestyles of a customer group; for example young, working professional, and pursuit of personality and fashion.

Most products can be perceived as “social accessories”, and so does a car (Jordan, 2000). Use of leather for steering wheel cover and dashboard, black color theme may reflect the socio-economic status as mid-class working professional. Customers may want to purchase a product which design fits their self-image. For example, a person who drives a sporty car may be perceived as someone who appreciates speed and risk-taking. In this study, SMEs of group 2 amended the design, the hidden air-condition vent – a futuristic and innovative design feature. This feature may satisfy the customer’s self-image is being advanced as well as fashionable. The programmable lunar calendar – fits the Chinese culture. The above mentioned features reflect on the third criteria – “culture status”, to appreciate the right thing.

Conclusion

Results showed the significant design improvements to the two groups’ designs. Hence, with utilization of the proposed framework, SMEs in both groups can achieve a more affective design, in terms of the three distinct design levels, namely visceral, behavioral and reflective design. The SMEs were mostly positive about the importance and effectiveness of considering affective needs into design. However, due to different nature of different organizations, the application of this proposed framework needs to be tailored.

5.4.2 Limitations

Due to the current company strategies, some SMEs felt that the proposed framework was difficult to implement into the current New Product Development (NPD) process. One concern may be the variation of customer affective and functional needs over time.

This method might not be very practical to use at this stage for China market. However they did not reject the possibility of using it in the future.

Effective utilization of the Citarasa Framework depends on the SMEs acceptance, especially those of the stylists and engineers. To minimize the gaps between customers' perception and designer's design, one stylist stated that they should help customer understand what a 'fashionable' design is. The automotive company should constantly guide the customers, for example, by promoting a series of designs, which are claimed to be "fashionable". This would allow customers to understand, accept and generate an idea of what fashion means to them. In contrast, the product planners had a greater acceptance at this point.

Moreover, mapping from customer needs to requirement and further to comprehensive design parameters was often difficult in practice due to several reasons; such as the vaguely defined customer requirements, diversity and variability of customer's needs, problems in identifying feasibility, value in increasing customer's satisfaction level and willingness to pay accordingly. Making trade-offs in customer requirements, remains the greatest concerns of SMEs.

There are limitations of this study. Due to the time and resources constraints, we are unable to obtain more groups of designers, who could participate in the study. This can be considered in extension of this work. Also questions that we asked could have been more structure and less open-ended. On the other hands, this would have been contrary to our desire to understand the expertise of SMEs, which is better captured using open-ended questions (Klein et al.1989).

Chapter 6 – Study 2: DECA Case Studies

In this Chapter, several case studies are documented. The purpose was to validate Design Equations for Citarasa Analysis (DECA) method proposed in Chapter 3. Three case studies were investigated, including car seat, car dashboard and truck living compartment. The findings and discussion of results are presented.

6.1 Case Study I - Automobile Seat Example

To evaluate the feasibility of DECA, the following cases were analyzed corresponding to the *Design Matrix* in the framework. In this section, the detailed answers are extracted from CARE survey sample, which related to car seat design were analyzed and mapped into the design matrix.

6.1.1 Reviews on Automobile Seat Design

Safety and comfort are the two factors that automobile seat manufacturers use to distinguish and evaluate products (Verver et al.2005). Every seat characteristic is important in designing an automobile seat. The geometric sections of the seat have been defined specifically in Figure 6-1; each element has its specific properties.

Figure 6-1 Overview of the division of the seat in several parts (Verver et al.2005)

Pheasant (2006) provided recommendations for car seat design, in addition to general seating:

- Good visibility of the road should be possible, together with a good view of all the instruments.
- The driver should be able to reach pedals and hand controls without stretching.
- The body should be supported and muscular effort minimized to allowing the driver to concentrate on the driving task.
- Shaping and padding should allow good distribution of body weight over the seat.
- Vibration and shock transfer should be minimized.

In order to minimize discomfort, the car seat should provide more adjustable components, such as the seat back, headrest, lumbar support, height, seat angle, etc. Generally speaking, the more adjustability offered, the easier it is for drivers and passengers to achieve a comfortable posture.

Additional criteria which need to be considered while designing a car seat were proposed by Reed et al. (1994), A detailed description is included in Appendix E:

- *Fit*: determined by anthropometry of the occupant population and include such measure as the length of seat cushion.
- *Feel*: the physical contact between the occupant and seat, including the pressure distribution and upholstery properties.
- *Support*: affect the posture of the occupant and include seat contours and adjustments.

6.1.2 Description of DECA Procedures

In order to illustrate the feasibility and power of DECA to resolve the complexity of design automobiles, we demonstrate how a car seat can be designed using DECA procedure. First, we listed and prioritized functional and affective user needs. Based on the needs, we then defined ARs and FRs accordingly at lower levels of hierarchy.

1. Product: Car seat
2. User Needs: a good car seat

Classify and prioritize functional needs (FNs) and affective needs (ANs), to simplify the case only one need is used here.

Define and decompose “A good car seat” into two ARs and three FRs into reasonable lower levels of hierarchy, which are related to specific user needs See Figure 6-2. The bottom row illustrates the design tools that can be used for design of the ARs and FRs.

FRs:

1. FR1: ergonomics
2. FR2: comfortable
3. FR3: spacious

ARs:

1. AR1: sporty

2. AR2: elegant

Figure 6-2 Decomposition of A Good Car Seat into two ARs and three FRs

- Decompose DPs into reasonable lower levels of responding hierarchy and put them in the design matrix. The general car seat design parameter is shown in Figure 6-3.

DP decomposition (general):

Figure 6-3 Decomposition of design parameters

- Specify corresponding user scenarios and affective user experiences.
Designers must have a clear understanding of product constraints, context of use and what sort of design is needed. Scenarios embody concrete and accurate design

requirements, which is helpful in discussing and understanding product features (Carroll, 2000). A specific scenario to perform the task is presented below:

Task: Test drive car

Persona: Patrick

User Group: Sales Manager

Background: Patrick would like to buy a new car. His old car seat is too small, fixed and cannot be adjusted. Patrick is a tall person with large body, and he would like a sports car. He has worked for more than 10 years and around 30 to 35 years old. He also needs to visit his client very often.

Scenario: In the car showrooms, few cars were selected for a test drive. Some of the cars which were test driven provided adjustable seats, with different levels of usability. Some seats tested were too narrow and small for his body. Patrick may need to drive for long time, and sometime would like to take a short rest in the car. Specific DP decomposition for Patrick's scenario, see Figure 6-4.

Figure 6-4 DP decomposition according to “Patrick scenario”

5. Analyze the mapping and coupling between ARs, FRs and DPs. Conventionally, the values in a design matrix will be either ‘x’ or ‘0’, where ‘x’ represents a

mapping between the corresponding vector components while ‘0’ signifies no mapping.

6.1.3 Result and Discussion

From the car seat case, the following matrix was constructed. We noted that the mapping does not have to be uncoupled; however, here a semi-coupled matrix is achieved to reduce the complexity of design. Map each AR and FR to several matching design parameters, and vice versa.

$$\begin{bmatrix} \text{AR}_1: \text{Sporty} \\ \text{FR}_1: \text{Ergonomics} \\ \text{FR}_2: \text{Spacious} \\ \text{FR}_3: \text{Comfortable} \\ \text{AR}_2: \text{Elegant} \end{bmatrix} = \begin{bmatrix} x & 0 & 0 & 0 & 0 \\ 0 & x & 0 & 0 & 0 \\ 0 & x & x & 0 & 0 \\ 0 & x & x & x & 0 \\ 0 & 0 & 0 & x & x \end{bmatrix} \times \begin{bmatrix} \text{Racing seat} \\ \text{adjustable seat and enlarged leg space} \\ \text{cushion : width > 500mm, length > 350mm} \\ \text{Leather seat cover} \\ \text{Black or unicolor} \end{bmatrix}$$

Figure 6-5 Example of car seat design using DECA

From Figure 6-5, the inputs are functional requirements (FRs) and affective requirements (ARs). Both can be obtained from customer surveys. It is observed AR₁-sporty is fulfilled by DP₁; AR₂ - elegant is fulfilled by DP₄ and DP₅. On the other hand, DP₂- adjustable seat can fulfill FR₁, FR₂ and FR₃.

Uncoupled design is desirable for the FRs, because several DPs may interfere in finding a good design solution. However several DPs can be associated with one AR, since in this case the function of a DP would not be functionality – but rather the affective effect of the DP. In this case “Comfortable” was identified as an AR. Although this is an affective parameter DP₁ and DP₂ - that were selected to satisfy FR₁ and FR₂- are also relevant for AR₂.

DECA method helps to structure the design process, and prompts the designer to consider both affective and functional design. It will also make the designer aware of

the importance of affective design and instruct him to make trade-off decisions that can promote affective design. It is therefore considered a helpful tool to support designers.

The car seat design demonstrated here is a simple application. For a more complex system, a semi-coupled design matrix might be difficult to achieve. The basic idea of promoting the use of design matrices is to motivate domain experts to consider affective design in the whole design process and to make trade-off decisions wisely.

6.2 Case Study II - Automobile Dashboard design

6.2.1 Reviews on Automobile Dashboard

The dashboard and instrument panel (see Figure 6-6) are perhaps the most important parts in automotive interior design. The driver needs to continuously collect information from and control the car using displays and controls on the dashboard. The design of dashboard has significant impact on customer's satisfaction, especially driver's satisfaction.

The designer will first position the instrument cluster on the dashboard. The instrument cluster includes: gauges such as a speedometer, tachometer, odometer, and fuel gauge. The designer will then add on heating and ventilation controls and vents, lighting controls, and audio equipment. In some cars, automotive navigation system and advanced entertainment equipments are also mounted on the dashboard.

Figure 6-6 Components of car dashboard

(http://www.infovisual.info/05/004_en.html)

The enhancement of dashboard design is primarily to increase the level of safety, comfort and convenience (control) for both the drivers and passengers. Adding more electronic systems and controls will probably increase the costs and may also create usability problems. Therefore, it is important to consider various trade-offs when designing a dashboard. Figure 6-7 presents the ontology of dashboard design provided by CRF et al. (2007).

Scenario: Lucas wants to buy his first car; he always wanted a sporty car. He prefers the car that looks visual appealing, ergonomic, and many more features which are able to accommodate his business and personal needs.

6.2.3 Result and Discussion

Customer requirement analysis

According to the above scenario developed by one customer, Table 6-1 provides a summary of detailed customer requirements analyzed.

Table 6-1 Results of customer requirement analysis

Customer needs	Customer Requirements	Design Parameters
Mobile phone usage	FR1: safety	DP1: Voice control (Hands-free)
Listen to music	FR2: Flexibility FR3: Easy to reach	DP2: iPod holder DP3: Location of holder: right hand side
Active night use	FR4: for night use	DP4: Illumination: blue
Need place to store devices/files	FR5: Space FR6: security	DP5: Glove compartment DP6: Slip free dashboard
Like sports car	AR1: sporty	DP4: Illumination: blue DP7: Silver accent /Metal theme DP8: Smooth lines/ edge, c.f. sharp corners DP9: Air-con vent shape: round DP10: Round dials instrument effect DP11: Analogue meter needle, diameter of speedometer, tachometer :88mm
Aesthetic value	AR2: Visually appealing	DP9: Air-con shape: round DP11: Analogue meter needle, diameter of speedometer, tachometer :88mm
	AR3: smooth/streamline	DP8: Smooth lines/ edge, c.f. sharp corners DP9: Air-con vent shape: round DP10: Round dials instrument effect

	AR4: simplicity	DP12:Uncluttered, simple layout DP7: Silver accent/Metal theme DP11: Analogue meter needle, diameter of speedometer, tachometer :88mm
Fit Business and personal image: young stylish executive	AR5: stylish	DP1: Voice control (Hands-free) DP4: Illumination: blue DP7: Silver accent/Metal theme DP8: Smooth lines/ edge, c.f. sharp corners DP12:Uncluttered, simple layout
	AR6: young/energetic	DP2: iPod holder DP3: Location of holder: right hand side DP7: Silver accent/Metal theme DP12:Uncluttered, simple layout

In Table 6-1, all the descriptors were included in CARE survey data, hence according to the proposed design matrix; DECA mapping can be developed and organized into a matrix as shown in Figure 6-8. The values in a design matrix will be either 'x' or '0', where 'x' represents a mapping between the corresponding vector components while '0' signifies no mapping.

$$\begin{bmatrix} \text{safety} \\ \text{flexibility} \\ \text{easy to reach} \\ \text{clear for night use} \\ \text{space} \\ \text{security} \\ \text{sporty} \\ \text{visually appealing} \\ \text{smoothness} \\ \text{simplicity} \\ \text{stylish} \\ \text{young/energetic} \end{bmatrix} = \begin{bmatrix} x & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & x & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & x & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & x & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & x & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & x & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & x & 0 & 0 & x & x & x & x & x & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & x & 0 & x & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & x & x & x & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & x & 0 & 0 & 0 & x & x \\ x & 0 & 0 & x & 0 & 0 & x & x & 0 & 0 & 0 & 0 \\ 0 & x & x & 0 & 0 & 0 & x & 0 & 0 & 0 & 0 & x \end{bmatrix} \times \begin{bmatrix} \text{voice control} \\ \text{ipod holder} \\ \text{location of holder right handside} \\ \text{illumination blue} \\ \text{glove compartment} \\ \text{slipfree dashboard} \\ \text{silver accent/ metal theme} \\ \text{smooth lines/edges} \\ \text{air - vent shape round} \\ \text{round dials instrument effect} \\ \text{analogue meter Diam = 88mm} \\ \text{uncluttered layout} \end{bmatrix}$$

Figure 6-8 DECA mapping of car dashboard

Analyzing the mappings in Figure 6-8, we conclude that the design matrix is a coupled design. It should be noted that the objective of this case study was to identify and understand the customer requirements, the design parameters and the mapping relationships. Therefore, it does not deal with the generation of an uncoupled/semi-coupled design from this design equation. Our main purpose is to map the DPs on the FRs/ARs. Figure 6-8 then demonstrates that some DPs fulfill many FRs and ARs. There is nothing wrong in this, on the contrary, it may be good to “hit two birds by one stone”, to find innovative design attributes that work as functional as well as affective design elements.

The mappings were verified in the interview with automotive designers. For example, one designer stated, when they looked at a number of different concepts, as “space” or “spacious” interior was required, we kept the cubic architecture, focus on the compartment, for example glove, tool box, and so on.

Moreover, the style of individual elements also affects the whole design look and feel. For example, as required to have a “smooth” and “sporty” feel, the air-condition vents would be designed as round shape, which is inspired by contemporary product design. For “sporty” dashboard design, blue illumination and round dial effect for the instrument panel is probably appropriate. For the perceived quality, such as metal-effect material or silver texture would be nice.

Hence, based on the domain expert evaluation, DECA matrix has been derived. As illustrated in the matrix, the customer’s FR – “clear for night use” can be satisfied by use of DP – blue illumination on the instrument panel. The AR – “sporty” was satisfied by a set of design parameters including: blue illumination, silver accent or metal theme, smooth lines in the dashboard design, round-shaped air-condition vent, round dials/instruments and use of analogue meters instead of digital meter. Here AR – “Sporty” is fulfilled by more than one DP, which is consistent with our hypothesis.

6.3 Case Study III - Truck Living Compartment

6.3.1 Reviews on Truck Living Compartment

Similarly, the truck system may be classified into different sub-systems.

Figure 6-9 shows the breakdown into various components that make up the living compartment of a truck cab, which is the focus of truck planning in CATER (VTEC, 2006). This figure gives a summary of affective needs, product requirements and design parameters as defined for a truck living cab.

Figure 6-9 Ontology of truck living cab (VTEC, 2006)

6.3.2 Results and Discussion

The data collected in Truck Needs Tracker (TNT) Survey was used to evaluate and validate the proposed DECA method. Data was analyzed and transferred to a Design Matrix. In this section, detailed descriptors were extracted from TNT data, which were compiled from the following nine data matrices covering areas including: General interior impression, Color impression, Material impression, Shape impression, Comfort impression, Fit & finish impression, Durability impression, Clean impression, Activities.

The number of Citarasa descriptors was reduced to 16, for describing affect information as perceived by different truck users, as shown in Table 6-2, the three columns represent data collected in:

- **Affective and functional needs:** What the drivers/owners experienced or would like to do experience when interacting with the truck.
- **Product features:** Equipment, component or area in the truck that is related to an impression or an activity.
- **Design parameters:** Attributes and physical elements that contribute to an impression or to an activity.

Table 6-2 Summary of customer needs and design parameters

No.	Area	Affective and functional Customer Needs	Product Feature	Design Parameters
1	General impression	Spacious Functional Comfortable Clean	Whole-cab Seat Bunk	Squarished-shaped Material Stain-resistant Leather
2	Color impression	Cosy Soft	Work-area Bunk	Black Grey

			Seat	
3	Material impression	Comfortable Durable Easy-to-clean	Bunk Dashboard Seat	Leather Fabric Plastic
4	Shape impression	Soft Good looking Spacious	Shape Dashboard	Rounded Curved Squared
5	Comfort impression	Spacious Ergonomic	Bunk Seat controls	Ventilated Adjustable Within-reach
6	Fit & finish impression	Quality Solid Comfortable Well-made	Seat Dashboard Controls	Smooth Material Color Seamed
7	Durability impression	Hard Long-lasting	Dashboard Seat Whole-cab	Metal Plastic Leather
8	Clean impression	Easy-to-clean Stain-resistant Clean	Seat Dashboard Bunk	Color-dark Leather Smooth
9	Activity	Eat Watch Sleep Listen	Bunk Seat	Audio Flat surface Bunk TV-equipment Seat comfortable

The data summarized in the above table was analyzed and mapped into the design parameters in design matrix. The values in a design matrix will be either 'x' or '0', where 'x' represents the existence of a correlation between the corresponding vector components while '0' signifies no correlation. Figure 6-10 shows the DECA mapping.

spacious functional comfortabl e clean cosy soft durable easy - to - clean good looking ergonomic quality longlastin g eat watch sleep listen	=	x x 0 0 0 0 0 0 0 0 0 0 0 0 x 0 0 0 0 0 0 0 0 0 0 x x 0 0 0 x 0 0 0 0 0 0 0 0 x x x 0 0 0 x x x 0 x x x x 0 0 0 0 0 0 x x 0 0 0 0 0 0 x x x 0 0 0 x 0 x 0 0 0 0 0 x 0 0 0 0 x 0 0 x x 0 x 0 0 x 0 0 x 0 x 0 0 0 0 0 0 x x 0 0 0 0 0 0 0 x 0 x x 0 0 x x x 0 x 0 0 0 0 0 x 0 0 0 0 x x 0 0 x 0 0 0 0 0 0 0 0 0 0 0 0 x x 0 0 x x x 0 0 x 0 x x 0 0 0 0 x 0 0 0 0 x x x x x 0 x 0 0 0 0 0 0 0 0 0 0 x x 0 0 x 0 0 0 0 x 0 x 0 0 x x 0 x 0 0 0 0 0 0 0 x 0 0 0 0 0 0 0 x 0 x x 0 0 x 0 0 0 0 0 0 0 x 0 x 0 0 0 x 0 x x 0 x 0 0 0 x 0 0 0 0 0 0 0 0 0 0 0 0 x x 0 0 0 0 0 x x 0 0 0 0 0 x 0 0 0 0 0 0 x 0 0 0 0 0 0 0 x x 0 x 0 0 0 0 0 0 0 0 0 0 x 0 0 0 0 0 0 x x x x x 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 x x 0 x 0 0 0 0 0 0 0 0 0 x 0 0 0 0	×	whole - cab whole - cab : ventilated seat : leather material : fabric seat : adjustable seat : comfortabl e bunk : material Bunk : adjustable Black colour grey colour work - area : flat surface dashboard : curved/rou nded dashboard : squared dashboard : smooth controls : within - reach seamed finish Audio equipment TV equipment stain – resistant material : metal material : plastic color - dark

Figure 6-10 DECA mapping of truck living cab

The DECA mapping of truck living cab was derived by domain experts by analyzing data from TNT survey and considering trade-offs in design. The iteration of design process allows the creation of product with not only forms and function, but also affective requirements and interpretation of individual user, which caters for different individuals.

As shown in Figure 6-10, the customer mentioned one AR as “cosy”, which can be associated with DP including the whole cab, leather and comfortable seat, major color is black color, and equipped with high quality TV and Audio devices. When customer wanted a “easy-to-clean” cab, the normal practice is to well-ventilated the cab and using leather or fabric material for seat or bunk, and also use darker color for well-maintain purpose. A “comfortable” cab is well-ventilated, with adjustable leather seat, and flexible bunk. All the customer requirements and design parameters were stored in

the Citarasa database for retrieve and analysis purpose. Based on the expert review, we manage to capture the underlined reason for design and generate the DECA matrix.

In this case study, the DP matrix is not very detailed. In order to extend the design parameters into more detailed level, a more specific and in-depth interview/study should be carried out.

6.4 Validation and Future Work

In the case studies discussed above, the DECA method was performed in a simplified manner for illustration purpose. It is observed that that the DECA method helps to structure the design process, and prompts designers to consider both affective and functional design. It makes the designer aware of the importance of affective design and instructs him to make trade-off decisions that can promote affective design. It is therefore considered a helpful tool that can support designers. The basic idea of promoting the use of design matrix is to motivate domain experts to consider both affective design and functional design, throughout the design process and to make decisions based on both.

For future implementation, it is possible to evaluate the DECA process by taking results from data mining analysis of customers' survey data, and match to the domain experts' deliberation of design parameters that store in the integrated database. Hence, in actual practice, once customers have specified a set of particular requirements, the system will be able to automatically generate the corresponding set of design parameters, which is stored in a database.

Chapter 7 – Conclusions and Future Research

7.1 Conclusions

Most automobiles today have excellent quality. Functionality, ease-of-use and reliability are considered as “must-have”, fundamental design elements. That is why we need to explore customer fulfillment from different perspectives of appreciation, explicitly to improve product competitiveness and subsequently customer satisfaction through affective and emotional factors. These factors may be influenced by individual preferences, status, life styles and values. Affective product design addresses customer values of appreciation, attractiveness and experience of products. Affect and emotions play essential roles in product evaluation phase, where customers tend to evaluate the product holistically.

The abstraction levels in generated affective evaluation need to be studied. Successful affective product design is all about offering customers the products in the way they want, which are appealing – socially, affectively and cognitively.

The objective of this research is to provide a systematic framework for affective design and evaluation. This will help designer understand and include affect and emotion into product design, and finally support the designer. It is important to explore the design methods that can effectively transfer the customer’s true needs.

In order to understand and predict customer’s needs better, we introduce the abstraction of customer’s requirements. A framework for affective design and evaluation has been proposed to illustrate the whole process from product planning to design, and finally to customer evaluation. We have also developed an Affective Requirements Hierarchy

(ARH) to get a better perceptive of how customers evaluate a product. Moreover, a specific design method – Design Equations for Citarasa Analysis (DECA), which involves both affective and functional requirements, has been developed to assist the designer to transform customer requirements into design parameters. This proposed framework and DECA methods are intended as design aids for designers.

In the proposed framework, the left box illustrates the methods, considerations and constraints that a designer can used in proposing a new design. One of the methods is Norman's three levels of design, namely: visceral, behavioral and reflective level. Each level associates with different design strategies. Constraints are formulated and they may come from marketing knowledge and context of use/activities, as well as current design trends. All contents mentioned above have been included in the proposed framework. The proposed affective design and evaluation framework integrates affect into product design process to achieve a more affective and then competitive design. It can increase the awareness of understanding and utilizing affective design, and it can also support trade-offs decision making around those customer needs concerned with affect or emotion, which have particular relevance to stylistic design.

The Product Planning (PP) Study shows that understanding and utilizing affective product design knowledge would enable product planning and design teams to design products that are more appealing to customers. Through the PP study conducted in automobile company, we would like to increase knowledge in affective design through research and design practice, and then transfer this knowledge to industry. During product planning activity, the team identifies the potential product, and then sets the aims and constraints of the product, and gives other functions and requirements. We can conclude that effective Product Planning is a critical stage within NPD. Furthermore, a strong understanding of the target customer segment and customer's true needs (including functional and affective needs) is vital. It is observed by using the proposed framework, PP teams are able to achieve a more affective design, in terms of visceral, behavioral and reflective design.

A series of case studies related to automotive context have been performed to evaluate the feasibility of proposed DECA method. It is shown that DECA method helps to structure the design process and prompts designers to consider both affective and functional design. It will also make the designer aware of the importance of affective design and instructs him to make trade-off decisions that can promote affective design. It is therefore considered a helpful tool to support designers. The basic idea of promoting the use of design matrix is to motivate domain experts to consider both aspects of design at the same time, and throughout the entire design process.

7.2 Future Research

Future research can focus on the following:

1. Replication of the DECA case studies on more complicated products/parts, to identify inappropriateness of the method and then refine the proposed method.
2. In addition, as mentioned in Chapter 6, DECA method is standalone in current study. However, it can be further developed and possibly be automated by taking data mining results from customer survey, when there is sufficient data to develop the database and algorithm.
3. Further investigation can be carried out to validate and refined the proposed ARH framework. The study can be expanded to other products to provide a more general pattern, and explore the design element influences consumer preference. This definitely would be an important area to be further researched.
4. On the other hand, comparative/replicated studies can be conducted to further validate the usefulness of the proposed framework, in which results can be compared with the PP China study. The study can be conducted using bigger sample size and/or with different design task. The data collection can be

combination of qualitative and quantitative data. This can possibly expand the applicability, and provide more comprehensive understanding on the impact on industry. The comparative results can be analyzed and suggest culture differences and inter-company differences in practice. Moreover, it is suggested that user scenario be refined to present a more specific and detailed concept for the efficiency consideration.

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