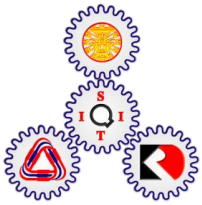

AN INTRODUCTION TO THE INTEGRATED DECISION-SUPPORT SYSTEM FOR GENERATING THE OPTIMAL ENGINEERING DESIGNS

BY

JINATTA TONGPINKAEW

A THSIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF ENGINEERING (LOGISTICS AND SUPPLY CHAIN SYSTEMS ENGINEERING)

SIRINDHORN INTERNATIONAL INSTITUTE OF TECHNOLOGY

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A Thesis Presented

By

JINATTA TONGPINKAEW

Submitted to

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MASTER OF ENGINEERING IN (LOGISTICS AND SUPPLY CHAIN SYSTEMS ENGINEERING)

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JULY 2017

Abstract

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by

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Identifying customer needs is a compulsory step in product design and development. All products are developed under the criteria of maximum customer's satisfaction. Recently, the factors influenced customer's decision have been studied and researched. The customers select and try to find the products that might suit them. Fortunately, some can find the desire product with the acceptable price and quality; however, in different situation, some fulfil their needs by purchasing the same quality of the product with higher price. For basic needs, people decide to purchase a product quickly from the regular market based on their experiences without considering and emphasizing on social classes or higher-level needs. For basic needs combining the social needs, the customer's decision for purchasing is influenced by fashion, advertisement, friends or culture. For these reasons, some hidden issues are existed and cannot be revealed. Presented in this research is the alternative channel or guideline for assisting the design engineer or manufacturer to translate the customer's requirements and behaviours on purchasing a basic need product and basic need combining social need. Foot inserts and pillows with different materials have been applied as the basic need product while eyeglasses with different shape and material have been applied as the basic need combining the social need product. The customer's behaviours, and factors influenced on purchasing will be analyzed and discussed before creating the guideline.

The objective of this paper is to propose how to set up design guideline in product design. It involves establishing target group, identifying customer needs, and performing competitive analysis. For the foot inserts, the interviewed 150 ladies from the central provinces of Thailand prefer to wear flat shoes for performing daily activities. A 54% of the interviewed group of prefers to apply heel insoles for releasing stress occurred during the day; especially the ladies who are members of an aircrew or a flight attendant. The applications of Tek-scan and finite element have been applied to help to select the appropriate insoles with a reasonable price for minimizing foot pain or extending the walking period tolerance of daily activities where the same or favorite shoes still be applied.

For the pillows, teenagers are used as target group respectively. The principle of randomized complete block design was introduced in order to investigate customer aspect on market pillow. The results reveal that twenty-five percent of teenagers purchase a pillow by looking at price and pillow made from memory foam has the highest effect on customer perception in term of comfort rate and expected price. However, ball fiber should be used to made pillow from considering customer purchasing behaviour.

For the eye glasses, Kansei Engineering (KE) with statistical analysis has been applied in this research for analysing the customer's behaviours and the specific requirements which have the direct effect on the number of products that cannot be sold or are left in the stock. Three main activities are required for accomplishing the proposed approach: identifying, measuring, and analysing the specific characteristics of the product and customer's requirement.

Keywords: Product design and development (PDD), Customer's requirement, Customer need identification, engineering design, emotional design, product design, Kansei engineering, design support tool Basic needs, Reverse Engineering (RE), Virtual Model, Contact Data Acquisition, Heel insoles, Insert Materials, Pillow concept design, Randomized complete block design (RCBD)

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Chapter 1
Introduction

1.1 Introduction

Nearly a million people who decided to purchase products in the last five years were influenced by various sources such as internet, social media, offline-magazines, and direct conversations. Among those factors, they prefer to consult friends and family for making a purchase, and they finally judge the quality and reliability of the product by using the emphasized face-to-face conversations. For needs, they can be classified into five main types: self-actualization needs, esteem needs, social needs, safety needs, and physiological or basic needs (*Maslow 1943*). Emphasizing the basic needs, it involves the fundamental requirements of life for survival including shelter, food, and clothing. When the influenced information obtained from the reliable resources is transferred to the user who decides to purchase a product, the user expects (feels) bias on the product recommended by the reliable resources. Purchasing and using experiences have become customer perceptions. If the launched product is satisfied and supported customer's requirement, it will be survived in the competitive market. If the product or service is really good, it can sell itself without requiring any advertisements. For a health-related product, a customer would like to test, check or analyze the product's characteristics and properties before making decision even the clear information is provided by the brand assistant or the animation advertisement. These will become to this research to establish the concept or make the guideline to create the optimal engineering design to meet the customer's satisfaction.

In order to satisfy the customer's needs, the concept of product design development has been applied to generate the optimal design. The accuracy of proposed design depends on the initial phase of PDD; concept development (CD) which has been played as a vital and an important issue. When the fabricated prototype (obtained from testing and refinement) cannot be accepted by the customer, the manufacturers start analyzing and converting all process back to the origin where the drafted design is launched. For CD stage, it involves with identifying the customer needs and establishing the target group etc. Therefore, well-translation between customers and

manufacturer communication is required for satisfying the customer's requirement. The interview with discussion in small group and to conduct the survey by using the questionnaire have been performed to capture the customer's wants (Voice of Customer; VoCs). However, some of the customers cannot express their needs directly through product characteristics; they decide to buy the product by using their personal feelings and emotions (Aziz & Lokman, 2011; Wiegers, Langeveld & Vergeest, 2011; Sarkar & Chakrabarti, 2011; Menezes & Lawson, 2006; Jonson, 2005; Lawson & Shee, 1997; Schütte, Eklund, Axelsson & Nagamachi, 2004). To be able to link those emotion or feeling with product characteristics, a method of Kansei Engineering are introduced (Mitsuo, 1995). After analyzing the collect data from survey, the new product has been designed by applying finite element analysis (FEA) method and reverse engineering (RE) technique. RE technique can be applied to create CAD model from the existing object. Then, applying FEA method will be performed for testing the new product. The components of CD related to the proposed approach where three main key components are considered: RE, VoCs, and customer's requirement. For RE, this process requires data acquisition, surface reconstruction, and surface fitting activities to quickly generate a virtual model where the engineering or geometric documentation is not required. The obtained virtual model can be directly transferred to the subsequence processes such as rapid prototype (RP) for making process or physical testing and simulation with less human labor required.

1.2 Problem Statement

Recently, to design the health-related products, the designers always focus on the ergonomics and the comfortable levels for reducing the pain that come from the external pressure applied on the human body part. One particular point of view of design conveys the distorted style and format since the specified or stated manner of consideration and attitude how the designers see or think of the product might not hit the customer's requirements. The designed product characteristics persuade, mislead, or deceive the target customers.

Some people cannot express their needs relating to emotions directly through product characteristics. Telling the designer directly makes they feel uncomfortable,

and, sometimes, they put a lot of thought into picking out the proper styles with influenced choices or new materials. These kinds of misunderstandings lead to conflict and resentment not just at design, but at company's reliability too. To recommend or find out the optimal design concerning matters of human body for satisfying with the customer's requirements and increasing the opportunity to launch new product to the right market, well-process planning and design should be constructed at the initial stage of manufacturing platform where some comments and ideas of the designers can be balanced by the voice of customers (VoCs).

1.3 Objectives of Thesis

The objective of this research is to generate the optimal engineering design of the health related product to meet with the customer's satisfaction by integrating the concept of product design and development (PDD); Voice of Customers (VoCs), Kansei engineering (KE), reverse engineering (RE), rapid prototyping (RP), contact measurement technique (*Tek-Scan*), and finite element analysis (FEA). The expectation of this research is about the creation of guidelines and designs to help the manufacturer creating a product with meeting the customer's point of view.

The benefits obtained from emotional analysis by KE can save a lot of time and money to create an entire new product or a minor-changed pattern since the intangible adjective words representing customer's wants can be revealed into the engineering specification directly. The customers can convey their wants without misunderstanding and repeating the specific requirements several times. Applying RE and RP in this research can create 3D model and a prototype quickly for checking the physical properties of the desired product. To maintain the quality of a new product for both physical and mechanical characteristics, the appropriate conditions and parameters of material for producing the products with the optimal engineering designs will be identified by applying the virtual simulation.

1.4 Scopes and Limitations

This research is proposed the optimal engineering design where the methods used for identifying the specific characteristics and analyzing the influences of the product design have been introduced and developed for satisfying the customer's requirement. To achieve the research objective, the first stage of PPD, which is CD, is applied to identify, create the guidelines, and analyze the parameters which have the direct effects on customer's behavior and brand characteristics. Finite element analysis (FEA), the accuracy of the solution depends on the type and size of the elements while the file size is limited, it must be in **.STL* format.

In this research, the examples used for demonstrating the basic products which relate directly to human body are foot insoles and pillow. For the product that contain the basic and social issues, the eyeglasses are selected where Kansei engineering (KE) is applied to reveal those hidden requirements into the recommended patterns, shapes, and styles. For all three case studies, the optimal designs with the appropriate material and the shape will be recommended to satisfy the customer satisfaction.

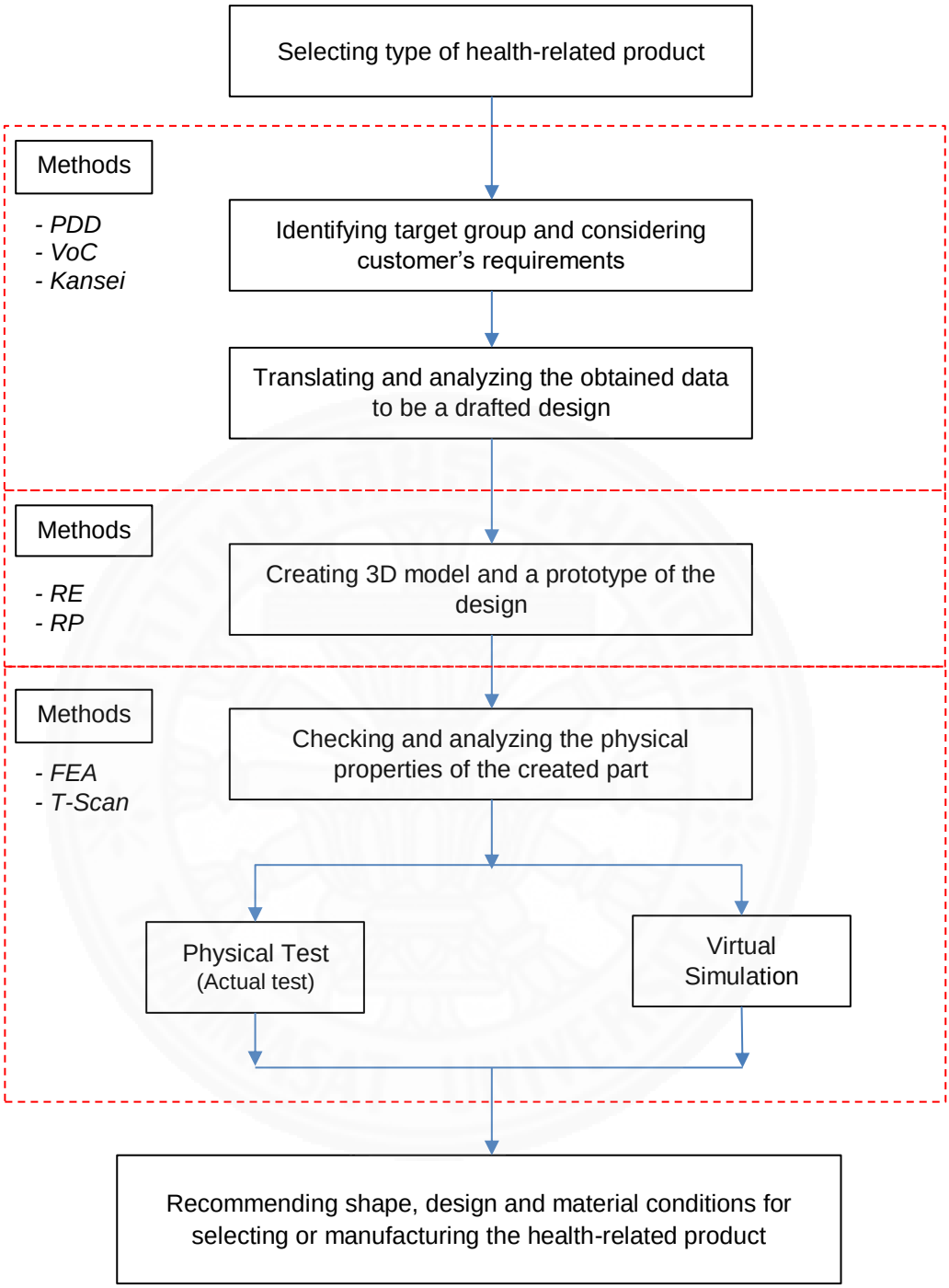


Figure 1.1: The overall steps required for accomplishing the proposed research

1.5 Organization of the Thesis

Thesis organization is arranged as follows.

Chapter I presents research motivations, the problem statement, the research objective, the research scope and limitation and a dissertation organization.

Chapter II reviews relevant literatures on the product design and development (PDD), the quality function deployment (QFD), Kansei engineering (KE), reverse engineering (RE), the previous works of finite element analysis--the distribution of external loads which have an effect on the human body, and case studies about the influences of customer's behaviors and purchasing decisions.

Chapter III explains the overall process of the proposed approach.

Chapter IV presents about the processes used for translating customer needs to the design where the foot inserts will be applied for demonstrating the proposed approach.

Chapter V describes the implementations of the proposed approach on the various styles of pillows.

Chapter VI shows the recommended design of the eyeglasses where the concept of integrated basic-social need is applied.

Chapter VII presents the accomplishment of this research and provides the recommendations for the future study.

Chapter 2
Literature Review

The contents in literature review chapter are divided into six sections. First section, it describe about the concept of product design and development. The second section is the voice of customer. The third section, it describes the method of Kansei Engineering. The fourth section, it is about reverse engineering. The fifth section, it describes about finite element analysis and the last section, it is about ergonomic product design principle.

2.1 Product Design and Development

Product Design and Development concept is a process of creating a new efficiently product to be sold to customers. Design means that the activities that involved in creating style of product, designing the mechanism of the product and select the product's materials. Development is the process of identifying a market, creating a product based on each market level, testing, and refining the product before it launched to the market with high amount of volume. Therefore, product design and development describes about the process of making product that can be sold to the market regarding the customer demands. The method covers five main stages which are concept development, system-level design, detail design, testing and refinement, and production ramp-up (Ulrich & Eppinger, 2007).

2.1.1 Concept development

During this stage, requirements of the target market are identified through questionnaire or interview the target group. The necessary information is gathered such as size, weight, and other specifications of the product. Then the information is analysed by various method to find the feasible product's specification that meet customer's need. Finally, the product concepts are generated and ready to be send to the next stage which is system-level design.

2.1.2 System level design

System level design, or the task of designing the architecture of the product, is the subject of this stage. The team was focused on the core product idea, and the prospective design was largely based on overviews rather than in depth design and engineering.

2.1.3 Detail design

Detail design, design for manufacture, is the stage where the necessary engineering is done for every component of the product. During this phase, each part is identified and engineered. Tolerances, materials, and finishes are defined, and the design is documented with drawings or computer files.

2.1.4 Testing and refinement

During the testing and refinement stage, a number of prototypes are built and tested. Even though they are not made from production components, prototypes emulate production products as closely as possible. The prototypes are necessary to determine whether the performance of the product matches the specifications, and to uncover design shortfalls and gain in-the-field experience with the product in use. Later, the prototypes are built from the first production components received from suppliers.

2.1.5 Production ramp-up

During production ramp-up, the work force is trained as the first products are being manufactured. The slow production time provides time to work out any remaining problems with supplier components, fabrication, and assembly procedures. The staff and supervisory team are organized, beginning with a core team, and line workers are trained by assembling production units.

2.2 Voice of Customer (VOC)

VOC is a process that is used to capture the customer requirements/perception or feedback about their experience with and expectations to provide the better quality products and services.

- **Customer Loyalty**: This can be measured by assessing the overall customer satisfaction. The higher customer satisfaction levels means that there is high probability to return to buy again or persuade anyone to buy. However, many organizations are often seduced by the high number of satisfied customers and forget the loss rates to existing customers. Besides creating new customers will have higher marketing costs rather than cost of maintaining existing customers, the organization also lost the opportunity that the existing customers tell the product to any people or persuade to make the people know that product.
- **Share of Customer's Wallet**: This is derived from the competitors which has indirect effect on the cost of building a customer base. The rising of sales or market share do not always increase the margins because the cost of building the new customers base is higher than the cost of maintaining existing customers which is 5-12 times.
- **Cost Reduction**: This is from the measurement of customer satisfaction because the customer is the most obvious source of information for improving products or services. Any organization has applied VOC process been and take into account to identify the various factors linking their production. By using the benchmarking principle, it is comparable between the competitive products or service to find the ways of development and improve the better product, which may results in reducing labor or raw materials.
- **High stock price**: Whenever the customers satisfy that product or service, there is the high probability that customers will return to buy over and over again and become brand loyalty. Then the brand will be told to other people by the customers which may results in increasing the sales, market share, and then the stock price will increase as well.
-

2.3 Kansei Engineering

Kansei Engineering (KE) is used for development or improvement of products and services by translating the customer's psychological feelings and needs into the domain of product design. In another word, we may said that Kansei Engineering is used for identifies engineering parameter that links to the customer's emotional responses to the properties and characteristics of a product or service. In consequence, products can be designed to bring forward the intended feeling. The methodology is mainly a facility for the systematic development of new and innovative products, but can also be used as a tool for the improvement of product concepts. There are three methods of Kansei Engineering procedures; Type I, II, and III

2.3.1 Type I: Category Classification

The Category Classification is a method that is simplest and fastest way to analyse that exploded down the targeted concept of a new product to a subjective Kansei words. Kansei Engineering type I starts with zero-level concept that broke down into many sub concept level. These sub concepts will be broke down until the product design parameters are known (in this case is customer’s feeling). In some cases it may be use a questionnaire to make a decision for the final concept. An example of this type is applied in automobile industry; Mazda Miata (in Europe MX5). The goal was to manufacture a sport and low-price car for young male drivers.

2.3.2 Type II: KE System

KE System is a computer-aided way to connecting the user’s Kansei to the product characteristics. It uses some expert programs supporting design decisions on different products. When Kansei word is send into a system, the computer will search for a certain product image from it database. Before the design elements matching the Kansei word is presented to the user of the system, the design and colour setting is carried out from data in the corresponding database. The case study of this type is a kitchen design program, where the customers are supposed to describe their dream

kitchen in their own words. The system chooses a kitchen system and design based on the customer's life style.

2.3.3 Type III: Hybrid Kansei Engineering System

In this type, the database from related products will be set before gathering the customer demand. This would be convenient to predict the Kansei that user will have from a drawing or concept. This type of Kansei Engineering can be called as Backward Kansei Engineering System. In some situation this type of Kansei Engineering is the same as type II.The process begins when designers input their own product and compare with the stored data. These data will link with Kansei word, then the related Kansei words are presented to the designer.

2.3.4 Type IV: Kansei Engineering Modelling

Type IV Kansei Engineering implements more than just a system, it also use a mathematical model to define fuzzy sets that express the degree of desirability of people. Sanyo successfully applied this type of Kansei Engineering to generate a mathematical model of a colour copy system to generate a desirable Japanese skin tone.

2.3.5 Type V: Virtual Kansei Engineering

Insufficient knowledge of the function of complex products like condominium or house when using Kansei Engineering Type II can lead to an error of results, since only several design elements are come from output of KES. This type of Kansei Engineering is an advancement of Type II technique. This type uses a powerful technology to place the user in a virtual 3D environment to help the user select a product with virtual 3D experience. A joint project of Matsushita works and Hiroshima University use this type of Kansei Engineering to kitchen design by collected an adjective, reduced the number of adjectives, and analyse them by using the correlation between customer feelings and kitchen's characteristics. This system will be connected

to 3D space to allow customer to walk through the virtual kitchen, attempt to do some operations and may change the detail design of the kitchen.

2.3.6 TypeVI: Collaborative Kansei Engineering Designing

Collaborative Kansei Engineering Designing or internet Kansei Designing system is an internet supported Kansei Engineering System. Internet offers the linkage of view point between customer and designer together. This type of Kansei Engineering offer many benefits such as cooperative work between customer and designer, product development speed, diversity of idea. The system allow customer to put their Kansei word to the system. Meanwhile, designer can use the data from the Kansei words from customer that has been analysed to generate the design. This allow customer to participate in designing their own product that get the designed directly from their own feeling.

2.4 Reverse Engineering

Reverse engineering (RE) is the process of use the knowledge or design information from anything man-made and reproducing anything based on the same old information (Eilam, 2005). RE can help rapid product development to quickly create a virtual model from the existing or master part where the details of original geometric shapes or documentations are not required. The process involves disassembling something such as mechanical device, electronic component, and computer program.RE is the process that allows 3D CAD model can be constructed quickly and directly from the physical or existing objects (Tamás, Ralph & Jordan, 1997; Besl & Jain, 1985; Rianmora, Koomsap & Van Hai, 2009).

2.5 Finite Element Analysis

Finite element analysis (FEA) is an engineering method for the numerical analysis of complex structures. FEA consists of a computer model of a material or design that is stressed and analyzed for specific results. It is used in new product design,

and existing product refinement (Thacker et al., 1998). A company is able to verify a proposed design that will be able to perform to the client's specifications prior to manufacturing or construction. Modifying an existing product or structure is utilized to qualify the product or structure for a new service condition (Cook, 1989). In case of structural failure, FEA may be used to help determining the design modifications to meet the new condition. There are generally two types of analysis that are used in industry: 2D modeling, and 3D modeling. While 2D modeling is conserving simplicity and it allows the analysis to be run on a relatively normal computer, it tends to yield less accurate results. 3D modeling can produce more accurate results; however, the fast computers are required (Adams & Askenazi, 1999).

2.6 Ergonomic Product Design Principles

- Product size fits in with body dimension and environmental space (1^{st})

As the Figure 2.1 the ergonomic workstation that related to the first ergonomics design principles that products such as a chair, desk, or computer must be design to fit the user's size and posture. And the product must have adjustable mode to for fit in different size of people and use in many environments not only in the office but it can be used in house, school, or in the meeting room.

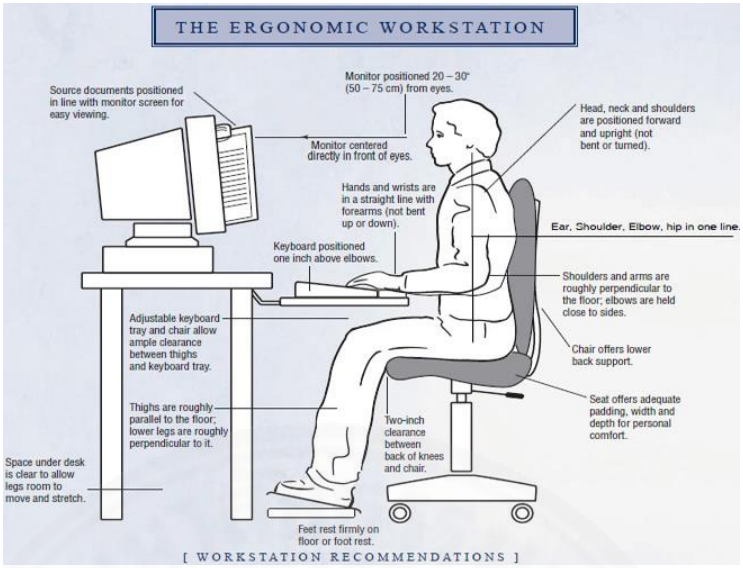


Figure 2.1: An example of ergonomic workstation

- Product form fits in with Human physiological structure and curve (2nd)

The Figure 2.2 is a one of an example of second principles as shown the product design of mouse. According to this product, it is designed to fit with human structure and curve. The mouse is designed for hand in suitable posture and flexible to use with the wireless.

Figure 2.2: The product designed to fit human physiological structure

- Product color in accord with human cognitive psychology (3rd)

This principle can be translated that the color of a product has to attract customers.

Table 2.1: The feeling of each color

Color	Picture	Meaning
Red		Energy, Strength, Passion, Love, and Power
Blue		Trust, Loyalty, Confidence, Truth, and Wisdom
Yellow		Happiness, Joy, Warm, Cheerful, and Spontaneous
Orange		Fascination, Encouragement, Success, and Enthusiasm
Green		Growth, Nature, Safety, Fresh, Healthy, and Fertility
Purple		Mystery, Ambition, Wealth, Magic, and Extravagance
Brown		Stability, Reliability, Wistful, Solid, and Dependability
White		Peaceful, Purity, Simplicity, Innocence, and Cleanliness

- Product interface correspondence with human cognitive behavior (4^{th})

The Figure 2.3 is one of the product that related to the forth principle. The washing machine is the best describe for this principles. Previously, the washing machines design to input clothes on the top and the side. Problems is in not easy to used and incorrect to the ergonomics design because the user need to bend down their body and stretch out their hand. However, currently the washing machine was developed by design the input to be slope about 45 degrees for user easy to put their clothes without bend or stretch their body.

Figure 2.3: The washing machine that has good ergonomic design

- User interacts with the product operating system intelligently (5^{th})

Chapter 3
Methodology

Presented in this chapter are the methods applied for finding the relationship between customer's requirement and engineering design where three case studies—the health-related products will be demonstrated the proposed approach. Recommending the proper shapes, designs, materials or sizes of these products is quite difficult since the specific and personal opinions influenced by family, friends or people who live in the same society have played as the important factors. Moreover, the fundamental ergonomic principles have been considered for creating the appropriate design. These three health-related products consist of *foot inserts*, *pillow* and *eyeglasses*. Along with the concept of product design development, the optimal engineering designs have been divided into three main stages. The 1st stage, *concept development*, this stage is about determining the target group to assist the manufacturers to define their target market, and figure out not only who has a need for their product or service, but also who is most likely to buy it.

Next, the survey has been done to reveal and identify the hidden issues, opinions, satisfaction levels of the existing products, and also the expectations of the new one. After completing the survey, the results from the survey have been interpreted for initiating some ideas and directions of the optimal design to meet the customer satisfactions. The 2nd and the 3rd stage which are *system level design* and *detail design*, will be done in parallel where the engineering tool has been applied to help for selecting and determining the appropriate material, shape, and style of the product specification. The obtained product characteristics will be applied to build a prototype or test in the further stage.

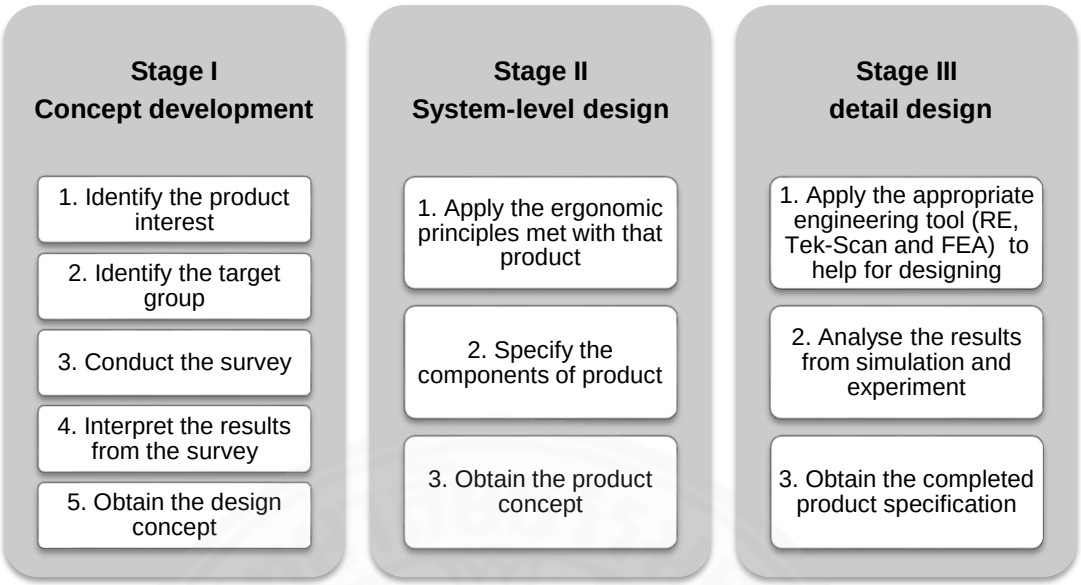


Figure 3.1: Methodology of the research

3.1 Identify the target group

The target group is specified by observing the customer behavior for buying that product and making the conversation with customer and sellers to understand that which type of customer would be the target group which the product would be sold for. According the products in three case studies, the place where to observe is the shopping mall around Bangkok and Metropolitan Bangkok because it is convenient for most people to buy their daily stuffs. According to the product related to the ergonomic matter, the condition of target group about must be concerned in this research, for example, people who ever have faced with the serious accident that affect with the nerve on human body related with that product, they will be ignored because they have always the pain on that problem area even though they use the health-related product and the results that come from those people are not reliable.

Three case studies of the health-related products; foot inserts, pillows, and eyeglasses, are applied for determining the characteristics of target group, identifying the issues hidden, and translating the requirements into the optimal designs where the relationship between basic and social needs will be presented and discussed in Chapter 4 to 6. Details of each case study will be introduced roughly in the next paragraph.

Case study I: Foot inserts

1. ***Ladies between the ages of 20 and 35 years:*** This is because ladies between the ages of 20 and 35 years have been influenced by the external factors such as fashions, culture, designs or friends (Rani, 2014). They always change and buy the shoes every few weeks, and they are very active for dynamic activities.
2. ***Heel height:*** According to a person in the age range of 20 to 35, wearing flat shoes (i.e., with 3.5 cm-heel height) is very popular since the majority of shoes type available for ladies in many department stores is flat-shoe-type.
3. ***Average weight:*** The weight range of Asian ladies is around 50-57 kg (SizeThai, 2006). Therefore, the sample who is asked for demonstrating the proposed approach should weigh around that considered range.
4. ***Normal feet:*** This research focuses only on the normal feet because the expected results should be analyzed and obtained without any hidden factors as happened in the flat or high arch feet.

Case study II: Pillows

1. ***People between 20-45 years old:*** This is because people in this age range have the problem about selecting the pillow the most.
2. ***People who prefers to sleep in supine or lying position:*** This is because it is a normal posture of customers when they buy a pillow.
3. ***Extra requirement:*** The pillow designed in this research can only satisfy regular people who do not have sleep disorder, including snore, or incur a neck accident.

Case study III: Eyeglasses

1. ***People between 20-40 years old:*** A young adult who is generally a person in the age range of 20 to 39 (or 40) years old will be influenced by fashionable materials and stuffs.
2. ***People who always wear glasses:*** These people can explain directly about the basic requirement for purchasing new glasses and selecting the glasses' design.
3. ***People who always wear contact lens:*** These people can reveal some hidden needs about glasses' design, function, and shape.

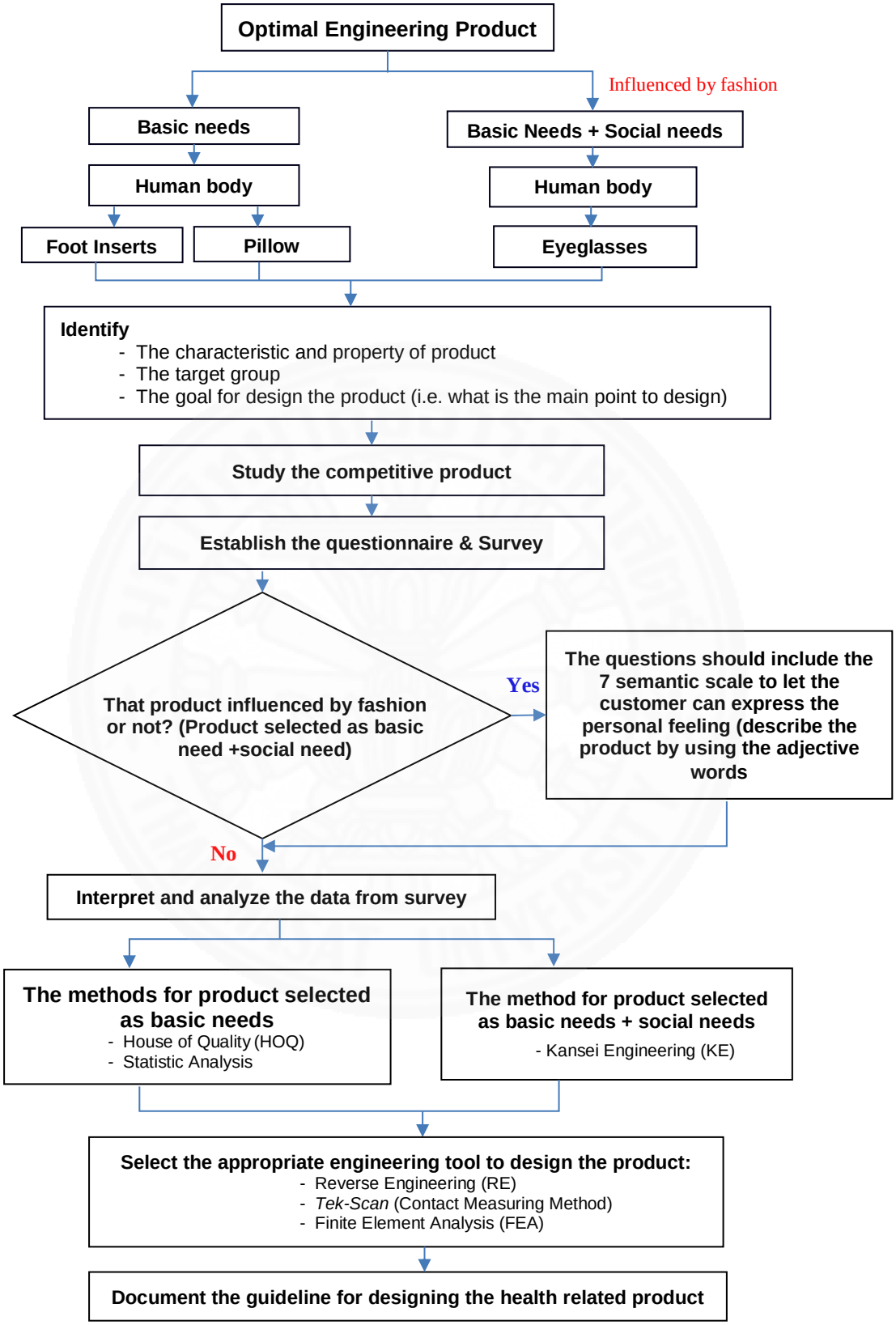


Figure 3.2: Procedures of the research

3.2 Conducting the surveys

After identifying the target customer, the ways to establish self-administered questionnaires are divided into 2 steps as follows,

Step 1: The open-ended question style, this has been applied to understand the basic characteristics of the target customer. The participants feel comfortable to answer without any guided choices or options. After that, these answers from the participants will be grouped as the customer needs.

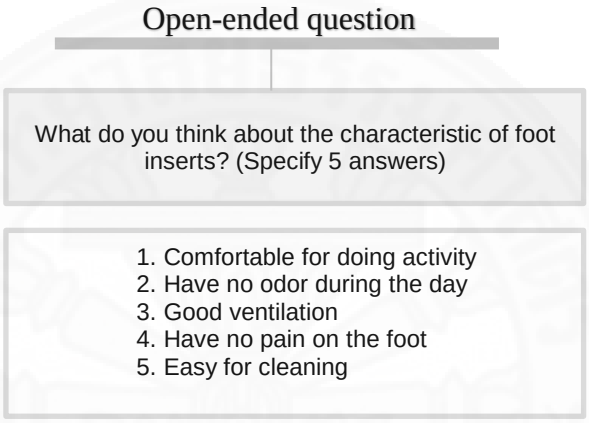


Figure 3.3: Open-ended question style

Step 2: After obtaining the basic requirements and characteristics of the health-related product from confidential self-administered answers, the another set of questionnaire will be established to find the opinions, perceptions, satisfactions and expectations of customers on the existing products (the competitive products) and the new designed product. For this stage, types of the questionnaire will be divided into 3 types as follows,

1. Closed-ended question: this type of question provides the limited option of answer for participant to respond in the questionnaire which includes dichotomous question (two-point questions; *Yes* or *No* answer), multiple choices (can choose more than 1 answers), and rating scales (semantic different scales).

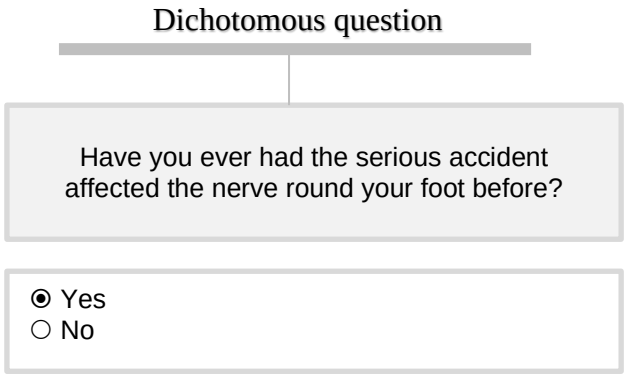


Figure 3.4: Dichotomous question

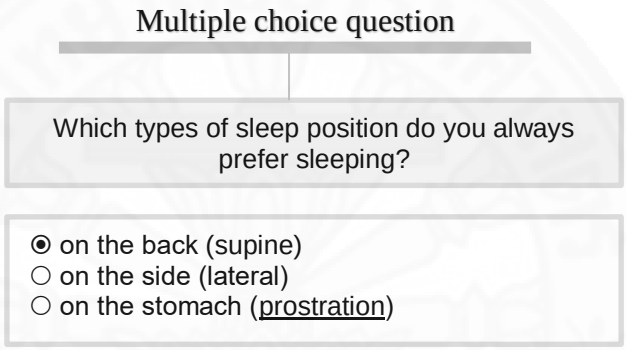


Figure 3.5: Multiple choice question

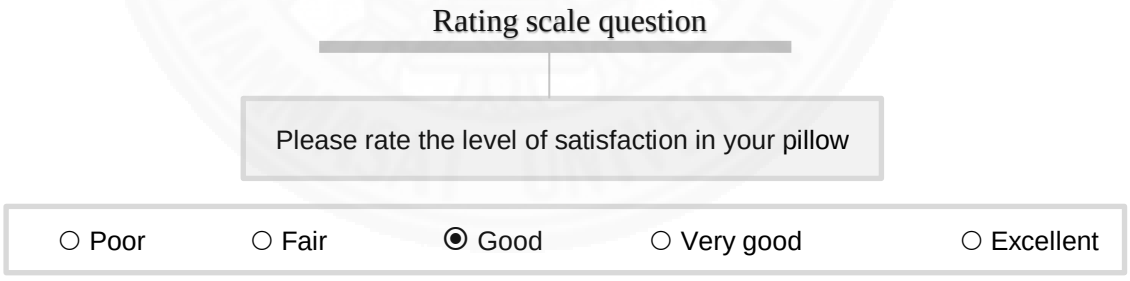


Figure 3.6: Rating Scale question

2. Matrix Question: this type is also closed-ended question but it is arranged in the form of matrix with the response options located on the top.

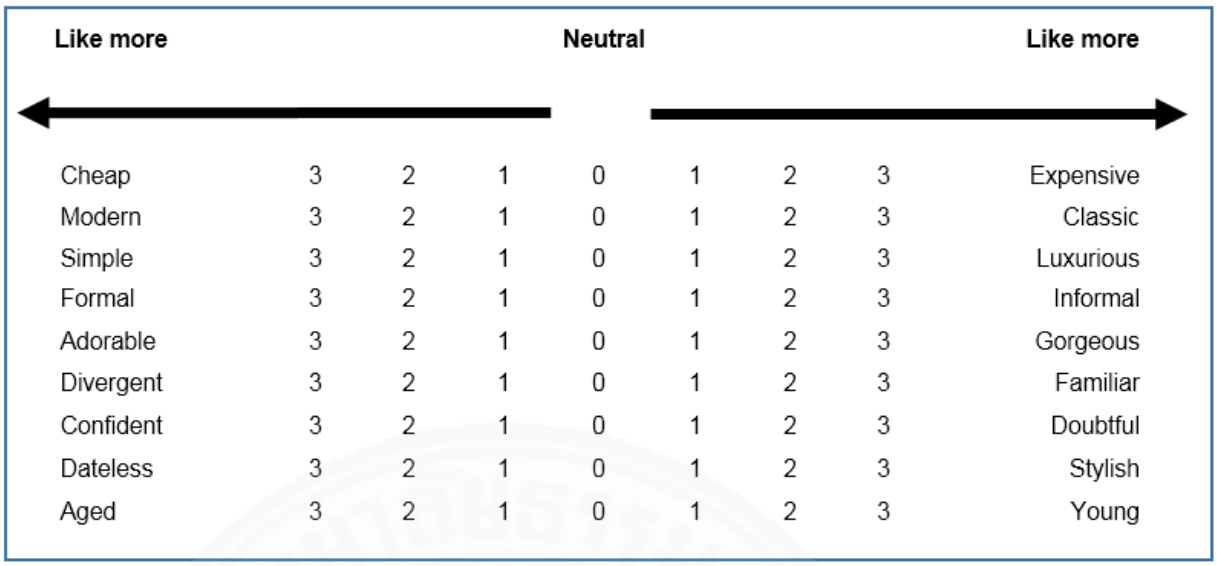


Figure 3.7: Matrix question

3. Contingency question: this type of question consists of the two-point question and multiple choice that are similar to the filters to avoid asking participants questions which are not applicable to them.

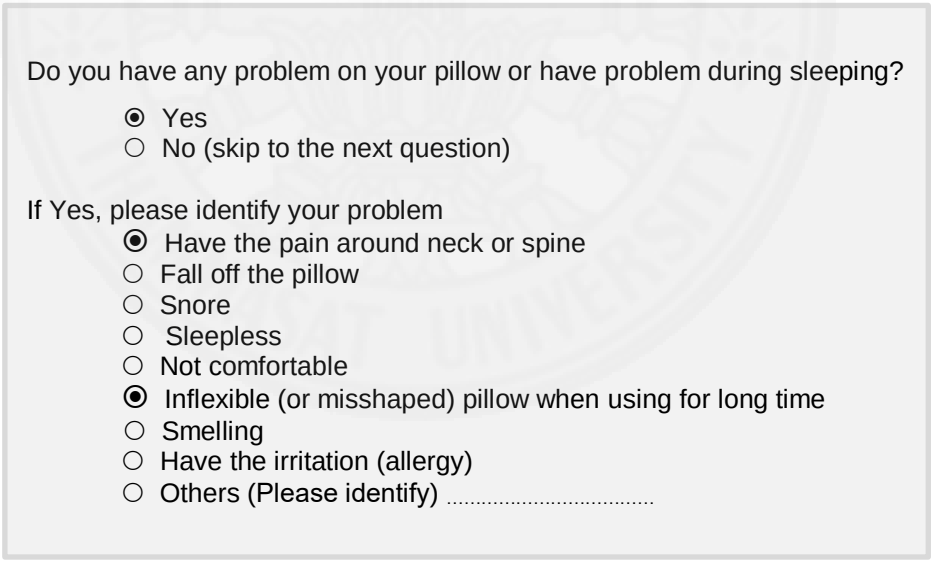


Figure 3.8: Contingency question

3.3 Interpreting the Results from Survey (Translating the Needs)

To translate the need from the survey in order to obtain the design concept, there are three methods performed to achieve the goals which are House of Quality (HoQ),

Kansei Engineering (KE), and Statistical Analysis (ANOVA and regression). According to some of health-related products which play with the emotions and the influenced information, some people cannot express their needs directly through product characteristics. Eyeglasses are selected as one of the basic-social needs since they are not just for vision correction, the people put a lot of thought into picking out the proper frames and styles with fashionable choices and new materials. Moreover, wearing eyeglasses can enhance the professional image. The face shapes and styles of the glasses have been taken into consideration for purchasing decision. For this case, the customers decide to buy the product by using their personal feelings, emotions, and reviewed forums. This type of product contains extra, beautiful features or fashionable characteristics. A method of Kansei (KE) will be applied in this case study.

3.3.1 House of Quality (HoQ)

HoQ is the matrix as the tool to help the manufacturer to identify the relations between the customers' needs and engineering characteristics. In this research, 2 case studies; *foot inserts* and *pillow*, will be apply this method to obtain the design concept. The way to achieve the HoQ is presented as follows,

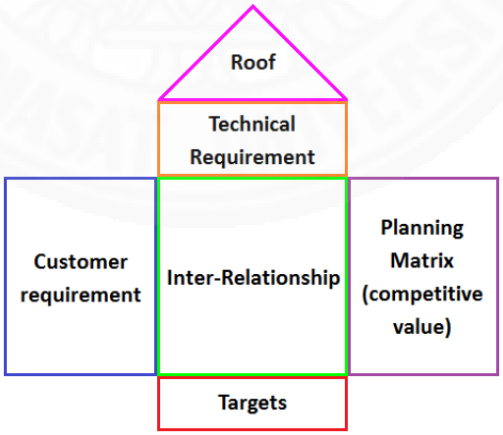


Figure 3.9: House of quality schematics

- *Identify customer need*

From the results of questionnaire, the needs of customer have been listed and they are placed on left- hand side area of the house. This information will be used to

identify the relationship between technical requirements and customer requirements in the next section.

- *Priority of the need*

After obtaining the specific requirements, each of them must be weighted according to the level of importance. The one that has "*high score*" from customer's decision is assigned to have "*height weight*". The weight is varied from 1 to 5. Weight of five is defined to be the most important level. In contrast, one is defined to be the least importance level.

Table 3.1: The defined important rating

Score range	Important rating
1-10	1
11-20	2
21-30	3
31-40	4
41-60	5

- *Defining engineering characteristics*

In this section, the enginnering parameters are defined. The parameters must be measurable and clear language. For example, the parameters related to pillow production are type of material, weight, height, deformation, surface area, density, pillow's case, cost, pillow shape, and color. Each of them will be analyzed to seek for the important one in the next section.

- *Interaction and conflict*

In this section, the researcher determines the positive and negative interactions between product requirements and technical characteristics by using the symbol. Square represents strong relationship. Triangle represents medium relationship, and circle represents weak relationship. However, if there is "*no relationship*", "*no symbol*" is put. The following figure represents the relationship between customer requirements and engineering parameters.

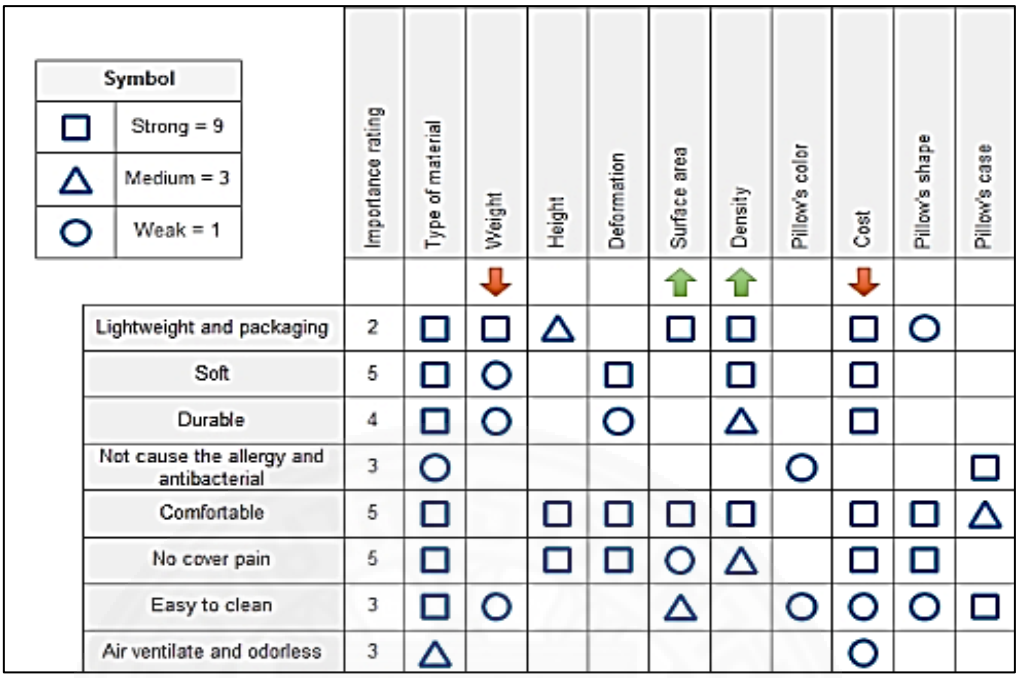


Figure 3.10: The interaction between customer requirement and engineering characteristics

- *Directional development*

The sign that represents the aspects of development which collect through the policy and the production plan whether which techniques and aspects should be improved or not.

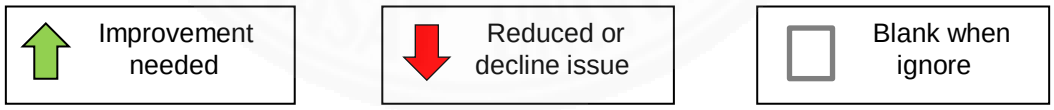


Figure 3.11: The definition of each sign

- *Performance weight (Correlation Matrix)*

The roof section represents the relationship between each pair of the engineering characteristics. "*Positive correlation*" means adjustment in a parameter generates positive effect on other parameter. For example, changing type of material of pillow provides better deformation when sleeping. "*Negative correlation*" means adjustment in a parameter generates negative effect on other parameter. For example, changing

type of material generates higher cost of production. The correlations between each characteristic are shown below:

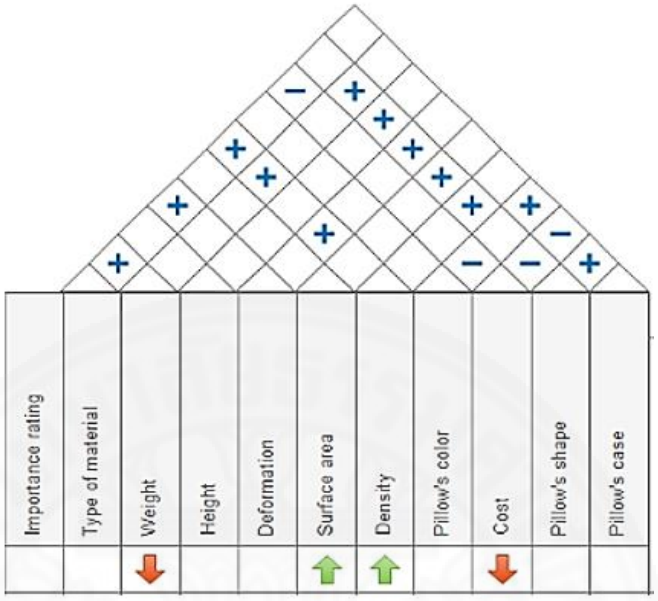


Figure 3.12: Correlation between each engineering characteristics

- *Compute total important rating*

Total important rating in each column can be calculated by sum product between interaction score and important rating. For example, to find total important rating of type of material, it can be calculated by the following method;

$$\textit{Total important rate} = \sum importance\ rating\ x\ relationship\ score \qquad \text{Eq. (3.1)}$$

$$= (2)(9)+5(9)+4(9)+3(1)+5(9)+5(9)+3(9)+3(3)$$

$$= 228$$

This calculation must be done for every engineering parameter. The one that has the highest value is the most important characteristic. It will be used to set up design target afterward.

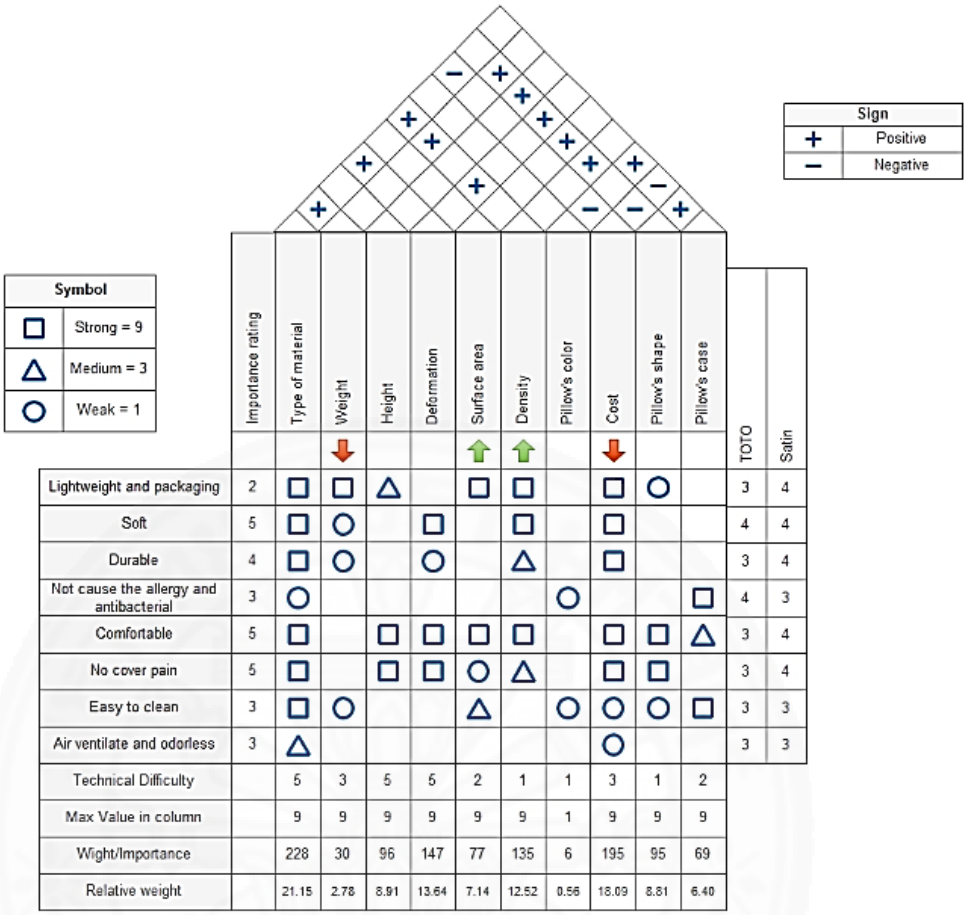


Figure 3.13: The complete house of quality

3.3.2 Kansei Engineering (KE)

In this research, eyeglasses will be selected as the case study that KE will be applied to find the guideline to design. The research is divided into 3 main steps to achieve the objective of the proposed approach (as shown in Figure 3.14). The first step starts with identifying the adjective words, the second step is about the adjective measurement, and the last step is the analysis of the listed adjectives.

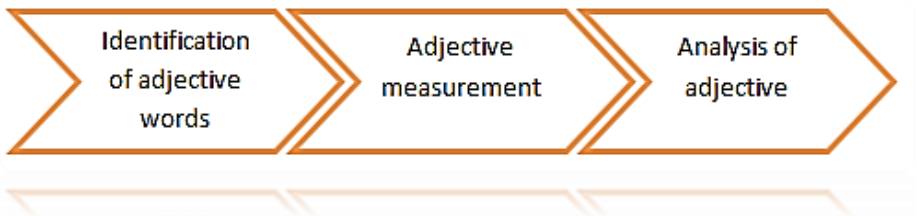


Figure 3.14: Research guideline

Before starting the Kansei Engineering (KE) process, the scope of the approach is firstly set before identifying the adjective words. The method is very sensitive to the case that different people from different ages and cultures usually think in different ways; the shapes and styles of the product designed by the western or the European platforms might not be flexible or fitted to Asian people or characteristics.

3.3.2.1 Preparations before identifying the adjective words

This would be better to analyse and identify people who live in oriental countries (i.e., Thai) before designing or ordering the products from those overseas countries to reduce the number of product left in the stock. Therefore, the scope of this research is set for Thai people with the age of 20 to 40 years old. To identify and obtain the effective results where the eyeglasses design can be optimized to the right targets and the living environment, financial status, culture, and familiarizing of technology have been taking considerations.

3.3.2.2 Identification of adjective words

In the identification of adjective words steps, the possible adjectives related to eyewear are collected from the brainstorming, the fashion magazines, and the interviewed customers. A 18 words of adjectives from customer's requirement and 18 adjectives from the product's characteristics are formed as shown in the Table 3.2 and 3.3.

Table 3.2: Possible product characteristic and its definition

Product characteristics	Descriptions
Heavy	Glasses contain high weight.
Light	Glasses contain light weight.
Loose	Glasses are easily moved apart from the nose.
Tight	Glasses are fitted to the nose.
Big	Perimeter of glasses rim is large.
Small	Perimeter of glasses rim is small.
Thick	The frame of glasses is thick.
Thin	The frame of glasses is thin.
Smooth	Eyeglasses contain no extra features all around its shape (excluding nose-pad area).
Rough	Glasses contain extra features all around its shape (excluding nose-pad area).
Flexible	Capable of bending or being bent easily without breaking
Inflexible	Glasses is not easily bent or twisted.
Durable	The glasses are design to withstand the stresses of demanding use.
Fragile	Glasses are very delicate or not strong.
Clear	Glasses are made from a material that contains a transparent colour.
Solid	Glasses are made from a material that contains a solid colour.
Edgy	Glasses contain high number of corner inside the frame.
Round	Glasses not contain any corner inside frame.

Table 3.3: Possible customer emotional requirement and its definition

Customer emotional specifications	Descriptions
Cheap	Eyeglasses should be sold with low price.
Expensive	Eyeglasses should be sold with high price.
Modern	Glasses are design based on latest style of fashion.
Classic	Glasses are design with the concept of timeless beauty.
Simple	Design of eyeglasses is not complicated.
Luxurious	Glasses are designed with the concept of feeling or showing a desire for expensive thing.
Formal	Glasses are design with the influences of culture.
Informal	The conditions applied for designing purpose are about having a friendly, relaxed quality and suited for ordinary use
Adorable	Eyeglasses make the user feel loveable and childlike.
Gorgeous	Eyeglasses make the user feel attractive.
Divergent	The design of eyeglass is different from other eyeglass.
Familiar	The design of eyeglass is the same or get used to other eyeglasses.
Confident	The design of eyewear makes user gain more confident when they wear it.
Doubtful	The design of eyewear makes user decrease their confident when they wear it.
Dateless	The design of eyeglasses will not be gone out of fashion in the next 4 years.
Stylish	The design of eyeglasses will be different from the others trends in the next 4 years with containing special style and characteristic.
Aged	Glasses make users feel getting older than the actual age.
Young	Glasses make users feel and look younger than the actual age.

3.3.2.3 Adjective Measurement

A 7-point semantic differential scale questionnaire (as shown in Figure 3.15) is used to measure the people's emotion toward eyewear is used in this research. In this step, participants are asked to describe their ideal eyewear through 18 pairs of adjective given. From a 99 interviewed people (i.e., 42 males and 57 females), the results obtained will be expected that a95% is the confident level which can ensure 10% of the errors.

Like more				Neutral				Like more
Cheap	3	2	1	0	1	2	3	Expensive
Modern	3	2	1	0	1	2	3	Classic
Simple	3	2	1	0	1	2	3	Luxurious
Formal	3	2	1	0	1	2	3	Informal
Adorable	3	2	1	0	1	2	3	Gorgeous
Divergent	3	2	1	0	1	2	3	Familiar
Confident	3	2	1	0	1	2	3	Doubtful
Dateless	3	2	1	0	1	2	3	Stylish
Aged	3	2	1	0	1	2	3	Young

Figure 3.15: Example of 7-points semantic differential scale of synonym adjective

3.3.2.4 Analysis of adjective

In this process, a statistical method called "*factor analysis*" is used for determining the number of product's groups and the product's characteristics where the customer's needs have been applied as the main criteria for creating the correlation between customer's requirement and designs of the desired product. Factor analysis has been introduced as a data reduction technique which is used for describing the correlation between each variable (i.e., product characteristics and customer's feelings), and for grouping these variables into one factors.

Using this technique can assist the designer to minimize analysing time and activities where the relationship between the customers' feeling toward eyewear and

eyewear characteristics is formed and identified. The data obtained from the questionnaires are tested for appropriateness of using factor analysis by using Kaiser-Meyer-Olkin (KMO) test and Bartlett's Test of sphericity. If the value of KMO test is greater than 0.5, mean that the sample size is suitable for factor analysis (Field, 2005). Bartlett's Test has the P-value less than 0 showing that there is some correlation between variables, where:

KMO;

$$KMO = \frac{\sum_{i \neq j} r_{ij}^2}{\sum_{i \neq j} r_{ij}^2 + \sum_{i \neq j} u_{ij}^2} \quad \text{Eq. (3.2)}$$

Where

$$r_{ij} = correlation\ between\ variable\ i\ and\ j$$

$$u_{ij} = partial\ covariance\ between\ variable\ i\ and\ j$$

Bartlett's test;

$$H0: Determinant\ of\ correlation\ matrix = 1$$

$$H1: Determinant\ of\ correlation\ matrix \neq 1$$

3.3.2.5 Statistical Analysis

The statistical analysis is applied to investigate the customer behavior about the relationship between the price and comfort of health related product. The regression and one way ANOVA will be applied to solve in this section.

(1) The regression analysis

It is a way to model the relationship between two variables, in this case the variables are the price and the comfort of health related product. The equation of regression analysis has the form;

$$Y = a + bX \quad \text{Eq. (3.3)}$$

Where, Y is the dependent variable, X is the independent variable, b is the slope of the line and a is the y-interception.

$$a = \frac{(\sum y)(\sum_x 2)-(\sum x)(\sum xy)}{n(\sum_x 2)-(\sum_x)2} \quad \text{Eq. (3.4)}$$

$$b = \frac{n(\sum xy)-(\sum x)(\sum y)}{n(\sum_x 2)-(\sum_x)2} \quad \text{Eq. (3.5)}$$

(2) One way ANOVA

It is used to determine whether there are any statistically significant differences between the means of three or more independent (unrelated) groups. In this research, the comfort rate for the type of specimen (health related product) are concerned;

H_0 : The means of all groups are equal ; $\mu_1 = \mu_2 = \mu_3 = \ldots = \mu_k$

H_1: There are at least two group means that are statistically significantly different from each other (the comfort rate of each types of health related product are different)

Where μ = group mean and k = number of groups.

3.4 Applying the engineering tools for designing product

In this research, reverse engineering (RE), *Tek-Scan* (actual test) and finite element analysis (simulation) are applied as the tools for identifying and checking the physical characteristics and conditions of the desired product. The obtained results can be used as the guidelines for generating shape of the new engineering design and selecting the appropriate design of the existing ones.

3.4.1 Reverse Engineering (RE)

In order to investigate the stress occurred between the human part and health-related product, applying RE method can generate 3D CAD model quickly from the existing object. 3D laser scanner and image-based acquisition techniques have been

applied for obtaining point cloud data which can be applied further for creating surfaces and virtual model in the subsequence processes.

3.4.2 Tek-Scan (Contact Measurement) for testing load distribution on the foot inserts

In the case study of foot inserts, in order to measure and analyze the force, area and pressure occurred on foot by using the flexible, actual simulation called *Tek-Scan* (Randolph et al., 1999) has been applied. The specimens (foot inserts) are located on the foot bed around heel position. Then the ultra-thin load cell with sensors (Figure 3.16(a)) is later placed onto the inserts. Before inserting the load cell, it needs to be cut into the desire shape to nearly fit the shoes of the participant. When a load (body weight) is applied on the load cell, the pressure and force distributed on the feet and inserts can be immediately recorded up to 8 seconds or 400-snapshot frames. The software will report the forces, contact areas and contact pressures of all frames taken as the graphs and numeric values of a period *oscillation.* In order to conduct the experiment to determine the force and pressure acting on the feet and inserts, a participant (lady who has the normal feet and her weight is around 53 kg) is asked for walking slowly and naturally. During the walking activity, *Tek-Scan* records up to 6-7 walking steps of each foot side within 8 seconds and provides the detail information about the forces, areas and the pressures.

(a) (b)

Figure 3.16: Tek-Scan simulation: (a) Flexible, thin-in shoe load cell, (b) The experimental conducting for walking

3.4.3 Finite Element Analysis (FEA)

Two case studies; foot inserts and pillow, FEA has been applied to investigate the internal stress after the load applied. Firstly, the variations of specimens (products) available in the market are generated as 3D CAD models. To obtain 3D CAD model of foot inserts, 3D laser scan has been applied to collect the point data of the objects. After that the 3D model reconstruction and surface fitting of each object was finished by using *Geomagic Studio* software. The finite element models of object were generated in SolidWorks. The overall steps of FEA will be shown in Figure 3.17.

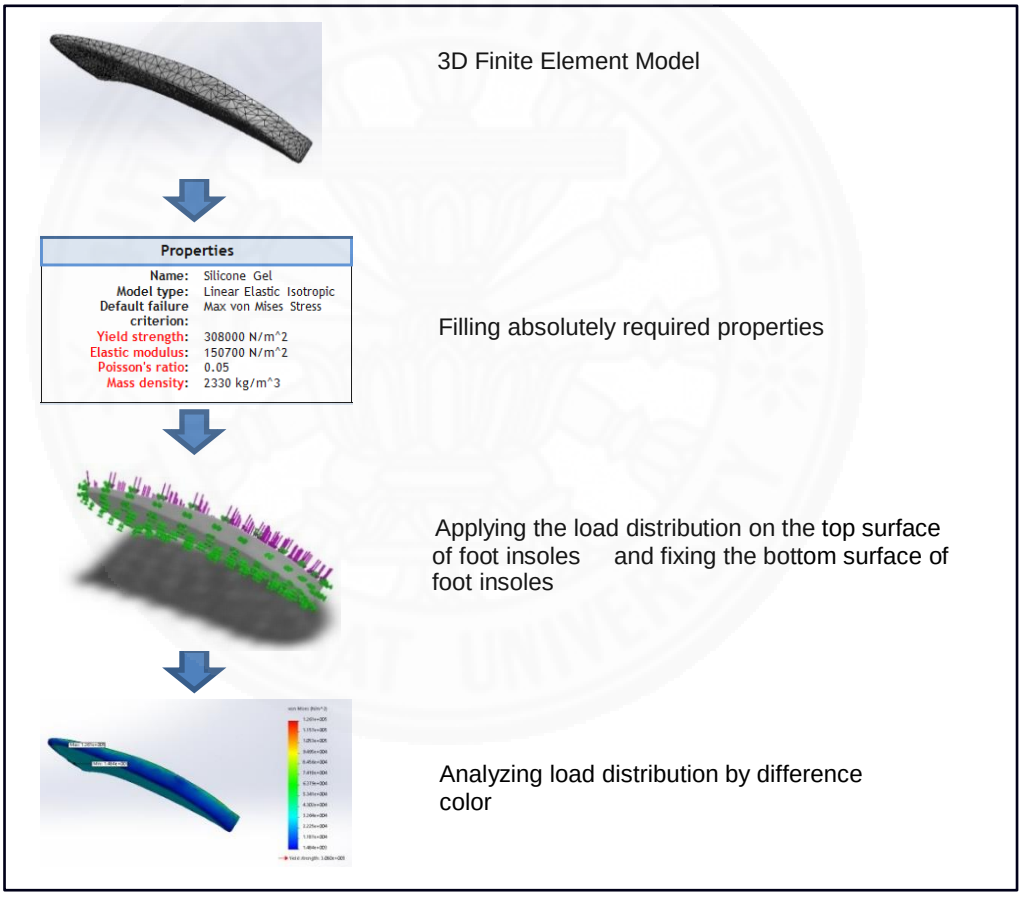


Figure 3.17: The steps of finite element analysis

The details of contact measurement (actual test) and virtual simulation will be explained clearly later in Chapter 4. For the basic need as pillow, the proper design will be introduced after considering customer's requirements and material simulation. The application of Kansei Engineering (KE) will be presented via eyeglasses in Chapter 6.

Chapter 4
Results and Discussions (Part I)
Case Study: Foot Inserts

In this research, the product interests that has been selected as the case studies are foot inserts and pillow. The contents in results and discussions chapter are divided into two case studies which are pillow and foot inserts.

4.1 Stage 1: Define the scope of the decision

Many aspects contribute to the whole experience with a heel inserts' product: the characteristics of the material used for making inserts, the inserts' size and shape, the lightweight insert material, the ventilation structure of a shoe insert, the breathable freshness inserts for making the feet and shoes stay fresh and hygienic even during a long day, and a very resistant and durability material of the inserts in terms of variation of insert stiffness or deformation and humidity

In order to observe ladies' behaviors for purchasing shoes, the surveys were conducted where 150 ladies between the ages of 20 and 35 years were asked for filling the questionnaires which were considered as self-administered questionnaires. Shoes shops in shopping malls around the central provinces of Thailand (i.e., Bangkok metropolitan region, Samutprakarn, and Nonthaburi provinces) were the sample locations used for observing the purchasing behaviors. To accomplish the aim of the proposed approach, details of shoes style, problems occurred on wearing shoes, experiences on using the heel insoles, satisfactions/expectations of applying inserts, types/materials of the used inserts, and prices of the inserts, were considered and analyzed. The results were shown that there is 90 % of those ladies have more than 5 shoes for supporting daily activity. A majority of ladies (i.e., 85%) has decided to buy flat shoes where the heel height of the shoes is less than 3.5 cm. (Wuttimanop, Rianmora & Mahattanakarn, 2013) (as shown in Figure 4.1).

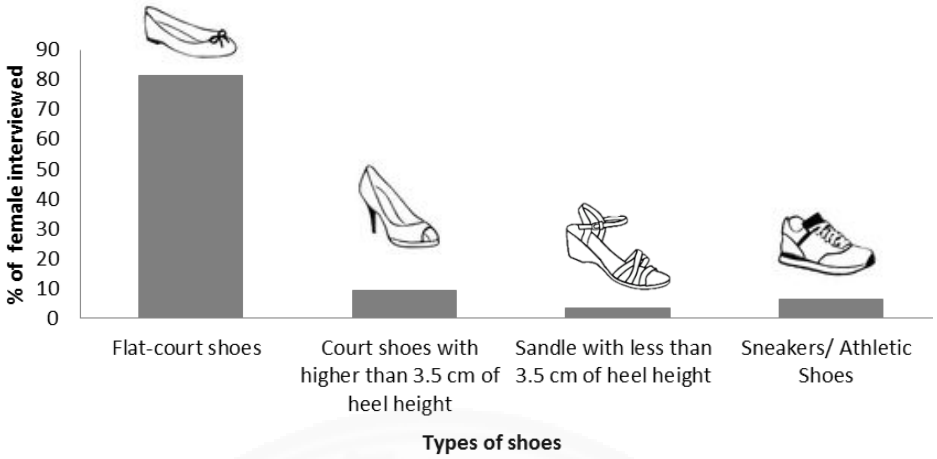


Figure 4.1: Results of the interviews: shoes selections from ladies

***DEFINE* issue I**: The type of everyday shoes worn for working (or 8-hour period).
In general, shoes often have leather or polymer rubber outsoles which can absorb force applied during walking or standing activities; however, for a long day, the continuous force distribution is occurred around the heel areas which have the direct effects on the working performance since this makes the people feel so fatigue and pain. Before starting to create the conceptual design of the heel inserts, the understanding shoe types and what style shoe are popularly worn according to the cultural influences on the target users have been analyzed through the questionnaires.

After interviewing the target users, the answers could be implied that 87% of them consult reviews and friends for purchasing decisions. For articulation of preferences, the popular style shoe is the woman flat shoes, and the second design is court shoes with less than 3.5-cm-heel height. The reasons for selecting these types were shown through the effects of wearing elevated heel shoes (> 3.5 cm-heel height) since these shoes can cause toe problems where the weight or the shock resulting from walking activity is transmitted directly to the bony structure of the body and the foot. Women feel more comfortable with flat shoes than high heel; however, heel pain is a serious problem after wearing the flat shoes for a long day. The women have tried to apply the heel inserts for releasing those pains; it is quite difficult to find the right one.

Table 4.1: The type of everyday shoes worn for working

Shoe Types	No. interviewees (Total = 172)
Flat shoes (Ballet Flats) 	48
Flat shoes (Man style) 	10
Court shoes with less than 3.5-cm-heel height 	34
Court shoes with over 3.5-cm-heel height 	22
Sandals with over 3.5-cm-heel height 	20
Sandals with less than 3.5-cm-heel height 	25
Sneakers 	13

Flat shoes: A shoe with a very flat heel or no heel

Sandal: The flat sole is fastened to the foot by a strap passing over the instep and sometimes around the ankle.

Slingback: These have an open back and a strap encircling the heel of the foot to keep the shoe secure.

Stiletto: It is defined by its very high tapering heel. A genuine stiletto heel contains a stem of solid steel or alloy for reinforcement.

(Guide shoes, 2016)

***DEFINE* issue II**: The way to relieve fatigue and stress on the feet after wearing flat shoes for a long day.

Small groups of the target users who are wearing court shoes (i.e., flat shoes) were interviewed about how to relieve fatigue and stress on the feet for a long day. Presented in Table 4.2 are the four main answers obtained from the target users. A majority, 58%, of women has decided to change their posture or bodily movement for relieving the fatigue and stress on the feet; however, these were personally experienced method based on their situation and level of the pain. The factors of different level of fatigue might come from the type of activity during the day, the posture of working, the numbers of hours women spent standing or walking, age or body mass index.

From the results, it shows that using the heel insoles for relieving the fatigue and stress is not quite interesting for the target group since they thought that whether or not wearing the shoes with proper heel inserts can improve the overall foot health, and adding the heel inserts may affect the feet because they will slide around awkwardly.

Table 4.2: The way to relieve fatigue and stress on the feet after wearing flat shoes for a long day

The ways to relieve fatigue and stress on the feet for a long day	No. interviewees (Total = 50)
Change posture/bodily movement	29
Stop working for a while	16
Apply the medicine/See the doctor	3
Change the shoes	2

4.2 Stage 2: Analyze the characteristics of the heel inserts for the flat shoes

After defining the group of target users, the proper heel inserts for a flat shoe type was selected to study in the proposed research. In order to analyze the characteristics of the heel inserts for the flat shoes, three main issues have been researched:

- The characteristics of the heel inserts (i.e., mechanical and physical characteristics).
- The most interesting material to support heel during a long day.

- The relationship between heel inserts' material and cost for determining the right purchasing decision.

***ANALYZE* issue I**: The characteristics of the heel inserts (i.e., mechanical or physical characteristics) that the users would like to purchase.

The 168 target users answered and discussed about the specific characteristics of heel inserts that they preferred to purchase the odorless and lightweight inserts which could reduce the pain immediately after wearing. These were implied about the type of insert material which should make the shoes stay fresh, hygienic and comfortable even during a long day.

Table 4.3: The required characteristic of heel insoles

The required characteristic of heel insoles	No. respondents (Total =168)
Reducing the pain immediately after wearing shoes with inserts	40
No odor	36
Lightweight	35
Easy for cleaning	26
Durable	24
Use various types of material	7

***ANALYZE* issue II**: The most interesting material to support heel during a long day.

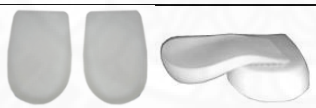
According the 168 women who answered the questions about the desire characteristic of the heel inserts, they, again, were asked about the material used for making those heel inserts. As presented in Table 4.4 and Table 4.5, five heel insert types were listed. Gel material was the popular type selected whereas the rubber one was not well-pleased since its smell was the issue, and the women who answered as "no idea" for selecting the insert material were not considered. These five material types will be

used in the subsequence stage for virtually simulating the force distribution around the heel.

Table 4.4: The most interesting material to support heel during a long day

Types of material	No. respondents (Total = 168)
Gel	40
Gel-Silicone	33
Foam	33
Silicone	7
Rubber	5
Have no idea	50

Table 4.5: The most interesting shape to support heel during a long day

Shapes	No. respondents (Total = 35)
	0
	4
	35
	1

****Note: After interviewing, people who choose type 3 says that this shape would support their heel the best because its shape match with their feet and it would be softer and more flexible that the others.

ANALYZE **issue III**: The relationship between heel inserts' material and cost for determining the right purchasing decision.

According the previous issue (II), five materials of the heel inserts (i.e., gel, gel-silicone, foam, silicone, and rubber) were applied as the reference products for finding

the relationship between heel inserts' material and cost. In order to design a heel inserts' product with a reasonable price, the study of determining how much the users can comfortably afford to spend on heel inserts relating to the material properties has been taken into account. After eliminating 50-not available- answers from 168 women, the rest were asked about the price of the heel inserts that they can effort. The answers presented that the price of the heel inserts' product could range from less than one dollar to hundreds of dollars over the shoes' price depending on the quality and the material used. The maximum price that the target users can afford was $150.

The target users mentioned that the mix-material heel inserts as gel-silicone might be more expensive than the other single material types; therefore, gel-silicone heel insert was ignored in the studied. Listed in Table 4.6 were the heel insert materials recommended by the users. *Silicone* material (53.39% of the 188 women experienced on wearing flat shoes) was shown the most popular material type for making heel inserts since the users thought (based on the reviews, the advertisement or the personal experiences) that its property was flexible than the gel (the second rank). When comparing the slip property, the gel was more slippery than the silicone and the stable foam material. If the gel was chosen for making the heel inserts, it might cause uncomfortable for standing or walking.

For the rubber (the forth rank), most of the users thought that sole of shoes was made from the rubber where it could not help them to reduce the pain on their foot. Wearing rubber sole shoes would make their feet smell bad and horrible after a long day of activity. Therefore, from the target users' opinions, the silicone was recommended to be designed as the heel inserts whereas the rubber must be the last choice for this case.

Table 4.6: The relationship between heel inserts' material and cost

Type of material	No. of the interviewees (Total = 118)	Cost	
		THB	USD
Silicone	55	52- 358	1.43 - 9.95
Gel	30	52 - 430	1.43 - 11.95
Foam	22	52 - 133	1.43 - 3.69
Rubber	11	42 - 113	1.15 - 3.15

** 36.00 THB per 1 USD (Date: 28/Dec/16)*

RESULT: All answers obtained from the target users were influenced by the reviews, close friends, sale assistants, fashion advisors, or media advertisements. Therefore, the customers believe that the *Silicone Material* is the best choice for making foot inserts. However, in order to check the data obtained from those perceptions are matched to the applicable mechanical or physical characteristics of the heel inserts where the materials and geometric shapes have been played as important issues. The engineering simulation has been applied in the next stage for identifying the proper design of the heel inserts for relieving stress and force distribution during wearing flat shoes for a long day.

4.3 Stage 3: Simulate the characteristics of the various shapes and materials of the heel inserts and virtual Teat by Tek-scan and

- Finite Element Analysis (FEA)

For the preliminary study, the appropriate shape and the material of foot inserts that provides the lowest stress would be analyzed and identified. The results from the experiment would be used as the original model to develop the new product designs in further investigation. For shortening time to test the sample models with varying shapes and materials, simulation by Finite element analysis (FEA) would be an alternative channel.

In the process, FEA was applied to simulate the load distributed on the foot inserts where types of the material and shapes of the inserts were varied. Four existing

foot insert products available in the market (as shown in Figure 4.2) were applied for conducting the experiment. There are 16 simulations for the experiment. however, the specific parameters required for the composite materials could not be found in the software library. The similar chemical substances or agents found were applied instead of those ones. The load of 500N (50 kg) was applied and the constraints; *elastic modulus*, *Poisson's ratio*, *mass density*, and *yield strength* were identified for simulation as shown in Table 4.7.

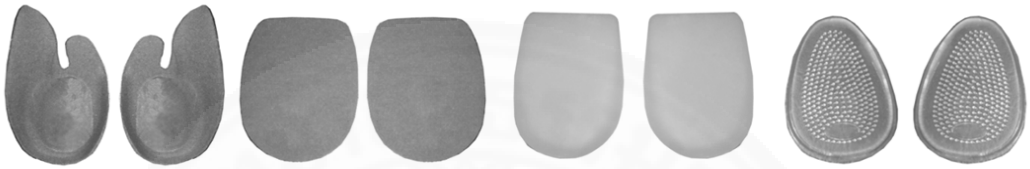


Figure 4.2: Sample shapes of heel inserts which were varied in material properties

Table 4.7: The absolutely required properties for finite element analysis

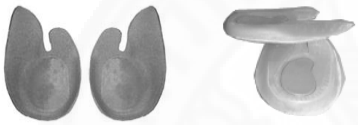
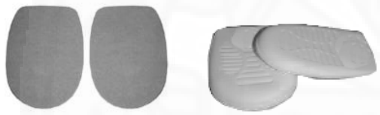
Material	Elastic modulus (N/m^2)	Poisson's ratio	Mass density (Kg/m^3)	Yield strength (N/m^2)
Latex foam	1900000	0.499	960	168000000
Silicone gel	150700	0.05	2330	308000
EVA foam	50000000	0.25	950	480000000
Original gel	28900	0.05	2330	102000

The stress value of each specimen (model) resulted from FEA were identified shown in Table 4.9, and they were used for analyzing the appropriate foot inserts for developing and generating the optimal engineering designs of foot inserts to satisfy the customer's requirement. From the results shown in Table 4.8, when the maximum stress value which was over than the yield strength would be circled and ignored for selecting as the guideline to create the optimal design since this condition might be effect on the foot inserts' structure which was deformed plastically.

The appropriate design of the inserts was based on the maximum stress (less than the yield strength); the higher stress could support the pressure occurred on the foot. The results of this simulation to select the appropriate the foot inserts; specimen (1), and (3) as shown in Figure 4.3. However, the price of EVA foam material is

expensive in the market comparing with the other types of material. This might not be preferred or satisfied by customer.

Table 4.8: Stress results from finite element analysis

No.	Shape / Material	Material Properties	Stress (kPa)			
			Latex Foam	Silicone Gel	EVA Foam	Original Gel
		Mass density	960	2330	950	2330
		Yield strength	168000	308	480000	102
		Elastic modulus	1900	150.7	50000	28.9
1		Simulated	636	1050	876.8	1060
2			420	222	331	216.3
3			325.5	285.6	260	285.6
4			199.6	1034	669.9	1034

(a) (b)

Figure 4.3: Finite element analysis results; (a) specimen 1 made of EVA foam and (b) specimen 3 made of silicone gel

- **Actual Test**

In order to measure and analyze the force, area and pressure by using the flexible, actual simulation called Tek-Scan (Randolph et al., 1999) has been applied. Six insert types (ranging from Figure 4.4(a) to (f)); gel and rubber with cloth on top, natural latex foam, silicone gel, gel with cloth on top, soft foam, and invisible gel, will be named as specimen 1 to 6 and they are located on the foot bed around heel position

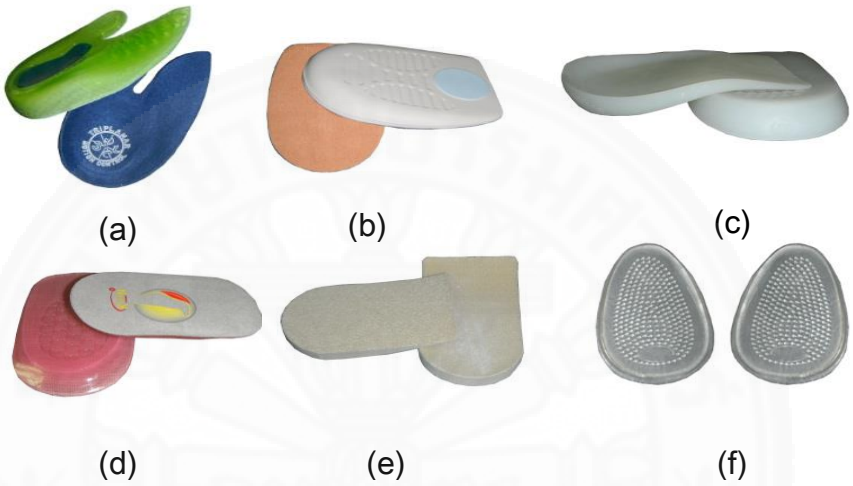


Figure 4.4: Six types of heel insoles: (a) specimen 1 (gel and rubber with cloth on top), (b) specimen 2 (natural latex foam), (c) specimen 3 (silicone gel), (d) specimen 4 (gel with cloth on top), (e) specimen 5 (soft foam), (f) specimen 6 (invisible gel)

Figure 4.5: Tek-Scan simulation: (a) Flexible, thin-in shoe load cell, (b) The experimental conducting for walking

After applying Tek-Scan for actual simulation, the best characteristic of shape and material of heel insoles that has the lowest pressure can be determined. The pressures that are used to analyzed come from the average of pressure of both foot sides

(left and right) for all five steps. The value of first step of walking is not used because during the experiment, it might occur the error from the beginning of walking (may come from feeling nervous by participant while conducting the experiment). To document guidelines for selecting the appropriate heel insoles for walking, the results from Tek-Scan obtaining the best characteristic of shape and material used to produce heel insoles for long-walking people is made.

The results are presented as the graph (shown in Figure 4.6(a)) and simulation on load cell (shown in Figure 4.6(b)). From the graphs of walking activity on left and right foot (Figure 4.6(a)), two peaks in each step are the positions of foot contacting the floor; the first position (i.e., the 1st peak) is the pressure on the heel happened when the participant starts walking in which the heel is the first area contacting to the floor. The second position (i.e., the 2nd peak) presents the forefoot region that is later touched the floor to fulfil the completion of one walking step. The obtained values of pressure can be used to determine the trend of insert type which provides the best result for relieving pain on the feet during walking activity.

During the test, from 8-second walking activity, the participant was allowed to walk only 7 steps. In order to obtain the accurate results, the 1st and the 7th steps were cut off since the force, pressure were not stable. Therefore, the consideration periods were considered and analyzed from the 2nd to the 6th step (as shown in Figure 4.7 and Table 4.9

After considering the values of average pressure on both left and right foot of all six specimens, the lower pressure indicates that the inserts can potentially absorb the pressures distributed on the forefoot region and the heel areas. The best absorber is presented at specimen 6 which is invisible gel. Hence, for supporting the one who would like to increase the performance of a long period or eight-hour workday such as an aircrew or a flight attendant, applying the heel inserts with invisible gel onto the flat shoe is recommended.

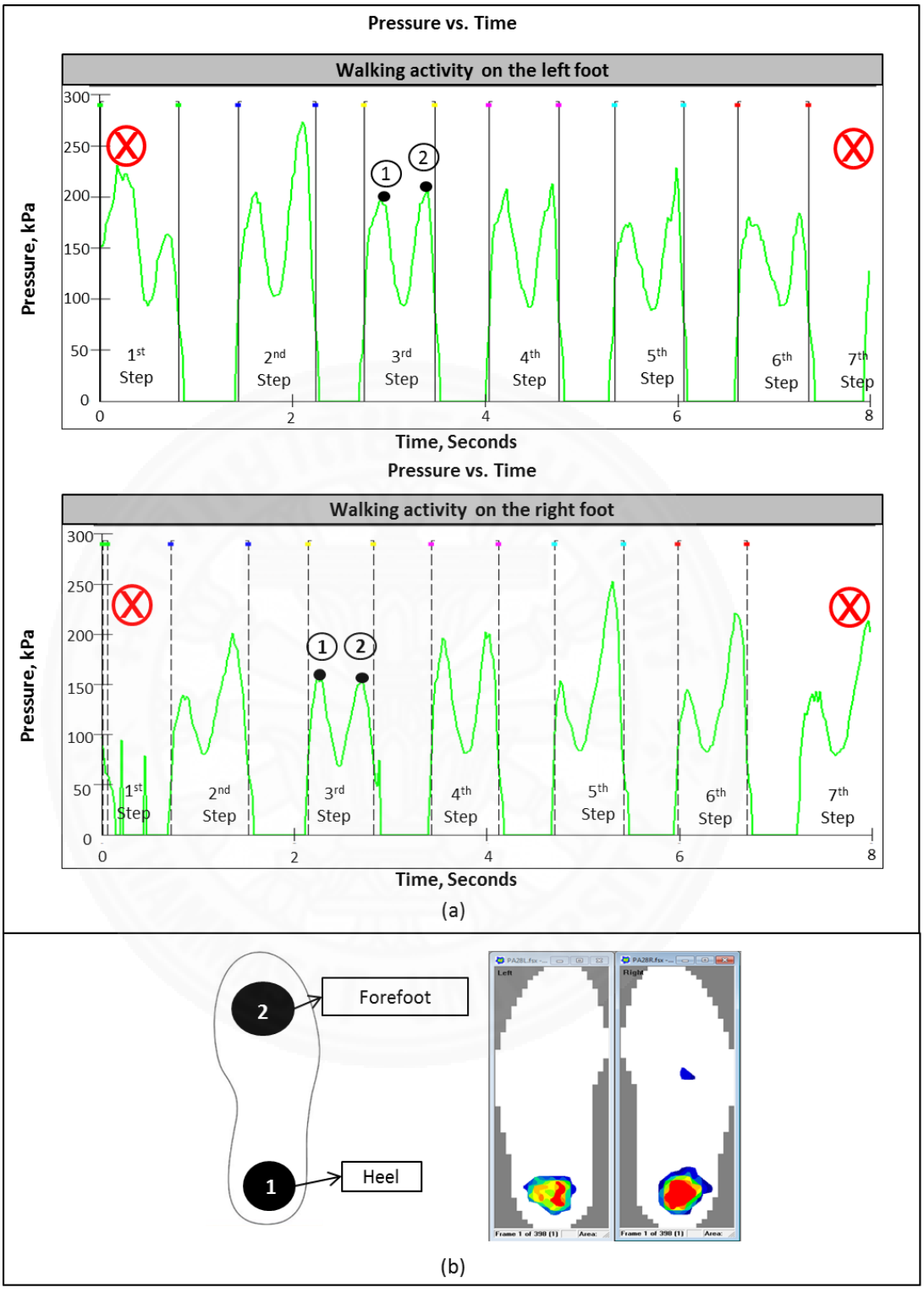


Figure 4.6: Testing results: (a) Graphs of walking activity on left and right foot, and (b) Pressure distributed on left and right foot

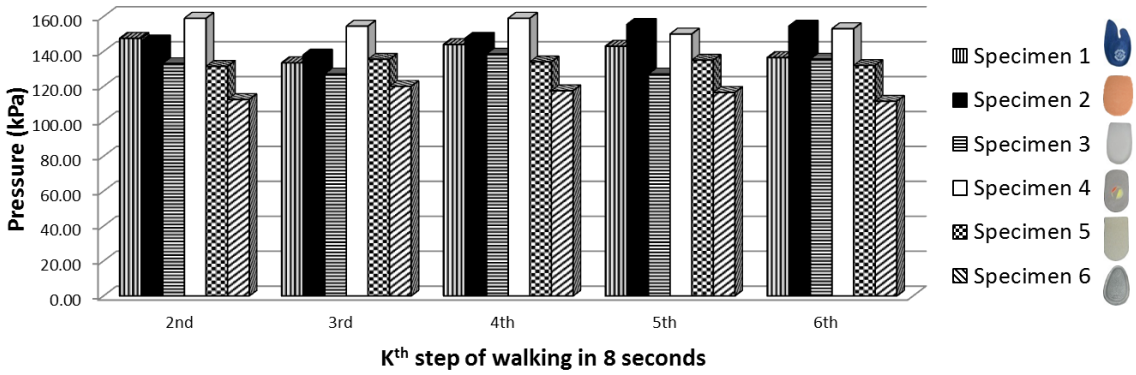


Figure 4.7: Graph showing results of pressure from Tek-Scan

Table 4.9: Results of pressure from Tek-Scan

Insert Type	K^{th} step of walking in 8 seconds	Average Pressure [kPa]		Average Pressure [kPa] (5 Steps)	
		Left	Right	Left	Right
Specimen 1 (Gel and rubber with cloth)	2	169.00	126.00	150.60	131.20
	3	151.00	116.00		
	4	151.00	137.00		
	5	143.00	143.00		
	6	139.00	134.00		
Specimen 2 (Latex foam)	2	161.00	131.00	164.20	132.40
	3	148.00	128.00		
	4	157.00	138.00		
	5	179.00	132.00		
	6	176.00	133.00		
Specimen 3 (Silicone gel)	2	142.00	124.00	147.40	117.00
	3	144.00	110.00		
	4	153.00	124.00		
	5	138.00	116.00		
	6	160.00	111.00		
Specimen 4 (Gel with cloth)	2	162.00	156.00	153.40	156.80
	3	159.00	150.00		
	4	161.00	157.00		
	5	133.00	167.00		
	6	152.00	154.00		
Specimen 5 (Soft foam)	2	137.00	126.00	140.80	126.40
	3	151.00	120.00		
	4	144.00	124.00		
	5	143.00	127.00		
	6	129.00	135.00		
Specimen 6 (Invisible gel)	2	126.00	99.00	130.00	101.20
	3	136.00	104.00		
	4	129.00	106.00		
	5	138.00	95.00		
	6	121.00	102.00		

After accomplishing the simulations, the obtained results can be used as the guidelines for the ladies who perform as aircrew duties or spend a long period for

walking activity to select the appropriate insert. From the experiment, it was suspected that the invisible gel provides the best result for relieving some pains around the heel, and making the ladies feel more comfortable when walking activity attempts since the pressure distributed on the area of the foot is minimum comparing to the other materials of the heel inserts. Moreover, having the shape and the textures similarly to the specimen 6 (Figure 4.8) provides increased stability, and keeps the shoes from slipping out of their feet while walking.

For eight-hour workday, a lady may perform standing activity for a long period to do some tasks; the specimen 5 (Figure 4.9) made from a soft foam is recommended (Wuttimanop, Rianmora & Mahattanakorn, 2013), since it can provide more flexible to form the heel insoles into the shape of heel area instantly. The recommendation of this proposed approach is about compromising between standing and walking activity for selecting foot inserts, the specimen 5 seems to be the best among the rest since it provides the second place for supporting pressure from the body during walking inferior to the specimen 6.

Selecting the material as soft foam and the shape as specimen 5 can help a lady feeling more comfortable for doing various activities; however, the rough cashmere or texture cloth is required on the topmost surface of the soft form insert for better and easily positioning the foot on without slipping during walking attempts.

Figure 4.8: Specimen 6 (Invisible gel)

Figure 4.9: Specimen 5 (Soft foam)

Chapter 5
Translating Customer Needs to Design (Part II)
Case Study: Pillow

5.1 Market Survey on Various Types of Pillow

This section aims to survey in order for obtaining the information of pillow available in the market, and customer behaviour when they buy the pillow. Robinson, popular retail store in Thailand, is selected as a study place. The data of available market pillow including type of material, and price are recorded. Pillow's seller is interviewed in order to obtain any complaints or requirements on pillow from customers along with their behaviour when they buy the pillow.

To generate the optimal designs – study case: pillow, the material and shape of pillow are focused and also including the price. It is needed to know the consumer's attitude and the consumer's taste on using the pillow and the pain around neck and spine which may occur in during sleeping or after sleeping. The level of pain may be different which it is based on shape, material of pillow, as well as the activity in a day that people did before go sleeping. In Table 5.1, it shows the characteristics of pillow that are available in the market. The questions in the questionnaire can be classified as follows,

- ***Question 1****: The type of pillow shape*
- ***Question 2****: The problem of using pillow during sleeping or after sleeping*
- ***Question 3****: The material of pillow*
- ***Question 4****: The level of satisfaction on your pillow*
- ***Question 5****: The expectation of using the pillow*
- ***Question 6****: The main point to make the decision for buying the pillow*

The interview is prepared for people of the working age and the interviewee must complete the questionnaire for 6 questions as following the plan,

The number of interviewee: 90 respondents

Place: Some companies around Bangkok Metropolitan Region

All of questions are presented as table and chart with description, and also contained the analysis and conclusion to find out the optimal engineering designs to satisfy the customer's requirement.

Table 5.1: The characteristics of pillow available in the market (Neck Solution, 2004; Tanase, 2010)

Characteristics of pillow	Shapes
Rectangular/ Square This shape of pillow is normal which is easy to buy in anywhere. The materials of this pillow type can be polyester, natural latex, feather, kapok, cotton and so on.	
Tempurpedic It is made of the memory foam. It is ergonomically shaped for proper support head, neck and spine.	
Tri-Core It has a trapezoid center which helps to keep the head in comfortable position while lying face up (back sleeping position). Moreover, there are two side wings of the pillows that support comfortable position by turning on side sleeping position and also it provides two sides with different sizes for support the neck. This pillow type is made of blended cotton.	
D-Core This type is similar to Tri-core but their difference is the shape of the center that D-Core has D shape design while Tri-Core has trapezoid shape design. This type of pillow is made of polyester fibre.	
Cervical Linear Traction Neck (V-shape) It has the special V shape design in the neck position which cradle the head and neck and lift the head away from shoulders at the same time the neck rolls underneath support the neck. It works for side sleeping and back sleeping positions. For the side sleeper, the wings of both sides help to keep the head at the right height from the mattress to relieve the strain on neck and shoulders. This type of pillow is made from polyester fibre.	
Atlas-T It is made of two main varying foam densities which are rigid foam and soft memory foam. It is designed to maintain 16 degrees that supports the top two vertebrate of spine. The rigid foam provides resistance to the body to maximize neck support and maintain correct AXS posture while soft memory foam allows flexibility for the body to mould the pillow for comforting in all other areas.	
Therapeutica Sleeping This pillow type is made of the memory foam which provides comfortable sleeping to correct spinal alignment. It works for back and side sleeping position. In the center cavity, it helps to support the head to maintain comfortable while in the cervical contour, it maintains the natural curve of the spine. The unique shape design is the wedge extension which supports the upper back.	

Question 1: The type of pillow shape

From the results of respondent's answers as shown in Table 5.2, the most popular shape style of pillow is rectangular. According to market survey, it was found that the pillows with rectangular shape are easy to buy in anywhere such as mall, market, or shopping online. Moreover, there is no a lot of choices of pillow shape sold especially in the mall and market where most people usually buy it. This corresponds with the answers of respondents that they use the pillow with rectangular shape.

Table 5.2: The number of respondents using the various shape of pillow

Shape Style	No. Respondents
Rectangular 	83
Square 	1
Circle	0
Tempurpedic Neck 	5
Tri-Core 	1
D-core 	0
Cervical Linear Traction Neck (V-shape) 	0
Atlas-T 	0
Therapeutica Sleeping 	0
U Pillow Neck Support 	0
Neck Roll Pillow 	0

Question 2: The problem of using pillow during sleeping or after sleeping

58% of 90 respondents have problems from using pillow during sleeping or after sleeping and a problem of 27% of people say "*Yes*" that has problems are the pain occurred around the neck or the spine, which is the biggest problem. The results are shown in the Figure 5.1.

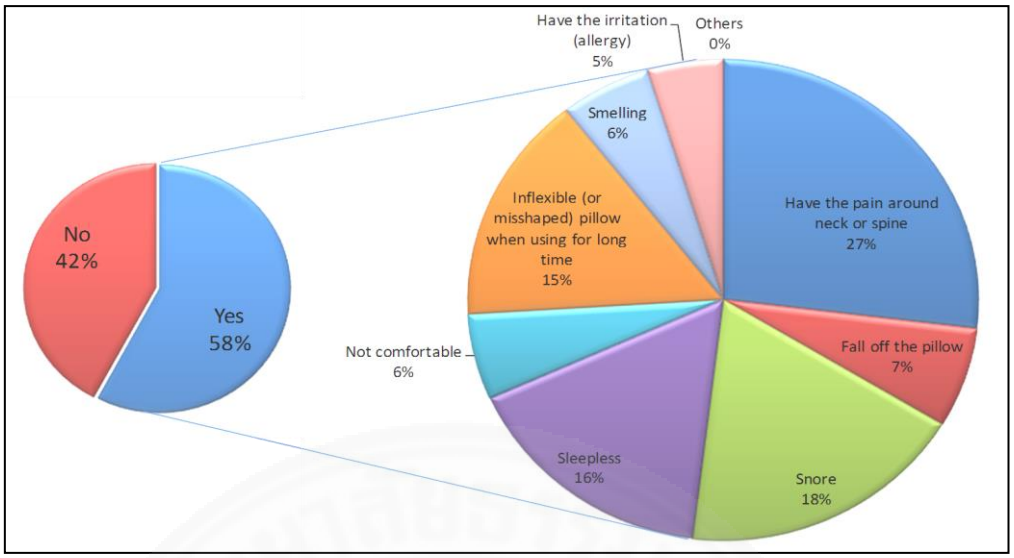


Figure 5.1: The problems of using pillow during sleeping or after sleeping

Question 3: The material of pillow

From the results shown Figure 5.2, it was found that about 60% of respondents use synthetic fiber as the material of pillow. Moreover, most of people that have the problems from using the pillow, they also use synthetic fiber. This can be implied that the synthetic fiber is not the best quality of material for making the good pillow.

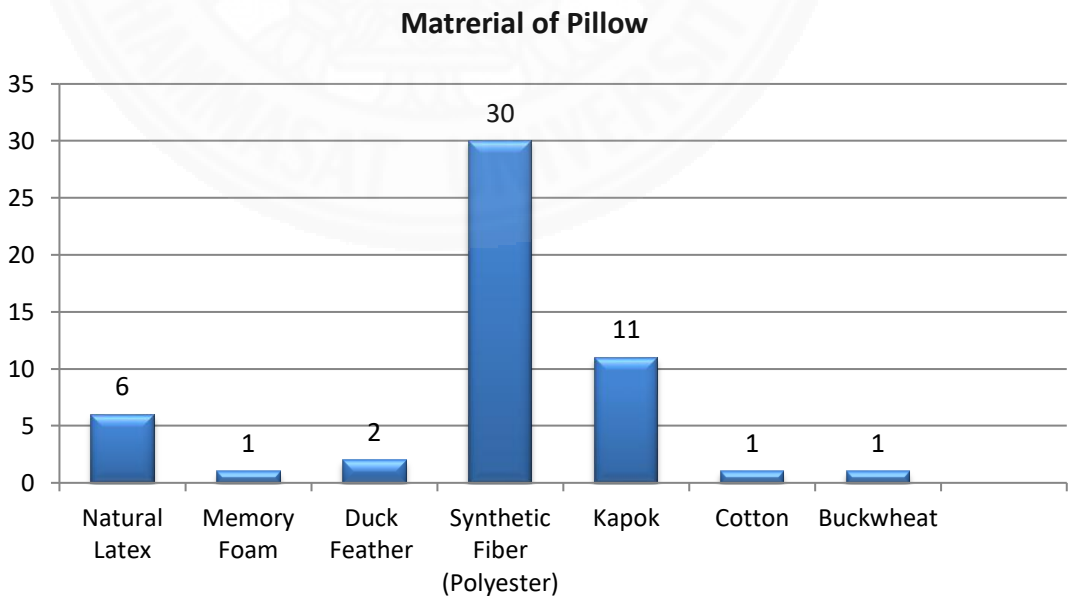


Figure 5.2: The material of pillow selected by respondents

Question 4: The level of satisfaction on your pillow

In Figure 5.3, most of respondents about 80% feel “OK” with their pillow but not the most satisfied. This can be implied that sometimes they still have problems from their pillow during their sleeping or after sleeping.

Figure 5.3: The level of satisfaction on using the pillow

Question 5: The expectation of using the pillow

The results shown in Figure 5.4 presented that the most expected issues on good pillow are as follow; it must be comfortable and not cause the pain around neck and spine, it must be soft and fluffy, and it must be flexible and not misshaped when using for long time.

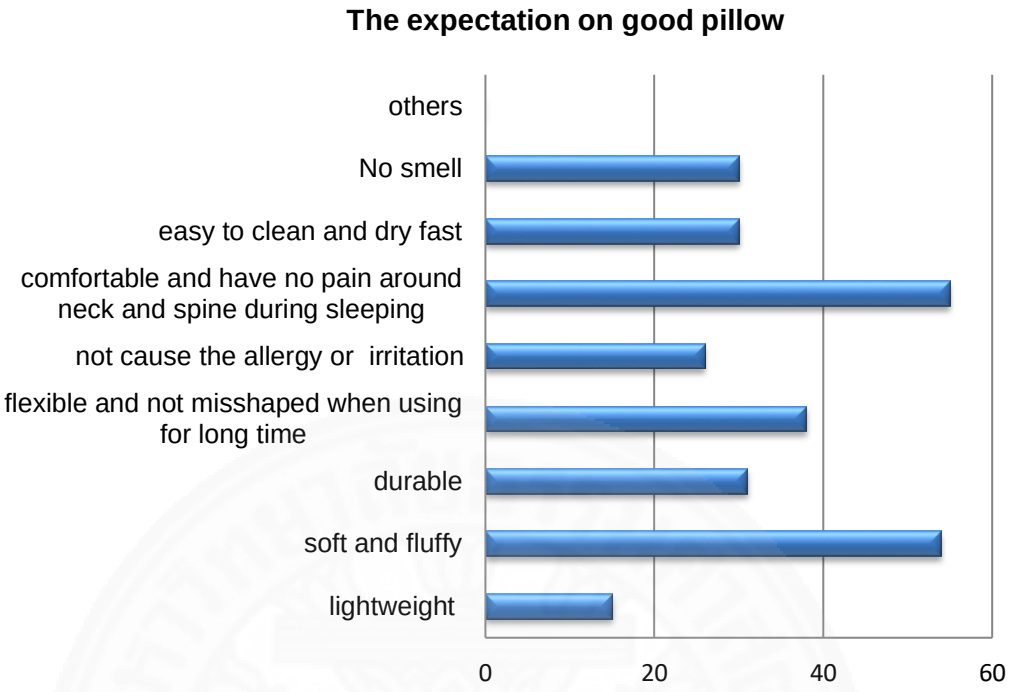


Figure 5.4: The expectation of using good pillow

Question 6: The main point to make decision for buying the pillow

From the result as shown in Figure 5.5, most respondents chose the cheap price between 150-300 baht, have normal quality, made from the quite quality good, general shape and no need to try before buying. According to the question 2, over than 50% of respondents have the problems of using their pillow but they choose the pillow with normal quality and normal shape instead of the ergonomic shape design and good quality of material. This can be implied that the respondents concern the price as the main point for buying the pillow.

According to the results from market survey, it shows that the price of pillow is ranged according to its material used representing in Table 5.3. Notice that the recorded prices were measured by including sale promotion. It is clear that pillow price is ranged according to material used. From interviewing, customers purchase a pillow according to the following reason: (1) brand personality, (2) seller recommendation, and (3) Pillow trial. Majorities of them purchase the pillow due to the last reason. In other word, pillow needs to be tested before purchasing.

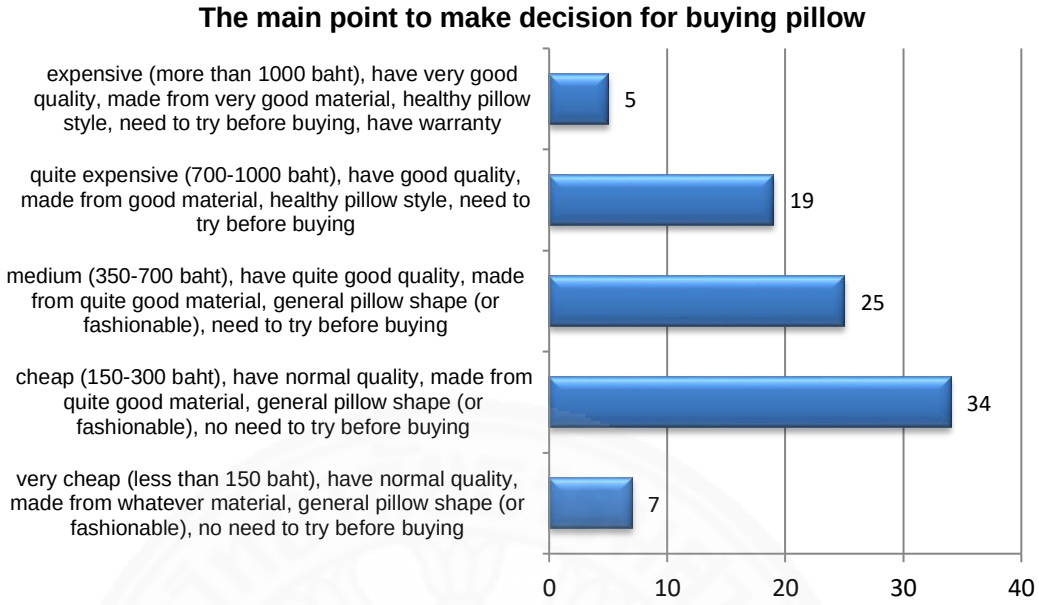


Figure 5.5: The main point to make the decision for buying pillow

Table 5.3: Price of pillow—Different materials

Materials	Price	
	(THB)	(USD)*
Polyester	199-500	5.86 - 14.72
Micro fiber	690-2500	20.31 – 73.58
Rubber	1050-2600	30.91 – 76.53
Memory foam	1495-3290	44.00- 96.82
Goose feather	3450	101.53

** 33.9794 THB per 1 USD (Date: 26/Jun/17)*

5.2 Customer Survey

5.2.1 Principles and methods

This study aims to obtain general requirements on pillow from customers along with their current used pillow information. Everyone cannot deny using pillow. Therefore, the population in this section were chosen at random from the one who works in an office, walk in a market, and shop at department store. A total of one-hundred samples were collected via questionnaire.

5.2.2 Results and discussion

Eighty-five people out of one hundred used rectangular shape pillow. They used pillow with different types of material representing in Table 5.4. However, the most wide-used one was polyester. Ninety-one percent of them reported that they haven't experienced any accidents affected the spine. They were most likely to sleep in lateral and supine position. They thought pillow price should be within 150 to 750 baht and the pillow needs to be tested before purchasing. The characteristics that respondents want from pillow represent in Table 5.5.

Table 5.4: Types of materials available in the market

Materials	Score
Natural Latex	11
Memory Foam	3
Duck Feather	5
Goose Feather	1
Synthetic Fiber (Polyester)	45
Kapok	20
Unknown	6

Table 5.5: Expected characteristics of pillow

Expectations	Score
Lightweight	15
Soft and fluffy	54
Durable	31
Not cause the allergy or irritation	26
Comfortable and less cervical pain	55
Easy to clean and dry fast	30
Odorless	30

Pillow with rectangular shape should be made since it is the shape that most people is familiar with and currently use. To meet customer expectation, it can be achieved by designing appropriate height, material, shape, and envelope. However, shape is already fixed to be rectangular as mentioned. The other parameters need to be designed in other stage of PDD.

5.3 Customer aspect on market pillow and their purchasing behaviour investigation

5.3.1 Principles

In this section, the researchers aim to identify two issues: (1) the customer aspect on market pillow such as comfort rate, and expected price, and (2) the decision of customer when they are about to purchase a pillow. For second issue, the researchers focus to identify whether the customer purchase the pillow by considering price or quality. The experiment can be conducted simultaneously to obtain both results.

5.3.2 Participants

Forty participants (20 males and 20 females) with an age ranged between 20-25 years old (average of 22.45 years), and average income of 13,750 THB ($393) were invited to participate the experiment. They are representative of teenager population- The main target group of this research. They are a normal people which mean they have no cervical pain or any sleep disorders. People who have faced with neck/sleeping problem cannot participate the experiment since they require special type of pillow.

5.3.3 Procedures

According to research background in previous section, rectangular shape pillow was selected as a shape of test specimen. Four specimens with different type of material and price were selected to conduct the experiment. The principle of randomized complete block design was introduced as an experiment format. To follow the principle of random, the participants slept on pillow with a random order, and the pillow information such as type of material, and price did not reveal. The participants tested each specimen individually with sleep duration of 5 minute. This value is selected based on the real situation. On average customers will test a pillow within 5 minute before making a decision to purchase the pillow. The participants tested the specimen on traditional bed to provide normal sleeping environment. After everything was set, the researcher asked the participants for comfort rate, and expected price of each specimen,

and also asked the participants to make a decision to buy the pillow according to what they prefer. In the last section of the experiment, researcher revealed the true information of each specimen including price and type of material, and asked the participants to make the decision repeatedly. The specimen's specification represents in Table 5.6. The experiment form is provided in the appendix C.

Table 5.6: Specifications of each specimen

No.	Materials	Price including Discount	
		(THB)	(USD)
Specimen 1	Polyester	360	10.59
Specimen 2	Ball fibber	695	20.45
Specimen 3	Rubber	950	27.96
Specimen 4	Memory foam	1500	44.15

** 33.9794 THB per 1 USD (Date: 26/Jun/17)*

5.3.4 Analysis criteria

There are four kinds of results that can be interpreted from the experiment such as (1) mean comfort rate, (2) mean expected price of each specimen, (3) the relationship between comfort level and expected price, and (4) customer decision-making to purchase a pillow. The criteria used to judge the customer decision is based on what they selected before and after revealing the price and type of material of pillow. For example, if in initial state (pillow information is not revealed) participants select specimen 4, but finally (pillow information is revealed) they select cheaper one, they will be grouped as the one who purchase the pillow by considering price rather than comfort. If initially participants select specimen 3, and in final state they select the same specimen or more expensive one, they will be grouped as the one who purchase the pillow by considering comfort rather than price.

5.3.5 Results and discussion

Presented in this section are about the customer considerations which are customer aspect on market pillow investigation, customer purchasing behavior

investigation, guidelines for analyzing customer's requirement and purchasing decision, translating customer's requirement to engineering design by quality function deployment (QFD), and research contributions.

5.3.5.1 Customer aspect on market pillow investigation

From Figure 5.6 which is the regression model between comfort rate and expected price, it can be concluded that there is a linear relationship between comfort rate and price ($P < 0.01$) which means market pillow with high price provides more comfort than pillow with low price by customer perception. The result implies that quality and price of market pillow is consistent. It is acceptable that R-sq, the parameter indicating how well the model can fit the data, is around 21.42 percent since the data used in this model were gathered from human aspect. Generally, the model that involves human behavior gets the value of R-sq lower than 50 percent (Minitab).

From performing main effect plot of RCBD and Tukey test representing in Figure 5.7 and 5.8 respectively, it was found that the comfort rate for each pillow type is significantly different to each other. The participants feel that the pillow made from memory foam provides the highest comfortable level whereas the pillow made from polyester presents the lowest comfortable level. The means of comfort level ordered from the highest to the lowest were pillow type 4 (*memory foam*), pillow type 2 (*ball-fiber*), pillow type 3 (*rubber*) and pillow type 1 (*polyester*), respectively.

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	1	5286901	5286901	43.08	0.000
Comfort scale	1	5286901	5286901	43.08	0.000
Error	158	19390536	122725		
Lack-of-Fit	2	678212	339106	2.83	0.062
Pure Error	156	18712324	119951		
Total	159	24677438			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
350.321	21.42%	20.93%	19.32%

Figure 5.6: ANOVA of regression model between comfort rate and price

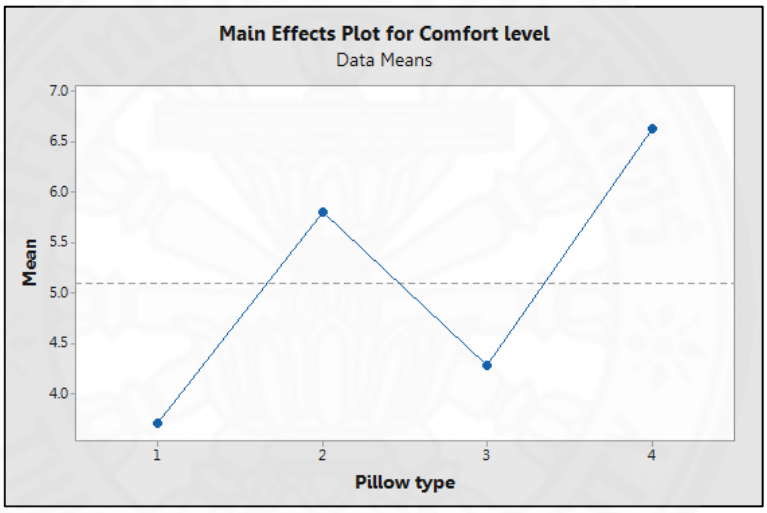


Figure 5.7: Main effect plot of Comfort Level

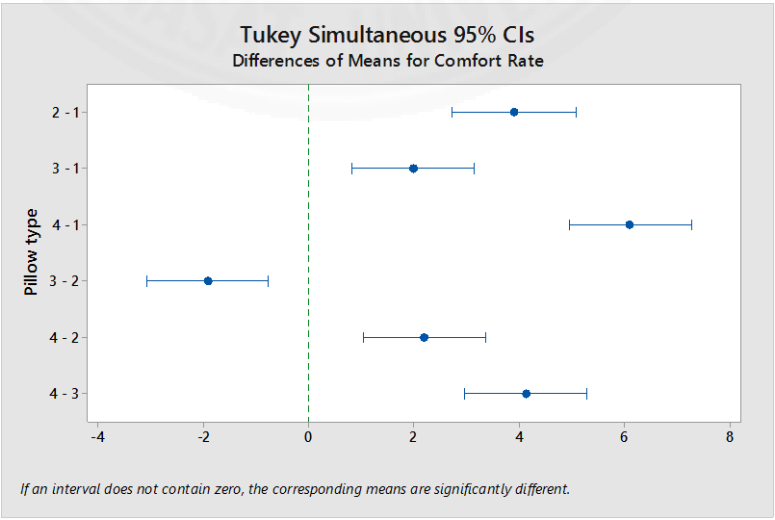


Figure 5.8: Main effect plot of Comfort Level

5.3.5.2 Customer purchasing behavior investigation

Considering Table 5.7 and 5.8, total summation of number of observation on memory foam is reduced from 23 to 13 which mean the participants change their mind to purchase other types of pillow due to the product's cost which is quite expensive price. This situation impacts the number of observation on ball fiber increasing from 10 to 16. Considering total summation of each pillow selected in figure 11, ball fiber gets the highest value which implies that pillow should be made by using this type of material. Producing ball fiber pillow can catch the customers who perceive it is the most comfortable, and the ones who do not want to purchase expensive pillow. Sometimes, making pillow with lower quality and cheap price is not quite a good strategy, since, as representing in table 5.7, only one participant decides to buy a pillow that is made of polyester. The testers, mostly, complain about the polyester pillow since it cannot support the structure of their bodies where the curvature around the neck is changed according to the movement of the users' bodies and the pillow does not maintain that shape; as the result, the users feel the neck pain. Five of male and female participants out of twenty change their mind to buy cheaper pillow, so it can be summarized that twenty-five percent of males and females purchase pillow by considering price rather than quality.

Table 5.7: No. of observation on each type of pillow selected by 40 participants: Not revealing pillow's price

Materials	No. of observations (before revealing price)		Total
	Male	Female	
Polyester	1	1	2
Ball fiber	6	4	10
Rubber	2	3	5
Memory foam	11	12	23
Total	**20**	**20**	**40**

Table 5.8: No. of observation on each type of pillow selected by 40 participants: Revealing pillow's price

Materials	No. of observations (after revealing price)		Total
	Male	Female	
Polyester	1	0	1
Ball fiber	9	7	16
Rubber	4	6	10
Memory foam	6	7	13
Total	**20**	**20**	**40**

5.3.5.3 Guidelines for analyzing customer's requirement and purchasing decision

To generate design guideline in product design, it can be done by the following procedure: (1) establishing target group, (2) identify customer needs, and (3) performing competitive analysis. Customer needs refer to their expectation and behavior on a product, and competitive analysis can be done in the way of investigating customer's aspects on competitor product. Customer expectation on a product can be found by using questionnaire, whereas their purchasing behavior and aspects on a product can be found by performing the experiment. The randomized complete block design experiment can be used to select the most effective product form in the desired aspect as illustrated in this research.

5.3.5.4 Translating customer's requirement to engineering design by quality function deployment (QFD)

After the data collecting, the customer needs will be translated into the engineering characteristic as the completed HOQ shown in Figure 5.9.

(1) Customer's requirement section

Customers are most likely to prefer the pillow that has following characteristics: (1) the pillow that provides comfort while sleeping, (2) has no cervical pain after used,

and (3) gives soft perception when touching. These characteristics mentioned were given an important rating of 5 by customers and design team needs to concern the characteristics intensely to meet customer's requirements. Some customers also expect the pillow to have lightweight. However, this factor can be less consideration since the importance rating is just 2. Design team should also consider the characteristics that have the important rating below 5 as second priority.

(2) Engineering characteristics (ECs) and roof section

Considering relative weight of ECs listed some characteristics such as weight and color of pillow can be ignored due to less weight calculated. The most important EC (highest relative weight) is type of material. Achievement in designing this parameter can satisfy customer need. However, changing this parameter can affect the cost of pillow (negative correlation). The other ECs that also have an influence on decision to buy of customer are height, shape, and cost of pillow. ECs can be divided into two groups in order to obtain specific value: (1) the ECs that require experiment to obtain the value such as type of material and height, (2) the ECS that can be assigned directly by questionnaire or reason such as surface area, pillow case, and shape. For deformation, it will be designed together with height, and for density, it will dictate by material used.

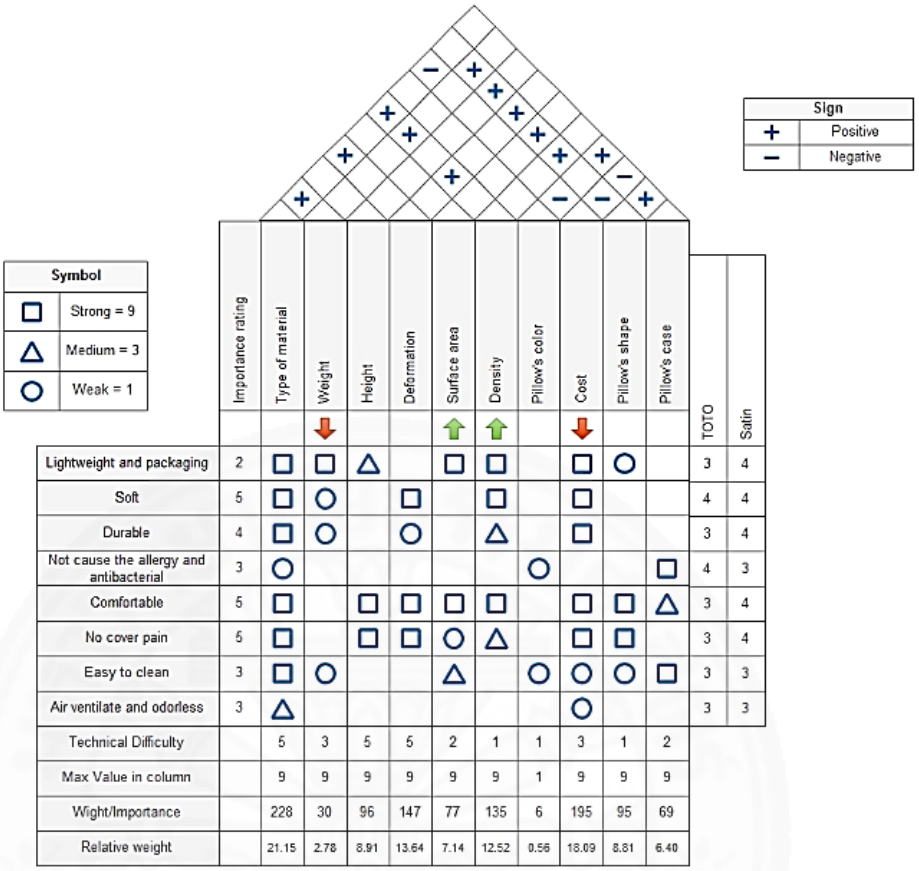


Figure 5.9: Completed HOQ

5.3.5.5 Research contributions

The method proposed in this paper can be used to design all types of product. However, only concept is generated, and for product specification, it needs to be defined in other stages of PDD. A designer can use the experiment illustrated to perform competitive analysis and to identify customer purchasing behavior. However, sometimes the experiment needs to be redesigned to match actual product characteristics. For example, pillows are a product that is not frequently purchased, less brand personality involved, and unfashionable product, so the main factor effect purchasing behaviour is price and quality. If a designer wants to determine the product involving with brand personality and fashion, the experiment needs to be redesigned to other ways.

5.4 Design and analysis of experiment

According to research background in previous section, rectangular shape pillow was selected as a shape of test specimen. Four specimens with different type of material and price were selected to conduct the experiment. The principle of randomized complete block design was introduced as an experiment format. To follow the principle of random, the participants slept on pillow with a random order, and the pillow information such as type of material, and price did not reveal. The participants tested each specimen individually with sleep duration of 5 minute. This value is selected based on the real situation. On average customers will test a pillow within 5 minute before making a decision to purchase the pillow. The participants tested the specimen on traditional bed to provide normal sleeping environment. After everything was set, the researcher asked the participants for comfort rate, and expected price of each specimen, and also asked the participants to make a decision to buy the pillow according to what they prefer. In the last section of the experiment, researcher revealed the true information of each specimen including price and type of material, and asked the participants to make the decision repeatedly. The specimen's specification represents in Table 5.9. The experiment form is provided in the appendix C.

5.4.1 Design of pillow

5.4.1.1 Human body measurement for supporting

I. Male body measurement

Body Dimension	N	Min	Max	Average	S.D.
Stature	20	163.0	183.0	171.33	4.80
Weight (Kg)	20	49.9	100.3	73.06	13.70
A, Head breadth at ear	20	15.0	17.4	16.12	0.78
B, Neck breadth at middle neck	20	9.3	13.0	11.17	1.17
C, Shoulder breadth, maximum	20	41.0	50.5	45.62	2.41
Ax, Width from ear to shoulder	20	12.3	17.3	14.75	1.16
Bx, Width from neck to shoulder	20	15.8	19.3	17.23	0.88
Ay, Height from ear to vertex	20	5.5	13.0	9.90	2.19
By, Height from neck to vertex	20	21.0	26.0	23.50	1.32
Cy, Height from shoulder to vertex	20	34.0	42.3	37.90	2.58
Dx, Length from hindbrain to wall	20	0.0	9.0	3.68	2.00
Ex, Length from middle neck to wall	20	4.0	11.0	6.67	1.80
Dy, Height from hindbrain to vertex	20	7.5	18.0	10.15	2.21
Ey, Height from neck to vertex	20	17.5	28.0	22.30	2.52
Fy, Height from upper back to vertex	20	34.5	41.0	38.16	1.70
G, Head length	20	17.5	20.4	19.04	0.81
H, Head height	20	25.4	23.1	23.15	1.52

Figure 5.10: Result of male body measurement

II Female body measurement

Body Dimension	N	Min	Max	Average	S.D.
Stature	20	151.0	166.0	158.60	4.21
Weight (Kg)	20	40.0	75.1	57.5	10.50
A, Head breadth at ear	20	14.0	17.0	15.74	0.86
B, Neck breadth at middle neck	20	8.4	12.0	9.90	1.10
C, Shoulder breadth, maximum	20	26.5	43.4	38.84	3.73
Ax, Width from ear to shoulder	20	6.3	13.7	11.55	1.68
Bx, Width from neck to shoulder	20	9.0	16.7	14.47	1.68
Ay, Height from ear to vertex	20	6.6	11.5	9.23	1.54
By, Height from neck to vertex	20	20.0	24.3	22.28	1.33
Cy, Height from shoulder to vertex	20	31.5	39.0	34.94	2.21
Dx, Length from hindbrain to wall	20	0.0	7.3	2.45	1.81
Ex, Length from middle neck to wall	20	3.3	9.2	5.42	1.47
Dy, Height from hindbrain to vertex	20	6.0	13.0	9.07	2.11
Ey, Height from neck to vertex	20	16.0	24.0	20.86	1.93
Fy, Height from upper back to vertex	20	30.5	44.0	36.7	3.29
G, Head length	20	15.0	19.5	17.88	1.04
H, Head height	20	18.5	25.2	21.57	1.65

Figure 5.11: Result of female body measurement

From the concept that a good pillow should maintain the curve of spine in a normal order, the length Dx is selected to be a design criterion since it has direct effect on spine. In other word, maintaining this length can make the spine align in normal order. Therefore, the pillow concept design is that the height after deformation of pillow should be around 3.7 cm. Length and width of pillow can be designed directly by using the concept that a pillow should be able to handle sleep rotation. Thus the length C is chosen as width of pillow which is the value of 45.6 cm. Allowance of sixty percent is given for designing the length of pillow to handle sleep rotation, so the length of pillow is around 74 cm. For female, as the reason with male, pillow height after deformation should be around 2.4 cm. Length and width of pillow is 62 and 39 cm respectively.

5.4.1.2 Finite element analysis

The result of the displacement analysis by using Finite Element Analysis came from 50 newton human head (5 kg) loaded on material polyester in a ball shape. The simulation was run on static analysis with the properties of the material consisting of elastic modulus, Poisson's ratio, mass density, and tensile strength as shown in Table 5.9. The force was assumed to be point load and applied in the middle of pillow since it is the location that most people sleep on.

In order to run the simulation, the pillow was assigned to be hollow due to many air gap inside the pillow. This can be achieved by creating surface instead of solid. Solid condition is not suitable for simulation, because the pillow will not be deformed after load applied. The result of the simulation was found that pillow was deformed 10*6.941 mm or 6.9 cm. The summery was that pillow should be high around 10.6 cm for male, and 9.3 cm for female. It is calculated from using the information from section 5.3.

Table 5.9: Properties of polyester for finite element analysis

Material	Elastic modulus (N/m^2)	Poisson's ratio	Mass density (Kg/m^3)	Tensile strength (N/m^2)
Polyester (ball fiber)	15000000000	0.3	1380	1000000000

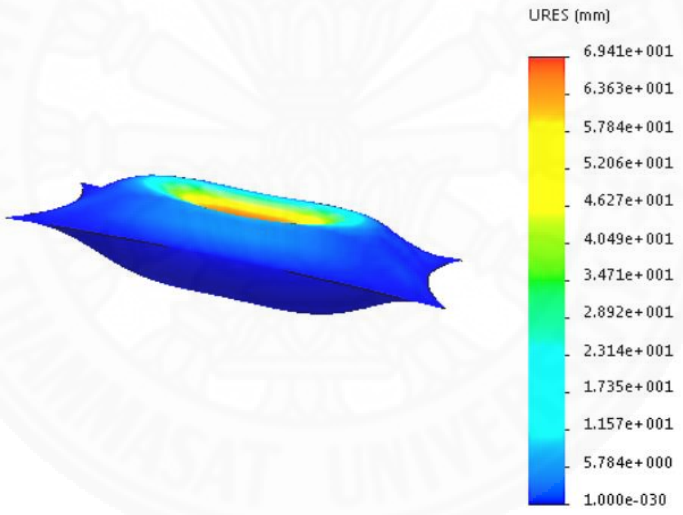


Figure 5.12: The simulation result

Chapter 6
Translating Customer Needs to Design (Part III)
Case Study: Eyeglasses

6.1 Research Background

Presented in the Table 6.1, the difficulties to identify the characteristics of the product through imaginary picture where the background experiences of each person have been played as the important factors. These have led to the research where the human's feeling and product's characteristics can be identified and integrated for assisting the designer to easily design the products and for the retailers, they can select the proper products into their shops. In order to select the appropriate product, eyewear, which matches to the customer's personality or physical characteristic, the special suggestions from the sellers or brand ambassadors (BA) have played as the important issues for purchasing decisions. The first conversation between the customer and the BA are about the price, special discount, new arrival or brand designers and identity. The customers have tried to express their requirements; however, BA keeps presenting the various styles of the eyeglasses and the promotion provided during that season. These affect to the product selection.

Most of those eyewear shops order many styles and categories of the eyeglasses without analyzing or predicting the real situation or trend of the eyeglasses required since the BA staffs are the key component of selling strategy. The results of the fail forecasting order, tons of eyewear are left in the stock and they cannot be sold even the discount campaign is immediately launched. It would be better that the owners of small and mid-size businesses can predict the customer's requirement directly through considering and interpreting the feelings to the product's specification and characteristic.

Eight main issues which are shapes of face, shapes of eyewear, contrast between shape of the face and glasses, proportion of the frames comparing to the rest of the face, colour of the glasses, acceptable range of the price, material of eyewear, and the target customers, have been raised in the proposed approach for classifying the eyewear into

the right groups where the customer's feelings can be interpreted to be the product's details. Some glasses advertisements or designers have tried to introduce their new creation by adding the tips for choosing eyeglass frames for user's face shape. As aforementioned face shapes, the user who really wants to buy the glasses for adding more confident or for better personality can apply some suggestions for selecting the proper designs (Jones, 2015; Opticians' Handbook, 2008). Before starting the concept design phase of the proposed approach, the questionnaires were raised and surveyed. In order to make the research to be more robust, the appropriate number of respondents (i.e., the people who have completely filled in the survey) is determined by assigning a margin of error of 5% and a confidence level of 95% for Thai people who spent their 5-day life in the metropolitan universities between the ages of 18 and 40, the population consist of approximately 250 adults in Bangkok Metropolitan.

The results reported that a 61% of all people in that age group was wearing eyeglasses, and feeling comfortable to purchase and select the style of glasses from the shop according to the recommendations of the brand ambassadors or salesperson. They recommended that the price of eyeglasses should be in the range of USD $85-115 (i.e., THB 3001-4000). Moreover, the factors influenced for eyeglasses-purchasing decisions ranging from the maximum to the minimum scores were shapes, design and style, matching frames to personality, quality of the materials applied, cost of the eyeglasses, and experiences, respectively.

The attitudes and experiences of different age groups towards eyewear design have been considered and analyzed where the interviewed results were classified into 2 sub-groups: 18-25 years old (48 men and 32 women), and 26-40 years old (7 men and 13 women). Gathering and considering the feelings and demands of the people who are in the same generation can help the manufacturers and designers to prevent the hidden needs and distorted concept design of the eyewear.

Table 6.1: Imaginary eyeglasses through the conditions

Condition	Young men	Young women
Modern		
Classic		
Simple		
Luxurious		
Formal		
Informal		
Confident		

Analyzing the target in the same satisfaction rate of the current eyeglasses presented that a 4% of them (both groups) dislike the current design and will plan to buy a new one, a 62% of them feel quite comfortable and are not sensitive to the factors influenced for purchasing glasses, 33% of them indicates that the interviewed people strongly satisfied their current glasses and do not need to buy a new one. The interviewed results also presented that 82% of people think that stores can provide the style of glasses that they need. The face shape of the interviewees are considered and analyzed where the various types of the face are listed. During answering the questionnaires, each interviewee was asked to describe his/her face shape (New Health Advisor, 2016). The results indicate as the following percentages shown in Table 6.2.

Table 6.2: The interviewed results indicating about the face shape in percentage

Face Shape		Interviewed Results (%)
Picture	Name	
	Round	22
	Heart	21
	Diamond	16
	Rectangle	14
	Pear	11
	Oval	9
	Square	6

6.2 Addressed Issues

In order to select the appropriate product, eyewear, which matches to the customer's personality or physical characteristic, the special suggestions from the sellers or brand ambassadors (BA) have played as the important issues for purchasing decisions. The first conversation between the customer and the BA are about the price, special discount, new arrival or brand designers and identity. The customers have tried to express their requirements; however, BA keeps presenting the various styles of the eyeglasses and the promotion provided during that season. These affect to the product selection. Most of those eyewear shops order many styles and categories of the eyeglasses without analyzing or predicting the real situation or trend of the eyeglasses

required since the BA staffs are the key component of selling strategy. The results of the fail forecasting order, tons of eyewear are left in the stock and they cannot be sold even the discount campaign is immediately launched.

It would be better that the owners of small and mid-size businesses can predict the customer's requirement directly through considering and interpreting the feelings to the product's specification and characteristic. Eight main issues which are shapes of face, shapes of eyewear, contrast between shape of the face and glasses, proportion of the frames comparing to the rest of the face, colour of the glasses, acceptable range of the price, material of eyewear, and the target customers, have been raised in the proposed approach for classifying the eyewear into the right groups where the customer's feelings can be interpreted to be the product's details.

6.2.1 Shape of face

The basic and classic decision (especially for the women) to select the eyewear is face shape since the customers cannot find the suitable pair of eyeglasses without trying it on their face. Some of the online-purchasing websites provide the convenient 3D virtual try-on technology to create 3D model of the customer's face to see how the eyeglasses will look on customer before buying it (Carroll, 2013; Yuan,Khan, Farbiz, Niswar & Huang, 2011). For offline-purchasing ones, the face shapes are documented generally to the customers as the special suggestions by the sellers (Hisrich& Jackson, 1993; Vossoughi, 2014). In order to measure the face, the width of the face across the forehead, the top of cheekbones and jawline are compared with the length of the face from hairline to the chin (New Health Advisor, 2016).

6.2.2 Shape of eyewear

The traditional styles of the eyewear, recently, have been shown as the round-rims design (Figure 6.2) where no extra decorations are provided. They all present the formal pattern and high weight. The circular shape (Figure 6.1) (Clipart.me, 2010) is very famous since it can be varied into many frame-pattern designs for supporting the

customer’s feelings and personalities where the younger-look characteristic has been played as a vital requirement.

Over the past five years, three-quarters of young adults (ages 18-30 years old) go online daily and they are influenced by the super stars, actors, actresses or singers. According the interviewed results of the this group, the rectangle-frame glasses with plastic material are the most popular glasses because this style can be worn suitably in various situations and provided better vision. Another types and characteristics of the glasses with the interviewed results (in percentage) are listed in Table 6.3.

Figure 6.1: Traditional shapes of eyewear; (a) thick-rectangle shape, aviator shape, and (c) round shape

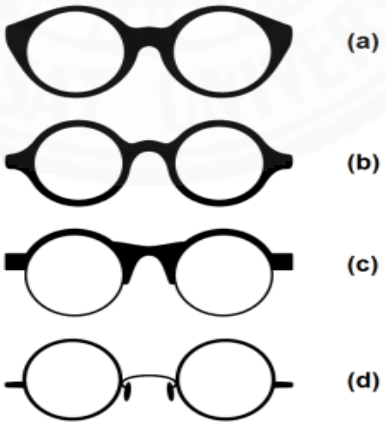


Figure 6.2: Various frame styles of the circular shapes of eyewear; (a) fashionable frame, (b) full-plastic frame, (c) semi rimless, and (d) full-metal frame

Table 6.3: Most preferable style of eyeglasses from 100 people

Types and Characteristics of Glasses		Interviewed Results (%)
Details	**Pictures**	
Frame styles		
With frame		
Full frame		77
Half frame/Semi rimless		23
Without frame		0
Materials		
Metals		20
Plastics		65
Others (e.g., mixed between plastics and alloys, wood, silicone or other polymers)		15
Frame shapes		
Rectangle		53
Round		17
Water drop/Trapezoid		13
Aviator		5
Others (e.g., cat eye-shaped frame or fashionable styles)		12

6.2.3 Contrast between the shapes of face and glasses

After interviewing and researching the people who wear glasses, and articles available in many sources, the results present that the another important issue for selecting the proper glasses is contrast between the shapes of face and glasses. The round face should select the rectangle/angular frames for reducing circular contour of the face shape. This face shape should avoid curved frames.

6.2.4 Proportion of the frames comparing to the rest of the face

The criteria used for considerations and analysis about this issue, after wearing glasses, are the user's personal feelings, and the direct comments conveyed from the group of closed friends or family (Pullin, 2009). For optical purpose, the interviewed people prefer to wear the glasses with the size matched to the eye sockets (i.e., the frames are comfortable for proper coverage; not too big or small).

6.2.5 Color of glasses

Sometimes for selecting the glasses, the color of the frame has the direct effect on the shape and size of the face. Black color (as recommended from 74%users) is selected for brightening the pale face skin, and wearing this can increase the user confidence when he or she would like to do some public activities. The colors of hair and eyes are also taken into considerations.

6.2.6 Accepted price

Imagine if a person goes to glasses shop then select the desire style of eyeglasses but when look for a price-tag, she cannot afford it. The only way to solve this situation is to select another eyeglasses that she like less than the desired one. Saying that the price of eyewear affect the style of eyewear that customer want to buy. However, some wealthy people can select any eyewear that they desire regardless the price of it.

6.2.7 Materials

Due to the current technology, many materials for eyeglass frame are introduced in to the market that make confusion for people who want to buy a new eyeglass and for manufacturer to select the proper material due to the design. It can be classified in to two major groups; plastic based and metal based. A metal based frame is consisted of lightweight, strong, flexible, and anti-corrosive properties that are an ideal production frame (Opticians' Handbook, 2008). Due to the better quality of the frame comparing to a plastic one; however, cost and processing time are higher. A plastic based frame can deliver a various colors, shapes and details with the major advantage of lightweight or a little heavier based on the manufacturer's production decision.

6.2.8 The target customers

Due to the different experience of human, the difficulty for product designer is that to make the product suit for all customers around the world. In the real world, the beautiful of one person may be the ugliest to other. This is the most important issue for designers to make every people all accept their single product. Traditional approach to solve this problem is to design the product specifically to gender, age, occupation, and regional culture.

6.3 Research Concept

The research is divided into 3 main phases to achieve the objective of the proposed approach (as shown in Figure 6.3). The first phase starts with identifying the adjective words, the second phase is about the adjective measurement, and the last phase is the analysis of the listed adjectives. The overall activities required for each phase are explained in the Figure 6.4.

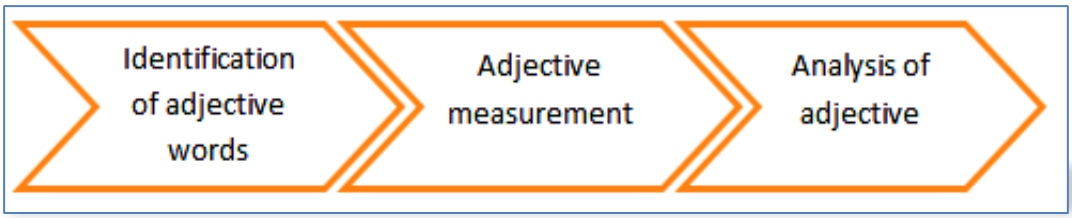


Figure 6.3: Research guideline

For the first step of *Phase I*, in order to launch a new product to the market design of interest will be chosen, and then identifying the target group has been raised for focusing on the right user's experiences which have the direct effect of the final design.

In *Phase II*, after identifying the desire product of interest and the right target group, the set of Kansei words which are about the possible product characteristics and their definitions have been determined. False determination about Kansei words will make the distortion in design of the final results. In order to create the relationship between customer's requirement and engineering specification, the confident level and margin of error have been assigned first before interviewing the target group. Using 7-point semantic differential scale questionnaire (Nazlina, 2013) can help the designer easily collecting the data where the scores are set from -3 to +3 where +3 means the maximum value for the positive Kansei words while the -3 means the maximum value for negative Kansei words. There are 2 platforms for launching the questionnaire: online (internet-based application) and offline (documentations).

For *Phase III*, three main steps are require. Multivariate statistical analysis called factor analysis is used in order to group the Kansei words from emotional need of customer and engineering specification together and also eliminate some uncorrelated Kansei words (Yodwangjai & Pimapunsri, 2011; Anitawati, 2010). The second step is to interpret the result from factor analysis into the group of Kansei words, in this research, the number of factor represents the number of product which is going to be launched. Finally, the product's characteristics have been determined and sent to the designer in order to choose the right materials and create the right design of the prototype of product. This is a kind of collaboration between Kansei engineer and designers.

Before starting the Kansei Engineering process, the scope of the approach is firstly set since, the method is very sensitive to the case that different people from different age and different culture usually think in a different way; the shapes and styles of the product designed by western or European platforms might not be flexible or fitted to Asian people or characteristics.

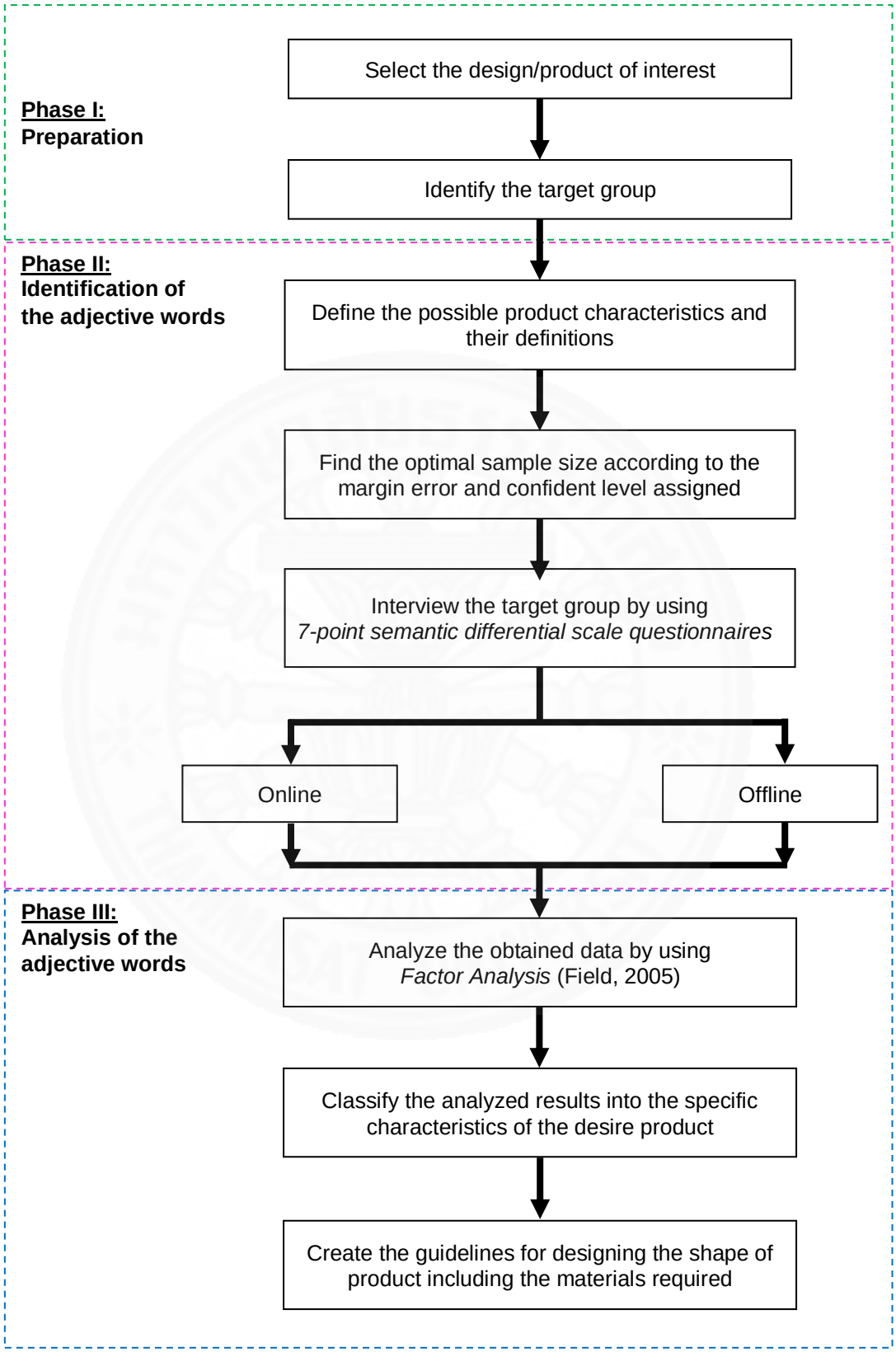


Figure 6.4: The overall steps required for the proposed Kansei approach

6.3.1 Preparation

This would be better to analyse and identify people who live in oriental countries (i.e., Thai people) before designing or ordering the products from those overseas countries to reduce the number of product left in the stock. Therefore, the scope of this research is set for Thai people with the age of 20 to 40 years old. To identify and obtain the effective results where the eyeglasses design can be optimized to the right targets and the living environment, financial status, culture, and familiarizing of technology have been taking considerations.

6.3.2 Identification of adjective words

In the identification of adjective words steps, possible adjectives related to eyewear are collected from brainstorming, fashion magazine and interview the customer. Eighteen words of adjectives from 18 adjectives of product characteristics and customer's feelings are formed and called Kansei word as shown in Table 6.4 and 6.5, respectively.

Table 6.4: Possible product characteristics and their definitions

Product characteristics	Descriptions
Heavy	Glasses contain high weight.
Light	Glasses contain light weight.
Loose	Glasses are easily moved apart from the nose.
Tight	Glasses are fitted to the nose.
Big	Perimeter of glasses rim is large.
Small	Perimeter of glasses rim is small.
Thick	The frame of glasses is thick.
Thin	The frame of glasses is thin.
Smooth	Eyeglasses contain no extra features all around its shape (excluding nose-pad area).
Rough	Glasses contain extra features all around its shape (excluding nose-pad area).
Flexible	Capable of bending or being bent easily without breaking
Inflexible	Glasses is not easily bent or twisted.
Durable	The glasses are design to withstand the stresses of demanding use.
Fragile	Glasses are very delicate or not strong.
Clear	Glasses are made from a material that contains a transparent colour.
Solid	Glasses are made from a material that contains a solid colour.
Edgy	Glasses contain high number of corner inside the frame.
Round	Glasses not contain any corner inside frame.

Table 6.5: Possible customer emotional requirement and its definition

Customer emotional specifications	Descriptions
Cheap	Eyeglasses should be sold with low price.
Expensive	Eyeglasses should be sold with high price.
Modern	Glasses are design based on latest style of fashion.
Classic	Glasses are design with the concept of timeless beauty.
Simple	Design of eyeglasses is not complicated.
Luxurious	Glasses are designed with the concept of feeling or showing a desire for expensive thing.
Formal	Glasses are design with the influences of culture.
Informal	The conditions applied for designing purpose are about having a friendly, relaxed quality and suited for ordinary use
Adorable	Eyeglasses make the user feel loveable and childlike.
Gorgeous	Eyeglasses make the user feel attractive.
Divergent	The design of eyeglass is different from other eyeglass.
Familiar	The design of eyeglass is the same or get used to other eyeglasses.
Confident	The design of eyewear makes user gain more confident when they wear it.
Doubtful	The design of eyewear makes user decrease their confident when they wear it.
Dateless	The design of eyeglasses will not be gone out of fashion in the next 4 years.
Stylish	The design of eyeglasses will be different from the others trends in the next 4 years with containing special style and characteristic.
Aged	Glasses make users feel getting older than the actual age.
Young	Glasses make users feel and look younger than the actual age.

6.3.3 Adjective measurement

A 7-point semantic differential scale questionnaire (as shown in Figure 6.5) is used to measure the people's emotion toward eyewear is used in this research. In this step, participants are asked to describe their ideal eyewear through 18 pairs of given Kansei words. 99 received back questionnaires from 42 males and 57 females give 10% error with 95% confident level.

Like more				Neutral				Like more
Cheap	3	2	1	0	1	2	3	Expensive
Modern	3	2	1	0	1	2	3	Classic
Simple	3	2	1	0	1	2	3	Luxurious
Formal	3	2	1	0	1	2	3	Informal
Adorable	3	2	1	0	1	2	3	Gorgeous
Divergent	3	2	1	0	1	2	3	Familiar
Confident	3	2	1	0	1	2	3	Doubtful
Dateless	3	2	1	0	1	2	3	Stylish
Aged	3	2	1	0	1	2	3	Young

Figure 6.5: Example of 7-points semantic differential scale of synonym adjective

6.3.4 Analysis of adjective

In this process, a statistical method called "factor analysis" is used for determining the number of product's groups and the product's characteristics where the customer's needs have been applied as the main criteria for creating the correlation between customer's requirement and designs of the desired product. Factor analysis has been introduced as a data reduction technique which is used for describing the correlation between each variable (i.e. product characteristics and customer's feelings), and for grouping these variables into one factors.

Using this technique can assist the designer to minimize analysing time and activities where the relationship between the customers' feeling toward eyewear and eyewear characteristics is formed and identified. The data obtained from the questionnaires are tested for appropriateness of using factor analysis by using *Kaiser-*

Meyer-Olkin (KMO) test and Bartlett's Test of sphericity. The value of KMO test is 0.734 which is greater than 0.5, mean that the sample size is suitable for factor analysis (Field, 2005). Bartlett's Test has the P-value less than 0.01 showing that there is some correlation between variables,

KMO;

$$KMO = \frac{\sum_{i \neq j} r_{ij}^2}{\sum_{i \neq j} r_{ij}^2 + \sum_{i \neq j} u_{ij}^2} \qquad \text{Eq. (6.1)}$$

Where

r_{ij} = correlation between variable i and j

u_{ij} = partial covariance between variable i and j

Bartlett's test;

$H0: Determinant\ of\ correlation\ matrix = 1$

$H1: Determinant\ of\ correlation\ matrix \neq 1$

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.734
Bartlett's Test of Sphericity	Approx. Chi-Square	374.917
	df	105
	Sig.	.000

Figure 6.6: KMO and Bartlett's Test

To know how many factors that have been extracted from the sample, eigenvalues of correlation matrix are calculated. Looking for the eigenvalue that is greater than one is one of the criteria to determine number of factor to be extracted. Because when eigenvalue less than 1, the percentage of variance explain by each variable is low and may lead to a situation that in 1 factor will contain only 1 variable that is not accept in factor analysis.

In Table 6.6, the first factor explained 27.131% of total variability of the data which take a major effect for the analysis. The second, third, fourth, and fifth factors explain 10.189%, 9.747%, 7.483%, 6.752%, respectively. The rest variable can be eliminated since it is not significant in the analysis (the percentage of their variances were less than 27.131%). Using this criterion may not be a good justify since variable

number 5 show 1.013 of eigenvalue which is near the criteria of 1. Scree plot is one of the criteria that have been used in factor analysis (Figure 6.7). It shows the eigenvalues on y-axis and number of factors on x-axis (Field, 2005). The point where the slope is rapidly steep; in this case is point number 3, indicates the number of factors that should be form by the analysis. In conclusion, from the sample 3 factors will be generated that accounted for 47.066% of total variability of the sample;

$$\%\ of\ variance = \frac{Initial\ Eigenvalue}{Total\ number\ of\ component} \qquad \text{Eq. (6.2)}$$

Table 6.6: Total variance explained

Component	Initial Eigenvalues			Rotation Sums of Squared Loading		
	Total	% of Variance	Cumulative (%)	Total	% of Variance	Cumulative (%)
1	4.07	27.131	27.131	2.929	19.529	19.529
2	1.528	10.189	37.319	2.114	14.091	33.62
3	1.462	9.747	47.065	2.017	13.446	47.065
4	1.122	7.483	54.548	-	-	-
5	1.013	6.752	61.3	-	-	-

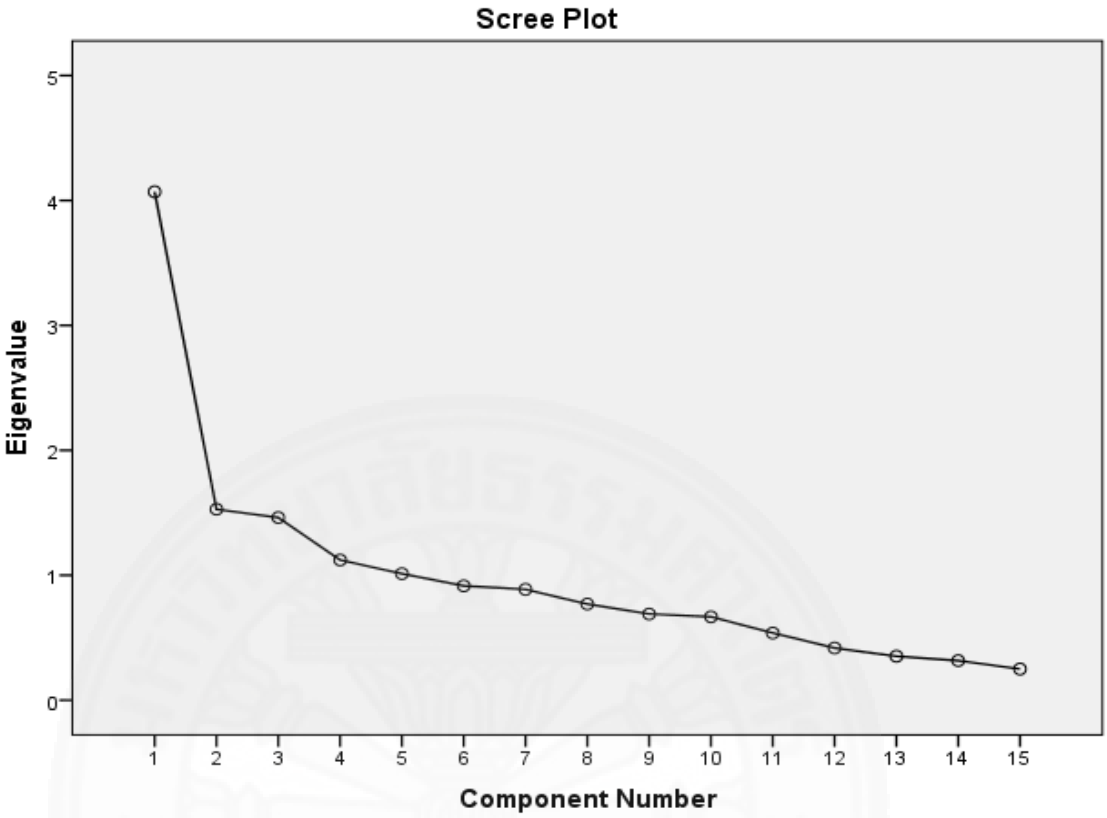


Figure 6.7: Scree plot

After extracting 3 factors, the members of each factor are grouped by using the correlation between each variable (product characteristics) and each factor (1 to 3) as shown in the Table 6.7. These relationships are called loading coefficients which are the correlations between standardized mean of each response and principal component score from the multiplication of transposed eigenvector matrix of correlation matrix and standardized matrix from the observation (Di Franco & Marradi, 2013).

High absolute value of loading coefficient indicates that the variable has a strong relationship with the factor. Table 6.7 shows the rotated component matrix which indicates what variable should be included in what factor. In this case factor1 contains “smooth”, “simple”, and “clear” since loading coefficients are shown in positive sign and also contain “young”, “familiar”, and “tight” since the loading coefficients are negative.

Table 6.7: Rotated Component Matrix

Rotated Component Matrix

Kansei words		Component		
Positive	**Negative**	**1**	**2**	**3**
Smooth	rough	.769	.336	
Simple	luxurious	.703		
Clear	solid	.557		.284
Aged	young	-.523	-.213	
Divergent	familiar	-.517	.376	
Loose	tight	-.427		-.216
Formal	informal		.659	
Durable	fragile	.391	.577	
Cheap	expensive		.504	
Elastic	inelastic	.232	.463	
Modern	classic			.711
Heavy	light	-.386	-.266	-.627
Big	small		.430	-.618
Confident	doubtful	.483	.372	.540
Dateless	stylish	.440	.349	.513

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 5 iterations.

6.4 Results of the Research

When the correlation between variables and factors mentioned in Table 6.7, the traditional way of Kansei Engineering is asked to define the name of that factor regarding to the member of that factor (Carmen & Alvaro, 2008; Nasser, Elnaz&Seyed-Reza, 2014; Nasser, &Marjan, 2010). In this research, the number of factors is identified as the type of eyeglasses that contain each variable (i.e., the product's characteristic) that is matched to the customer's demand. Three types of eyeglasses (as shown in Table 6.8 and Figure 6.8 – 6.11) are formed according to the analysis of factor analysis method.

Table 6.8: Results of the analysis

Eyeglasses	Customer requirement	Product's specification
Type I	"simple" "young" "familiar"	"smooth" "tight" "clear"
Type II	"formal" "cheap"	"durable" "elastic"
Type III	"modern" "confident" "dateless"	"light" "small"

Figure 6.8: Product examples of *Type I* glasses

Figure 6.9: Product example of *Type II* glasses

Figure 6.10: Product examples of *Type III* glasses

(a) Round + Cat eye-shaped frame (b) Rectangle + Thin temple/arm

Figure 6.11: 3D CAD models of the two glasses designs inspired from the recommended *Type I* and *III*

6.5 Conclusion and contributions

In the initial stage of the proposed research, a target group has been identified to be the people (ages 18-40 years old) who spent at least 5 days in the metropolitan universities were interviewed. Based on the backgrounds of the interviewed people, they commented that wearing unsuited eyewear style on their faces make they look and feel unnatural and uncomfortable during performing daily activities. Moreover, the young adults need to wear the products that look stylish everyday on their face or body. However, it is quite difficult for creating the product such as the eyewear to make the people look stylish at every age, the standard design of the frame as a rectangle shape is still existed and popular.

At the first stage of the conceptual design applied in the proposed approach, to provide the guideline for choosing the eyewear that flatter and match the user's face, personality and lifestyle, the basic conditions: types of frame material, and user's personality after wearing eyewear were firstly analyzed and discussed as shown in Table 6.9. For obtaining the reliable answers without hidden issues, the samples of the people were separated into two groups according to the age ranges; 18-25, and 26-40 years old.

Table 6.9: The interviewed results on the basic conditions to select eyewear

Basic conditions to select eyewear			
(18-25 years old)		**(26-40 years old)**	
Frame Material	**Expected result after wearing**	**Frame Material**	**Expected result after wearing**
Plastic or Polymer	For supporting young look	Metal	For supporting professional look

After analyzing the interviewed answers, six main factors can be raised since they may have the direct effects on purchasing decisions and designs: quality, cost, designer who provides the special geometric characteristics of the glasses shape, physical looking after wearing eyewear, trend and current style or a general direction or something popular (influenced from the advertisement, social media or superstar), and experiences or background of the interviewees. The eyewear designs are guided and introduced as 3 main types where each factor represents one design of the product. For supporting the customer's demands, the chance that *Type 1* of eyewear is more satisfying than others is about 27.131%, even eyewear *Type 2* and *3*, they can enhance and flatter the customer's personalities and characteristics to be more elegant and confident; however, both still provide less popular than the aforementioned *Type 1*'s style.

From the application of the proposed approach, they presented that the emotional needs of the customers can be transformed directly and quickly into product's characteristics where Kansei Engineering with statistical analysis is applied at the concept development and detail design phases. In order to contribute this approach to the other application, the following steps are required:

- ***Identifying:*** Customer's Kansei words expressed in adjective forms are identified for letting the customer and the designer understand the same meaning of each adjective and product's characteristics clearly.

- ***Measuring****:* Customer feelings, the adjective words, are measured by using *Semantic Differential Scale* that the respondents have to rate their feelings between each pair of adjective word where the two adjectives are antonym to each other.
- ***Analyzing:*** *Factor analysis method* was applied to group customer's feelings with product's characteristics into one factor based on their correlations between each variable and the factor.

For the designers, the link between customer's emotional demand and product's characteristic can be obviously shown in the bright direction for drafting and creating some ideas of the new product to satisfy the customer's needs and requirements. Since the customers cannot explain exactly about the product's characteristics that they desire, they can only express their feelings and emotions toward the products.

For the manufacturers, providing the appropriate products or services to the customers, in various industries (i.e., especially, in fashion industries) can help the manufacturers to easily specify and put the right types of the product to the right market group. This strategy may assist the manufactures to increase their selling volumes.

For the retailers or boutiques, this method helps the retailers to select the proper products from manufacturers in order to reduce the number of products left in the stock, as the results, they can reduce their holding cost. The customers can find the desire product immediately from the first or one stop-shopping boutique that they visit, and the selected product can make them feel comfortable and stylish when they wear it. However, the method has been further complicated by the culture change, the specific characteristics of culture or the social status that have been in process within concept development process. For the recommendations, the factors that affect risk more than styles, shapes or patterns of the eyewear such as the responsibility of the shops/boutiques (interfacing to the customers), manufacturers (dealing with the shops or boutiques for quality issues), and designers (working with manufacturer to interpret the customer's needs to be a design) have been added and analyzed during concept development phase for supporting the tactical and strategic decisions where the distorted design and redundant tasks can be eliminated.

Chapter 7
Conclusions and Research Contribution

7.1 Conclusion

The initial stage of the proposed research started with identifying the target group of each case study. The target customers should be the people who always spend their daily activities with a health-related product since the characteristics of this product type are related directly to the ergonomics and human factors. Recently, the designed product cannot hit the customer's requirements and its specific characteristics persuade, mislead, or deceive the target customers. Some people cannot express their needs relating to emotions directly through product characteristics. Telling the designer directly makes they feel uncomfortable, and, sometimes, they put a lot of thought into picking out the proper styles with influenced choices or new materials. These kinds of misunderstandings lead to conflict and resentment not just at design, but at company's reliability too.

Using the proposed approach can help the designer and the customer understand each other for finding and creating the optimal design concerning matters of human body where the well-process planning and design cane be constructed easily. For three case studies; foot inserts, pillow and eyeglasses, the backgrounds and experiences of the interviewed people have the direct effects on selecting design and making decision on the product of interest.

In this proposed approach, needs are classified as two types of the product which are the basic and the basic-social products. For the basic product, footwear inserts and pillows are applied as the case study since the purpose for this type is to help the user relieves pain (like a medicine) and feels more comfortable during the day or after using. For the basic-social product, eyeglasses are selected for presenting about the product that is used for both vision corrections and good personality. After a long day of work, with the right design of eyeglasses, the user feels less stress and tension around the contacted areas between face and glasses' frame.

The comments were mostly mentioned about the price which is ultimately what they are willing to pay. Some designs and materials are worse than the quality and advertisement announced by the attached product's descriptions or the words from product ambassadors. The comfortable or satisfaction levels were difficult to be indicated the direct demands or requirements from the hidden issues (e.g., personal feelings, behaviors, and opinions).

The interviewed results were direct toward the drafted design of the new product. The concept of product design and development (PDD) has been applied for transferring the intangible feelings into the tangible format and platform. The first three phases of PDD are emphasized on generating the specifications of a desired product when the fourth and fifth phases are mentioned and focused on testing and production respectively.

For the first and the second steps, the interviewed data are translated to be the geometric shapes, the components, and material selections are suggested and recommended. The expected result of this phase is the drafted engineering design with the specific product's characteristics. Kansei Engineering (KE) method has been applied for translating the intangible needs/requirements to be the engineering specifications and characteristics whereas House of Quality (HOQ) method has been asked for finding the relationship or link between customer's requirements and the engineering specifications where the physical characteristics of the product and engineering parameters are listed for drafting the design.

To study the customer's behaviors versus the prices, the regression analysis or ANOVA method has been applied for conducting the experiments. The comfortable levels and purchasing decisions obtained from the calculation can be used for constructing the guideline for creating the new design of the health-related product.

For the third step, it is to select the appropriate engineering tools to check and analyze the physical properties of the created model which are divided into two types; physical test and virtual simulation. The suitable results which are the recommended shape, design, and material conditions are raised and introduced.

7.2 Research Contributions

The contributions of this research are summarized as follows:

- *Supporting a designer to create a new model by applying the proposed guideline*

Illustrated in Fig. 7.1 is the proposed guideline which can be applied as the alternative direction to assist a manufacturer or a designer to select the appropriate methods for estimating, forecasting, or creating the platform or plan of a new design where the application of image processing (i.e., reverse engineering) is introduced for fast creating the geometric shapes of the desired model. The obtained model can be used for identifying manufacturing parameters directly in the subsequent processes. Time and investment costs spent for redesigning or the change of a minor form of a prototype can be reduced or eliminated since the virtual simulations are applied for testing and refinement stage.

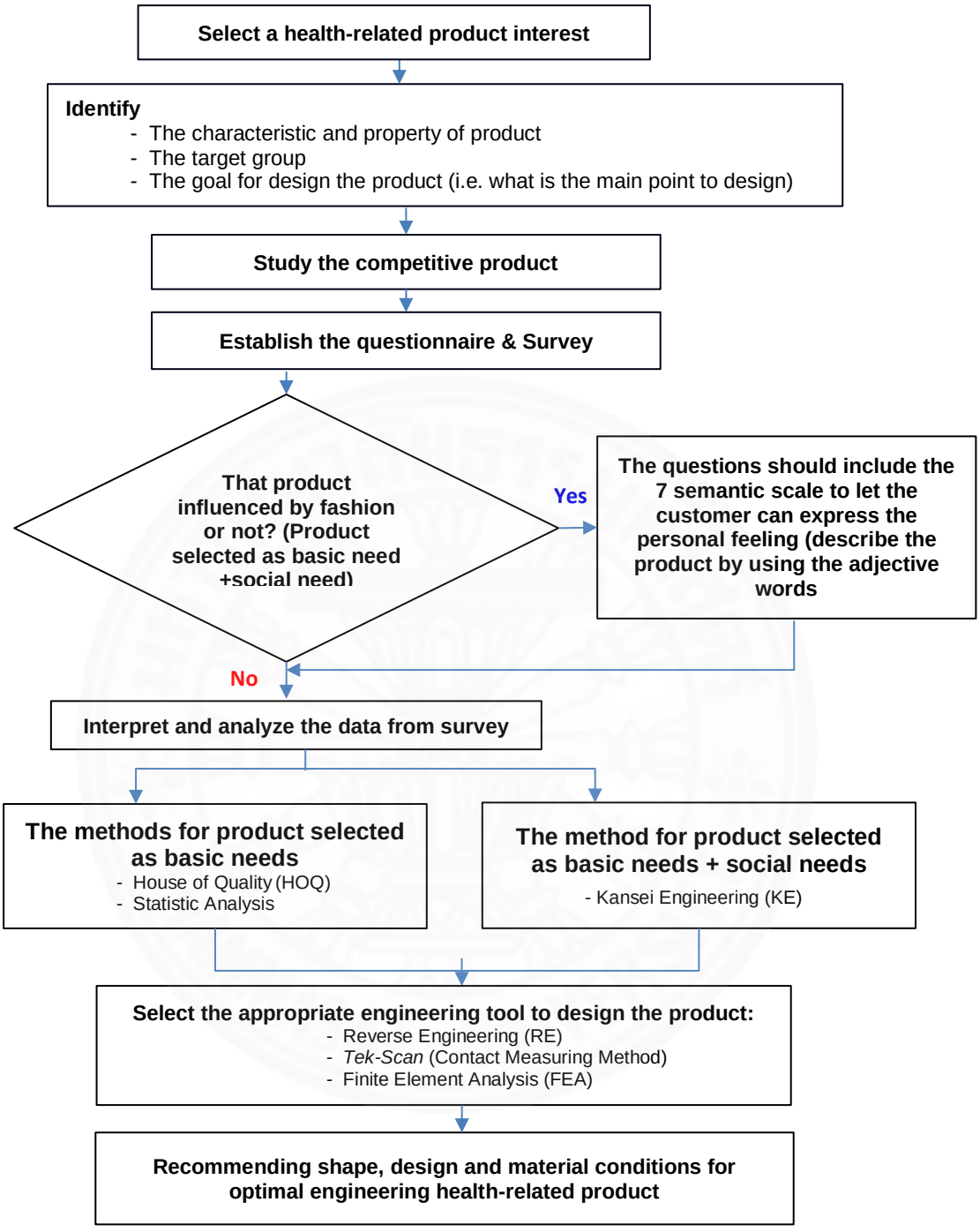


Figure 7.1: The guideline for designing the optimal engineering product

- *Supporting logistics and supply chain management*

Recently, driving customer satisfaction is quite difficult and spend a lot of conversations and discussions with a customer, especially for the health-related products. The conversations, most of the time, are spent for the hidden issues regarding

part's details since it is related to feelings where the geometric forms or engineering scales cannot be expressed directly, using a digital camera (in reverse engineering process) is fast and comfortable for a customer to create some ideas for designing a new product where some feature details can be easily explained via images. The finite element analysis (FEA) can reduce cost, time, and waste from testing the physical characteristics on the real prototype repeatedly. The obtained simulated results can be shown as the suitable materials for creating the appropriate design. Transportation cost for sending or transferring the engineering details from one place to another by vehicles can be eliminated since the digital files can be uploaded or downloaded easily via the internet or mobile applications.

7.3 Recommendations for the future study

- *For 3D virtual application and simulation (surface reconstruction, and finite element analysis)*

Taking images under proper light conditions and camera's parameters will make clean and clear images which can be sent directly to create 3D model without any improvement or corrections. The obtained results can present more accurate physical characteristics of the area of interest.

- *For analyzing the relationship between customer's requirement and engineering design*

In order to enhance the ability of customer's requirement analysis, the quality function deployment (QFD), the other optimization methods should be emphasized more on the existing research. The self-administrated questionnaires should be distributed to the people who live in another regions or parts of Thailand or areas for achieving various comments or opinions which can make the guidelines and suggestions to be more robust and reliable.

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Appendices

Appendix A
Questionnaire of Foot Inserts

แบบสอบถามงานวิจัย

<u>เรื่อง</u>

การเสนอแนวทางการเลือกใช้อุปกรณ์เสริมเท้าที่เหมาะสมสำหรับส้นเท้าอักเสบ

ผู้ที่ยืนเป็นเวลานานด้วยกระบวนการวิศวกรรมย้อนรอยและไฟไนต์เอลิเมนต์

คำชี้แจง โปรดทำเครื่องหมาย ✓ ลงในช่อง ❍ หน้าข้อความที่ตรงกับสภาพความเป็นจริงของท่าน หรือเติมข้อความลงในช่องว่างที่กำหนด

1. อายุ .....

2.น้ำหนัก .....

3. ความสูง .....

4. Size รองเท้าของท่าน .....

5. รูปแบบลักษณะเท้าของท่านเป็นอย่างไร

❍1. เท้าปกติ  ❍2. เท้าแบน  ❍3. อุ้งเท้าสูง 

6. ท่านเคยประสบอุบัติเหตุหรือมีโรคประจำตัว (เช่นโรคเบาหวาน) ที่ส่งผลกระทบต่อการเจ็บปวดทางเท้าหรือไม่

❍ มี (กรุณาไปที่ข้อ 13) ❍ ไม่มี (กรุณาทำต่อข้อที่ 7)

7. จำนวนชั่วโมงเฉลี่ยที่ท่านใช้ในการยืนทำงานใน 1 วัน ..... ชั่วโมง.....นาที

8. รองเท้าที่ท่านใส่ปฏิบัติงานส่งผลกระทบต่อปัญหาสุขภาพเท้าของท่านอย่างไร (มากที่สุด)

❍1. ปวดส้นเท้า (กรุณาทำต่อข้อที่ 9) ❍ 2. ปวดกลางฝ่าเท้า (กรุณาไปที่ข้อ 13) ❍3. ปวดด้านหน้าฝ่าเท้า (กรุณาไปที่ข้อ 13)

9. ลักษณะของรองเท้าที่ท่านใช้ในการปฏิบัติงานเป็นแบบใด

 ❍ 1. รองเท้าคัทชูส์ไม่มีส้น

 ❍ 2. รองเท้าคัทชูส์เปิดปลายมีส้นสูงเล็กน้อยไม่เกิน 3.5 ซม.

 ❍ 3. รองเท้าคัทชูส์ปิดปลายมีส้นสูงเล็กน้อยไม่เกิน 3.5 ซม.

 ❍4. รองเท้ากึ่งแตะมีส้นสูงเล็กน้อยไม่เกิน 3.5 ซม.

 ❍ 5. รองเท้ากึ่งแตะไม่มีส้น

 ❍6. รองเท้าคัทชูส์ (ชาย) รองเท้าแวน

 ❍ 7. รองเท้าผ้าใบ

 ❍ 8. รองเท้ารัดส้น

 ❍ 9. รองเท้า safety

10. พื้นรองเท้าที่ท่านใส่ปฏิบัติงานเป็นวัสดุประเภทใด

❍1. ยาง ❍ 2. เจล ❍ 3. โฟม ❍4. ซิลิโคน ❍5. อื่นๆ โปรดระบุ .....

(มีต่อด้านหลังค่ะ)

1

11. จากกิจกรรมที่ทำในขณะยืนปฏิบัติงาน ท่านมีการลงน้ำหนักลงบนส้นเท้าซึ่งก่อให้เกิดการเจ็บปวด ระดับของการเจ็บปวดบนส้นเท้าของคุณอยู่ในช่วงใด

❍ ถ้าได้เปลี่ยนอิริยาบถแล้วอาการเจ็บจะหายไป

❍ ถ้าได้เปลี่ยนอิริยาบถแล้วอาการเจ็บจะ***ไม่***หายไปจนกว่าจะได้พักเป็นเวลานานๆ

❍ ต้องใช้ยาในการรักษาจนกว่าอาการเจ็บจะหายไป

❍อื่นๆ โปรดระบุ .....

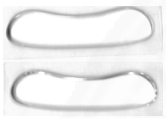
12. ท่านเคยใช้ผลิตภัณฑ์เสริมรองเท้าอะไรบ้างเพื่อช่วยในการลดปัญหาสุขภาพ*ส้นเท้า*ของท่าน (ตอบได้มากกว่า 1 ข้อ)

❍1. ซิลิโคนเจลรองส้นเท้า 

❍2. เจลรองส้นเท้า 

❍3. ซิลิโคนรูปทรงยูรองส้นเท้า 

❍4. เจลรองส้นเท้า 

❍5. เจลรองส้นเท้า 

❍6. ซิลิโคนรองส้นเท้าส้น 

❍7. ซิลิโคนเจลรองส้นเท้า 

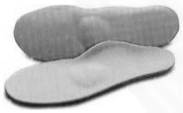
❍8. ซิลิโคนเจลรองส้นเท้า 

❍9. ซิลิโคนเจลรองส้นเท้า 

❍10. โฟมรองส้นเท้า 

❍11. *เจล*รองฝ่าเท้า 

❍12. เจลรองส้นเท้า 

❍13. *โฟม*รองฝ่าเท้า 

❍14. ไม่เคยใช้ผลิตภัณฑ์เสริมรองเท้าเลย

13. ถ้าให้ท่านออกแบบวัสดุเพื่อนำมาใช้ในการทำผลิตภัณฑ์เสริมรองเท้าเพื่อสุขภาพ ท่านคิดว่าควรเลือกใช้วัสดุชนิดใด

❍1. เจล ❍2. ยาง ❍3. ซิลิโคน ❍4. พลาสติก ❍5. ลาเท็กซ์โฟม ❍ 6. อื่นๆ.....

14. ท่านคาดหวังในเรื่องผลิตภัณฑ์เสริมรองเท้าที่ช่วยในการแก้ปัญหาสุขภาพเท้าของท่านอย่างไร (ตอบได้มากกว่า 1 ข้อ)

❍ 1. มีการออกแบบผลิตภัณฑ์เพื่อแก้ปัญหาได้ตรงจุด ❍ 4. ไม่ก่อให้เกิดกลิ่น

❍ 2 .มีการใช้วัสดุที่หลากหลายในผลิตภัณฑ์หนึ่งชนิด ❍ 5. สามารถถอดทำความสะอาดได้

❍ 3. มีน้ำหนักเบา ❍ 6. มีอายุในการใช้งานนาน

❍ 7. อื่นๆ โปรดระบุ.....

ขอขอบพระคุณท่านเป็นอย่างสูงที่ท่านกรุณาให้ความร่วมมือในการตอบแบบสอบถาม

Appendix B

Questionnaire of Pillow (Set I)

1. Gender ☐ Female ☐ Male

2. Age

☐ below 15 years ☐ 15-20 ☐ 21-25 ☐ 26-30 ☐ 31-35

☐ 36-40 ☐ 41-45 ☐ 46-50 ☐ over than 50 years

3. Your weight (please identify) ..... kgs.

4 Have you had the accident that affects the spine before?

☐ Never ☐ Yes

5. On the average, how many hours do you sleep?

☐ below 3 hours ☐ 3-4 ☐ 5-6

☐ 7-8 ☐ over than 8 hours

6. Which types of sleep position do you always prefer sleeping?

☐ on the back (supine) ☐ on the side (lateral) ☐ on the stomach (prostration)

7. Do you have any problem on your pillow or have problem during sleeping? (If yes, identify your problem)

☐ No

☐ Yes (can choose more than one problem)

☐ Have the pain around neck or spine ☐ Fall off the pillow ☐ Snore

☐ Sleepless ☐ Not comfortable

☐ Inflexible (or misshaped) pillow when using for long time ☐ Smelling

☐ Have the irritation (allergy) ☐ Others (Please identify).....

8. Which type of pillow shape do you use?

☐ Rectangular ☐ Square ☐ Circle



☐ Tempurpedic Neck ☐ Tri-Core ☐ D-core



☐ Cervical Linear Traction Neck (V-shape) ☐ Atlas-T ☐ Therapeutica Sleeping



☐ U Pillow Neck Support ☐ Neck Roll Pillow


9. According to your sleeping pillow from question 8, what is your pillow made from?

☐ Natural Latex ☐ Memory Foam ☐ Duck Feather

☐ Goose Feather ☐ Synthetic Fiber (Polyester) ☐ Kapok

☐ Water ☐ Cotton ☐ Wool ☐ Others (Please identify).....

10. Please rate the level of satisfaction in your pillow

☐ Very satisfied ☐ OK ☐ Partly satisfied ☐ Not at all satisfied

11. What is your expectation or reason for buying the pillow? (Can choose more than one reason)

☐ Lightweight ☐ Soft and fluffy ☐ Durable

☐ Flexible and not misshaped when using for long time ☐ not cause the allergy or irritation

☐ Comfortable and have no pain around neck and spine during sleeping

☐ Easy to clean and dry fast ☐ No smell

☐ Others (Please identify).....

12. What is your main point to make the decision for buying the pillow?

☐ Very cheap (less than 150 baht), have normal quality, made from whatever material, general pillow shape (or fashionable), no need to try before buying

☐ Cheap (150-300 baht), have normal quality, made from quite good material, general pillow shape (or fashionable), no need to try before buying

☐ Medium (350-700 baht), have quite good quality, made from quite good material, general pillow shape (or fashionable), need to try before buying

☐ Quite expensive (700-1000 baht), have good quality, made from good material, healthy pillow style, need to try before buying

☐ Expensive (more than 1000 baht), have very good quality, made from very good material, healthy pillow style, need to try before buying, have warranty

13. Suggestions

……

Appendix C

Questionnaire for Pillow (Set II)

Participant information

Gender:..... Age:.....

Income per month: ☐ below 10,000 ☐ 10,000 – 20,000 ☐ more than 50,000

Case I When everything is not revealed including price

	Comfort rating			
Specimen	Bad 1	Fairly non-comfort 3	Pretty good 6	Very comfortable 10
1				
2				
3				
4				

	Expected price			
Specimen	300	600	900	1500
1				
2				
3				
4				

If you were about to buy the pillow, which one you prefer?

	1	2	3	4
Specimen				

Case II When the pillow information is revealed

If you were about to buy the pillow, which one you prefer?

	1	2	3	4
Specimen				

Appendix D

Questionnaire for Eye Glasses (Set I)

1. เพศ ☐หญิง ☐ชาย

2. อายุ

☐ต่ำกว่า18ปี ☐ระหว่าง18-25ปี ☐ระหว่าง25-30ปี ☐ระหว่าง30-35ปี

☐ระหว่าง35-40ปี ☐ระหว่าง40-45ปี ☐ระหว่าง45-50ปี ☐50 ปีขึ้นไป

3. ท่านเคยได้รับอุบัติเหตุที่มีผลกระทบต่อใบหน้ามาก่อนหรือไม่

☐ไม่เคย ☐เคยได้รับอุบัติเหตุมาก่อน(ข้ามไปคำถามที่8)

4. โดยเฉลี่ยท่านใส่แว่นสายตาวันละกี่ชั่วโมง

☐ต่ำกว่า1ชม. ☐ระหว่าง1-3 ชม. ☐ระหว่าง3-6 ชม. ☐ระหว่าง6-8 ชม

☐มากกว่า8 ชม. ขึ้นไป ☐ไม่ได้สวมใส่แว่นสายตา

5. ในระหว่างการสวมใส่แว่นสายตา ท่านมีปัญหาใดบ้าง หรือ แว่นสายตาของท่านที่ใช้อยู่มีปัญหาอย่างไรบ้าง ถ้ามีโปรดระบุปัญหาของท่าน

☐ไม่มี

☐มี ปัญหานั้นคือ (ตอบได้มากกว่า1 อย่าง)

☐แว่นไหลลงมาตรงปลายจมูก ☐เกิดอาการปวดที่จมูกจากแรงกดของแว่น

☐อื่นๆ(โปรดระบุ).....

6. กรอบแว่นสายตาที่ท่านสวมใส่อยู่หรือชอบเป็นลักษณะใด

6.1 ☐มีกรอบ  ☐ไม่มีกรอบ  ☐ครึ่งกรอบ 

☐อื่นๆ (โปรดวาดรูประบุ) .....

6.2 ☐ทำจากโลหะ  ☐ทำจากพลาสติก 

☐อื่นๆ (โปรดวาดรูประบุ).....

6.3 ☐ทรงเหลี่ยม  ☐ทรงกลม  ☐ทรงหยดน้ำ 

☐ทรง Aviator 

☐อื่นๆ (โปรดวาดรูประบุ) .....

6.4 ☐มีแป้นรองจมูกแยกจากกรอบแว่น 

☐มีแป้นรองจมูกที่ติดกับกรอบแว่น  (ข้ามไปคำถามข้อที่ 7)

☐อื่นๆ (โปรดวาดรูประบุ).....

6.5 ☐แป้นรองจมูกทรงหยดน้ำ  ☐ แป้นรองจมูกทรงรี 

☐แป้นรองจมูกทรงกลม  ☐แป้นรองจมูกทรงD 

☐อื่นๆ (โปรดวาดรูประบุ).....

6.6 วัสดุที่ใช้ทำแป้นรองจมูก

☐ซิลิโคน ☐PVC ☐พลาสติก ☐อื่นๆ (โปรดระบุ).....

7. ท่านพึงพอใจกับแว่นสายตาที่ใช้อยู่ปัจจุบันของท่านมากน้อยเพียงใด

☐พึงพอใจมาก ☐ปานกลาง ☐พึงพอใจน้อย ☐ไม่พอใจเลย

8. โปรดพิจารณาคุณสมบัติต่างๆของแว่นดังที่แสดงในข้อ 1-18 หากคุณต้องการซื้อแว่นสายตาอันใหม่ คุณมีความคิดเห็นว่าคุณสมบัติใดควรจะมีในแว่นของคุณโดยเรียงล าดับ ความพึงพอใจจาก 0 ถึง3 (น้อยไปมาก) ตัวอย่างเช่น

มาก น้อย น้อย มาก

ยืดหยุ่น 3 2 1 0 1 2 3 ไม่ยืดหยุ่น

(สรุปได้ว่าคุณต้องการแว่นที่ไม่มีความยืดหยุ่นอย่างมาก)

	มาก			น้อย	น้อย			มาก	
1.	หนัก	3	2	1	0	1	2	3	เบา
2.	หลวม	3	2	1	0	1	2	3	แน่น
3.	ถูก	3	2	1	0	1	2	3	แพง
4.	ใหญ่	3	2	1	0	1	2	3	เล็ก
5.	หนา	3	2	1	0	1	2	3	บาง
6.	เหลี่ยม	3	2	1	0	1	2	3	กลม
7.	เรียบ	3	2	1	0	1	2	3	ขรุขะ
8.	ยืดหยุ่น	3	2	1	0	1	2	3	ไม่ยืดหยุ่น
9.	ทันสมัย	3	2	1	0	1	2	3	คลาสสิค
10.	เรียบง่าย	3	2	1	0	1	2	3	หรูหรา
11.	เป็นทางการ	3	2	1	0	1	2	3	ไม่เป็นทางการ
12.	ทนทาน	3	2	1	0	1	2	3	ไม่ทนทาน
13.	น่ารัก	3	2	1	0	1	2	3	สวยงาม
14.	แตกต่าง	3	2	1	0	1	2	3	คุ้นเคย
15.	มีความมั่นใจ	3	2	1	0	1	2	3	ไม่มีความมั่นใจ
16.	ใส่ได้ทุกงาน	3	2	1	0	1	2	3	ใส่ตามแฟชั่น
17.	ใส	3	2	1	0	1	2	3	ทึบ
18.	ดูมีอายุ	3	2	1	0	1	2	3	ดูอ่อนวัย

9. ข้อเสนอแนะเพิ่มเติมอื่นๆ

.....

.....

.....

Appendix E

Questionnaire for Eye Glasses (Set II)

1.เพศ ☐หญิง ☐ชาย

2.อายุ

☐ต่ำกว่า18ปี ☐ระหว่าง18-25ปี ☐ระหว่าง25-30ปี ☐ระหว่าง30-35ปี

☐ระหว่าง35-40ปี ☐ระหว่าง40-45ปี ☐ระหว่าง45-50ปี ☐50 ปีขึ้นไป

3.ท่านสวมใส่แว่นสายตาหรือไม่

☐ใส่ ☐ไม่ใส่

4. ในระหว่างการสวมใส่แว่นสายตา ท่านมีปัญหาใดบ้าง หรือ แว่นสายตาของท่านที่ใช้อยู่มีปัญหาอย่างไรบ้างถ้ามีโปรดระ บุปัญหาของท่าน

☐ไม่มี

☐มี ปัญหานั้นคือ(ตอบได้มากกว่า1 อย่าง)

☐แว่นไหลลงมาตรงปลายจมูก ☐เกิดอาการปวดที่จมูกจากแรงกดของแว่น

☐อื่นๆ(โปรดระบุ).....

5.ราคาของแว่นสายตาที่เหมาะสมต่อคุณ

☐ต่ำกว่า 500 บาท ☐ระหว่าง501– 1000 บาท ☐ระหว่าง1001 – 2000 บาท ☐ระหว่าง2001-3000 บาท

☐ระหว่าง3001-4000บาท ☐ระหว่าง4001 – 5000 บาท ☐มากกกว่า 5000 บาท

5. ปัจจัยตัวใดดังต่อไปนี้มีผลต่อการเลือกซื้อแว่นของคุณ (โปรดเรียงลำดับปัจจัยที่มีผลต่อคุณมากที่สุดโดยเรียงลำดับจาก 1 =มีผลมากที่สุด ถึง 6 = น้อยสุด)

	1	2	3	4	5	6
คุณภาพ						
ราคา						
รูปทรง						
ความเข้ากันกับใบหน้า						
แฟชั่น						
ความคุ้นเคยจากอดีตที่เคยใส่มา						

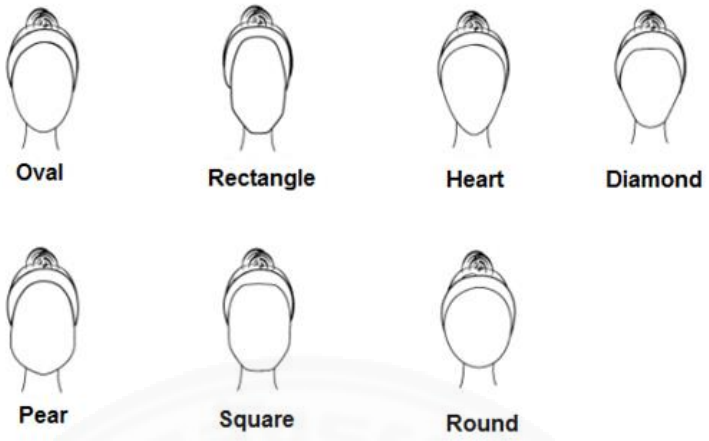
7. ท่านพึงพอใจกับแว่นสายตาที่ใช้อยู่ปัจจุบันของท่านมากน้อยเพียงใด

☐พึงพอใจมาก ☐ปานกลาง ☐ไม่พอใจเลย

8. ท่านคิดว่าร้านขายแว่นในปัจจุบันนั้นมีกรอบแว่นที่ท่านพึงพอใจหรือไม่

☐มี ☐ไม่มี

9. ท่านมีลักษณะใบหน้าแบบใด (โปรดทำเครื่องหมาย √ ทับบนใบหน้าที่ท่านเลือก โดยเลือกจากข้อมูลที่จัดทำไว้ด้านล่าง)



- Oval: จะมีสัดส่วนคล้ายไข่กลับหัว ใบหน้าจะมีความยาวยาวกว่าความกว้าง โดยหน้าผากจะกว้างกว่ากรามเล็กน้อยและมีคางโค้งมน
- Rectangle: จะมีความยาวยาวกว่าความกว้าง แก้ม หน้าผาก และกรามจะมีความกว้างพอๆ กัน
- Heart: จะมีลักษณะเหมือนสามเหลี่ยมกลับหัว ด้วยคางที่แหลมและหน้าผากกับแก้มที่กว้างปานกลางถึงมาก โดยปกติใบหน้าแบบนี้จะมีความยาวใบหน้ายาวกว่าความกว้างของแก้มเล็กน้อย (ประมาณนิ้วครึ่งหรือน้อยกว่านั้น)
- Pear: จะตรงข้ามกับใบหน้ารูปหัวใจ ใบหน้ารูปสามเหลี่ยมจะมีความกว้างที่สุดที่ด้านล่างและแคบที่ที่ด้านบนของ หน้าใบหน้ารูปสามเหลี่ยมจะกรามที่ยาว กว้าง และเหลี่ยมและมีหน้าผากแคบ
- Square: จะมีความกว้างกับความยาวของใบหน้าพอๆ กันความยาวใบหน้ากับแก้มจะต่างกันเพียงหนึ่งถึงสองนิ้ว นอกจากนี้ความกว้างของแก้ม หน้าผาก และคางจะคล้ายกัน ขอบของใบหน้ารูปสี่เหลี่ยมจะตั้งตรง จุดที่กว้างที่สุดของกรามจะเป็นมุมเหลี่ยมชัดเจน
- Round: จะมีความกว้างพอๆ กับความยาวคล้ายหน้ารูปสี่เหลี่ยมแต่จะมีหน้าผากและกรามที่เล็กกว่า ถ้าแก้มและความยาวหน้าแตกต่างกันเพียงหนึ่งนิ้ว ความหน้าผากสั้นกว่าความยาวแก้ม และกรามไม่เป็นมุมเหลี่ยมเหมือนหน้ารูปสี่เหลี่ยม แสดงว่าคุณมีใบหน้ากลม
- Diamond: จะกว้างที่สุดบริเวณโหนกแก้มและแคบลงบริเวณหน้าผาก คางแหลมเล็ก ใบหน้าจะมีความยาวยาวกว่าความกว้างเล็กน้อย ถ้าความยาวแก้มยาวกว่าหน้าผากและกรามและคางค่อนข้างแหลม แสดงว่าคุณมีใบหน้ารูปเพชร

9. ข้อเสนอแนะเพิ่มเติมอื่นๆ

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