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COLLABORATIVE DECISION-MAKING: DESIGN PROCESS TOWARD INTEGRATED PRODUCT DESIGN

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ABSTRACT:

Based on a prior research of seamless creation of seamless fashion via the technique of double weaving, a study is being undertaking to explore further benefits of research collaboration between an innovative clothing-making technology and an effective design management instrument, Quality Function Deployment (QFD), toward integrated products design development.

This paper reports two stages in this collaborative mode, namely, pre-design and design. At the pre-design stage, certain proposed customer requirements (PCR) were defined for the universal seamless woven fashion design. Apart from that, some real customer requirements (CR) of well-defined products were achieved by surveys to set up prototypes for woven seamless fashion at the design phase. QFD separately helps the researchers to identify how important the nine parts of seamless woven fashion were, and as a result, certain important items can be concentrated and explored well. Through the collaborative design process, some subjective decisions undertaken at the exploratory phase were ignored. The whole concept, design, and practice of seamless woven fashion were implemented.

Keywords: Integrated design, QFD, seamless woven fashion

1. INTRODUCTION

From a research project titled "Integrated Creation of Seamless and Shaped Fashion via Multiple Layered Weaving", this paper deliberated how Quality Function Deployment (QFD) was integrated in the course of technology-driven seamless fashion creation.

Prior literature suggested two major design modes by which researches integrated into textile and clothing product design: Customer-oriented product design and Technology-deployment product design. Applications of QFD have been found to have improved some Customer-oriented clothing product designs, while most of the Technology-deployment product designs are pitched in investigating new technologies, exploring the variety and performance of new products.

The study that this paper reports aimed to design and fabricate woven clothing without cutting and sewing. In clarifying certain relationships and values of individual elements for a further accurate direction of design research, attempt of merging the QFD with adapted customer requirements in the creative design process was made, which in turn yielded some interesting.

2. INTRODUCTION OF QFD

QFD was developed initially by Akao in Japan in 1966. Akao (1990) defined it as "a method for developing a design quality aims at satisfying the customer and then translating the customer's demands into design targets and major quality assurance points to be used through out the production stage". This method is used in many design fields for various purposes (Chan and Wu, 2002), and it is used at the early investigation and later evaluation stages of a project in order to make more accurate decisions in terms of design quality and client's needs. QFD is capable to lead innovation product designs. An innovative product development process requires an understanding of continuously changing customer wants and needs. Hence, there is a need to study and develop procedures that can help a company or project team gain a profound knowledge of customer requirements (CR) and satisfaction, and then develop products with innovative features (Shen, Tan, and Xie, 2000).

Four benefits of QFD for design research have been demonstrated by Dikmen, Talat Birgonul, and Kiziltas (2005), namely, precise collection and identification of client needs/expectations, better planning, enhanced communication and concurrency, and reduced uncertainty.

QFD is a very powerful and complex instrument. A four-phase approach is accomplished via a series of charts that guide activities of a product team by providing standard documentation during product and process development (Cohen, 1995) (see Fig. 1).

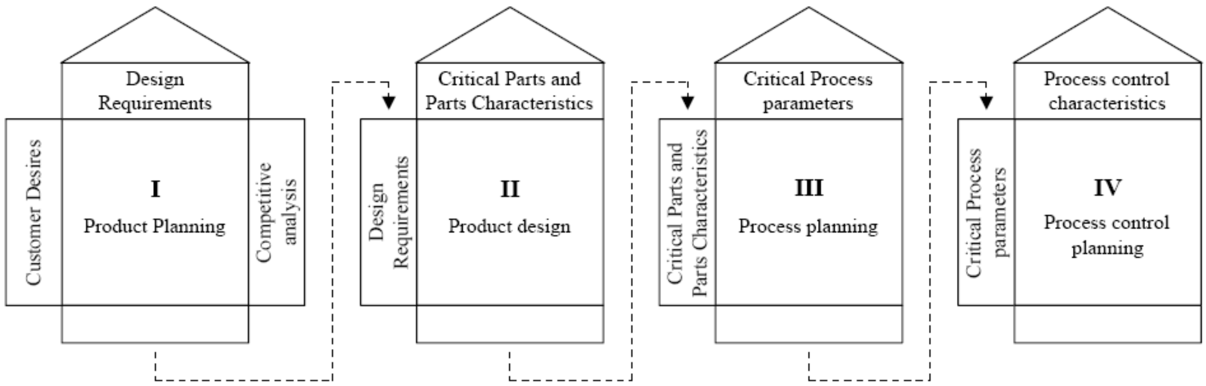


Figure 1: Four-phase approach of QFD

3. QFD AND TWO MODES OF INNOVATIVE PRODUCT DESIGNS IN TEXTILE

AND CLOTHING (T&C)

Although literature shows QFD applications in T&C are growing slowly (Shahin) (Chan and Wu, 2002), there are a few QFD implementation examples found in managing the T&C design research. Toward different purposes, a mode called Customer-oriented product design and another mode called Technology-deployment product design are observed and compared here through literature review (Table 1). The relationships between QFD and these two modes are discussed.

Product design that developed for a specific market or for some defined consumer is called customer-oriented product design. Examples from Haar (1998), Labat and Sokolowski (1999), Parkin, Stewardson, Peel, Dowson, and Chan, (2000), Carroll (2001), and Lin, Wang & Chen (2006) show some common ground, and is concluded in Table 1. Based on a defined market, it is possible to get enough consumer requirements (CR) for some affirmative directions of product development.

Mode	Customer-oriented product design	Technology-deployment product design
Examples	1) Haar (1998) 2) Labat and Sokolowski (1999) 3) Parkin, Stewardson, Peel, Dowson, and Chan,(2000) 4) Carroll (2001) 5) Lin, Wang and Chen (2006)	1) NG (1998; , 2001) 2) Parsons and Campbell (2004) 3) Wang and Ng (2007)
Product Types	1) An Therapy Garment for Preschool Children 2) An Athletic Ankle Brace 3) A Fireman's Safety Harness 4) Business Clothing for Women with Physical Disabilities 5) Functional Clothes	1) Seamless Fashion Using Polyvinyl Alcohol as An Intermediate Medium 2) Digital Apparel Design 3) Seamless Fashion via Double-weaving

Objectives	Deploying relative elements for integrated design Solving problems Satisfy consumers	Invent or deploy new technologies Variety of products Aesthetical and functional exploratory Possible performance analyses
Design Criteria	Tangible consumer needs Very detailed criteria	Universal customer needs Aesthetical evaluation Specific physical or chemical testing Cost or experiment analysis
QFD Applications	A few E.g. Lin, Wang, and Chen (2006), Parkin, Stewardson, Peel, Dowson and Chan (2000)	None

Table 1: Examples of customer-oriented and technology-deployment product design.

The objectives of customer-oriented product designs are to find real customer needs, satisfy consumers and solve current problems via possible various approaches. Additionally, some design criteria relative to CR can be set up to assess the result afterward. In this mode, all relative or important elements, such as customer needs, product ideas, technological capabilities and design characteristics, can almost be included for an integrated development. In this mode, for instance, Parkin et al (2000) have used QFD in improving the design of a kind of fireman's safety harness; Lin, Wang, and Chen (2006) have adapted QFD for a research of functional clothes.

Unlike the first mode, many design researchers tend to develop diverse technologies or speculate on a new technology as so to explore new approaches to create novelties. Thus, this approach is regarded as technology-deployment product design. The technology-deployment product development can be a part of customer-oriented product development. T&C design projects by NG (1998; , 2001), Parsons and Campbell (2004), and Wang & Ng (2007) are just some of the many examples of technology-deployment product design. Generally, because a large amount of attributes of both new technologies and new products are yet to discover, most of these designs are oriented to investigate at large the variety of realizable products and certain relevant performance. The emphasis is to research on internal factors deeply and comprehensively. Some objective results or artifacts are vital. Occasionally, as opposed to customer-orientated product design, if there are some defined customer needs, the creative scope of these designs may be limited and constrained by these requirements.

No relevant information has been found in using QFD as an instrument for the technology-deployment product designs in T&C. Such lack of information is suspected to be due to this type of research is in pursuit of a cognitive profundity of technologies in nature, the final designs are not for the end-use, nor are there well-defined customers in a universal design project,

4. CASE STUDY

4. 1. INTRODUCTION

Technologies of seamless garments have been considered as innovation. Seamless garment, with little or no seams could well be an alternative to the garment reconstructed by cutting and sewing fabrics. To this end, it has been proved that both handcrafts and automatic mechanized processes are possible in producing seamless fashion (NG, 2001).

With the development of sophisticated CAD and CAM systems, authors found through primary researches, adequate potentials for designing seamless woven fashion (SWF) or textiles (Wang & Ng, 2007). Wang and Ng demonstrated a method of multi-layer weaving techniques on jacquard looms that yielded a few viable examples of seamless fashion. This type of clothing started from raw yarns toward directly specific end-uses for consumers.

Although the research is still at its early stage, with the researches' prior experience in weaving technologies, attempts had been made intuitionally to have accomplished some pilot designs. Some artifacts were created with success. Yet, in the course of such intuitive enquiry, some problems came forth when the research pitched to investigate a systematic and comprehensive design research mode for various specific three-dimensional "SWF" products. A great number of undefined elements were found. These ranged from yarns to clothes, from software to hardware of technology, in this cross-disciplinary design. If

CR is not included in an exploratory phase of this integrated design, it is difficult to evaluate the importance of every technical part and relevant experiment, as well as to place emphasis. In addition, without formulation of a systematic plan, it is difficult to manage the relationships among elements, express and assess findings, and communicate effectively.

In order to produce resolutions to the above questions effectively, QFD was adapted to monitor the project. The first and second steps of the four-phased planning process of QFD were used. Complex analysis of the market competition, production-planning matrix, and process-control matrix were not speculated here, as this research focused largely on deployment of new technologies and variety of SWF, rather than for launching a marketing strategy of customer oriented product design.

QFD was used with different aims at two different stages, namely pre-design and designing stages. The purposes are listed below:

1) Pre-design (Exploratory phase): Determining a primary investigate strategy for general SWF products with some universal CR, guiding experiments based on technologies, so as to evaluate the relationships among design requirements, main technological elements and customer requirements.

2) Designing (Prototype phase): Using some findings and primary defined relationships in the pre-design stage, a few specific prototypes were created with detailed target customer requirements, complementing and reinforcing a universal SWF concept with concrete examples.

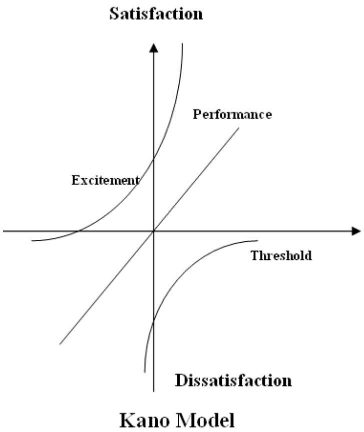
4. 2. CUSTOMER REQUIREMENTS (CR) AND DESIGN REQUIREMENTS (DR)

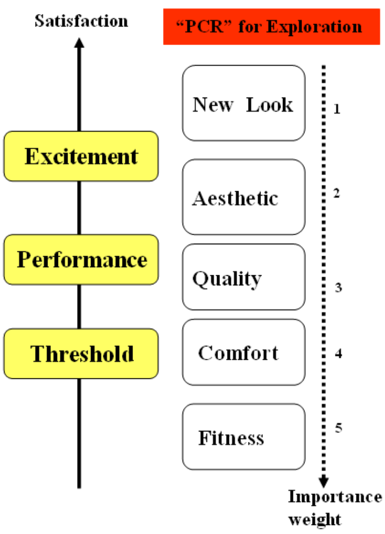
4. 2.1. CR AND IMPORTANCE

4. 2.1. 1."PCR" FOR EXPLORATION (PRE-DESIGN)

Since clear target customers were not identified in the exploratory phase of this technology-deployment product design, some proposed customer requirements (PCR) were established for the universal fashion in the pre-design phase in the light of fashion design theories, experts' advices, and researchers' personal views.

In the fashion design field, Lamb and Jo Kallal (1992) found a "Functional-Expressive-Aesthetic" (FEA) criterion as the consumer need. Nowadays, most of normal daily garments are expected firstly to fit with bodies for normal movements, be comfortable in everyday life, have appropriate qualities, and then to beautify body curves, build role for people, and even to express personalities and aesthetic taste. To some extent, it is believed that there are certain commonalities between the three attributes (Fig. 3) of the Kano model (CQM, 1993) and the above customer requirements of clothing. Five main requirements, namely "fitness", "comfort", "quality", "aesthetic", and "new look" for clothing are kept parallel to the three attributes, which are "threshold" "performance" and "attractive".





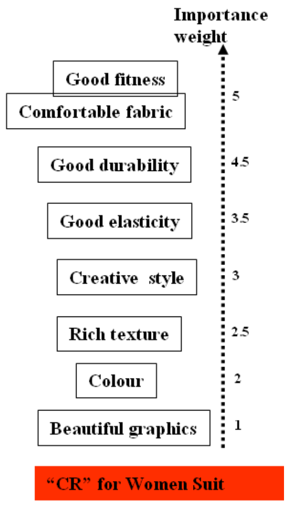


Figure 3: Kano model.

Figure 4: "PCR" and importance for general seamless woven fashion.

Figure 5: "CR" and importance for women suit prototype.

At the very begin stage of an innovative product, designs should be created to satisfy lower attributes than higher ones. Therefore, some "threshold" attributes and parts of "performance" attributes are the most important part in primary SWF research. Later, visual attributes such as "aesthetics" and "new look" should be observed to add values and to appeal customers. According to our analysis, the relative importance among these five requirements to SWF are rated as “Fitness-5”, “Fabric comfort-4”, “Quality-3”, “Aesthetic-2”, and “New look-1” (Fig. 4).

4. 2.1. 2. “CR” FOR PROTOTYPE (DESIGNING)

Advancing into the prototype stage when prototypes were created for specific clothing, the customer profile of the prototype would need to be defined. Take a prototype of suit wears for office ladies as an example. Twenty-five women were asked questions with five numerical ratings for different requirements. The importance weightings for each customer of their requirements were obtained (see Fig. 5).

4. 2. 2. DESIGN REQUIREMENTS AND PARTS CHARACTERISTICS

4. 2. 2. 1. SWF DESIGN REQUIREMENTS

Fashion always changes with the applications of elements. Fashion design is a matter of mixing elements in new and exciting ways in order to create fresh combinations and products (Jones, 2005), so the design requirements in this study has been the way of arranging these elements together to satisfy customers.

Elements used in fashion design are diverse indeed. During the course of creation, silhouette, proportion, construction, fabric, colour, graphic, texture, fabric and embellishment should be considered and planed to pursue good styles. According to Davis (1996), McKelvey and Munslow (2003), and Jones (2005), the main design elements of SWF are two-dimensional shape, three-dimensional silhouette, constructing line, graphics, colour, and texture, which are extended from three main elements: silhouette, line and textile (Table 2).

Silhouette		Line		Textile		
2D shape	3D silhouette	Construction line	Graphics	Colour	Texture	Handle

Table 2: Design requirements of seamless woven fashion.

4. 2. 2. 2. PART CHARACTERISTICS OF WOVEN TEXTILES DESIGN

This study attempted to deploy jacquard weaving technology as a basic approach to create a kind of seamless fashion. The way to translate the above key SWF design requirements into the woven textile design was a vital question in this study. To provide answer to this question, almost all detailed part characteristics of woven textile design were reviewed and concluded from literature (Adanur, 2001; Grosicki, 1977; Grosicki., 1975; Wilson, 2001; Yates, 1995). To summarize, woven textiles comprise of three items: material (e.g., yarn), graphics (e.g., motif), and structure (e.g., weave construction). Some detailed technical parts are shown in Table 3. These specific parts formed the major research areas for the SWF technology.

Structure (Weave construction)			Graphics (Motif)		Material (Yarn)			
S1: Basic weave	S2: 3D structure	S3: Arrangement and proportion	G1: Pattern graphics	G2: Decorative graphics	M1: Type (Functional)	M2: Thickness and smoothness	M3: Arrangement and proportion	M4: Colour

Table 3: Parts characteristics of seamless woven fashion.

4. 3. QFD ANALYZING

In QFD, the relationships between customer needs and design requirements, as well as between design requirements and parts characteristics for this one had to be identified. Through a form of matrix, QFD obtains a good quality of being expressive in linking CR with some part characteristics or technical measures of design elements. The scoring scale and the corresponding explanation of relations utilized within the case study are shown in Table 4. Most of the scales were assessed objectively according to technical results experiments, while part of them were valued subjectively by experiences.

Meaning of relationship	Strong	Moderate	Weak	No relationship
Score and Mark	9 ●	3 ○	1 △	0 Blank

Table 4: Parts characteristics of seamless woven fashion

After finishing the relationship matrixes, the Total Importance Weight and the Relative Weight for each part characteristics were calculated by the equations in Table 5 (Santow and Clausing, 1993), and the Relative Weight is expressed in percentage.

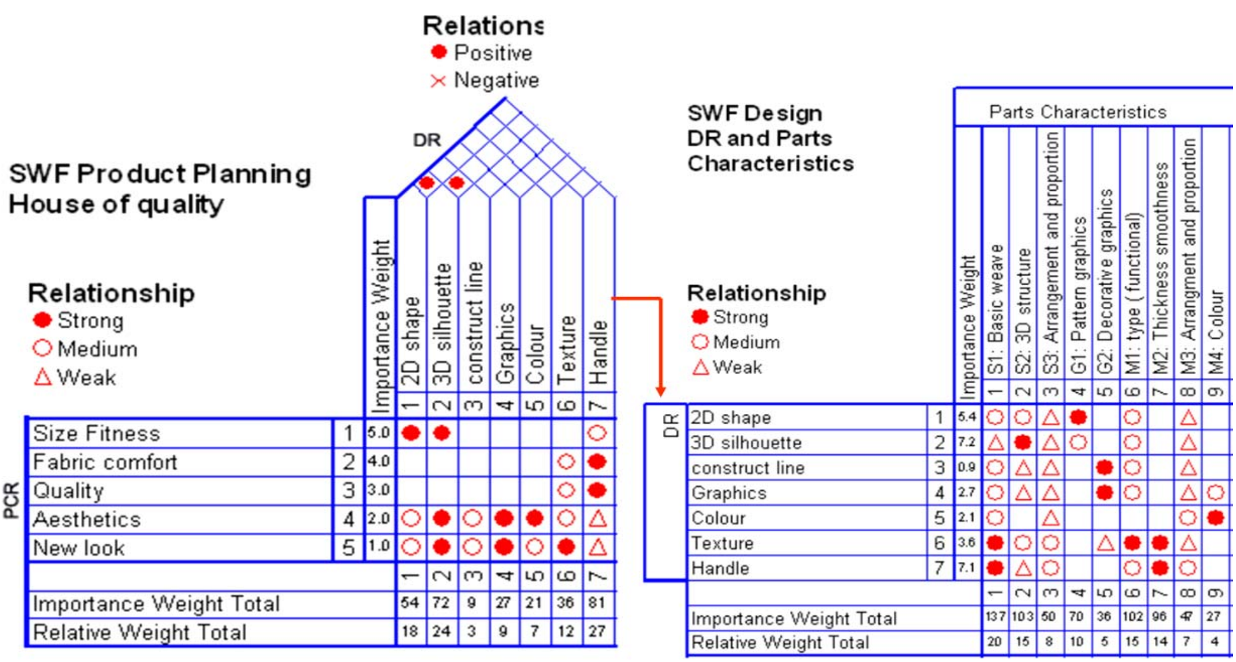
In the following section, Figures 6 and 7 that were created according to the QFD approaches show each requirement, each relationship and the relative weight in details.

$\mathrm{I}_t = \sum_{i=1}^{i=n} W_i * R_{ij}$ $\mathrm{I}_r = \dfrac{I_j}{\sum_{j=1}^{j=n} I_j}$ I : Part Characteristics Importance Weight, W: Customer Requirement Rating (1 to 5), R: Correlation factor (0, 1, 3, or 9).	Subscripts i: CR Row Reference Number, j: DR Column or Part Characteristic Column Reference Number, n: Any number of CR and DR >1, t: Total Importance Weight, r: Relative weight.

Table 5: The equations for calculating the importance weight of part characteristics.

4. 4. FINDINGS OF THE CASE STUDY

At the pre-design stage, some specific "CR" were replaced by "PCR" in order to achieve a general direction of SWF product design. Details relationships and final values are shown in Fig. 6. The four most



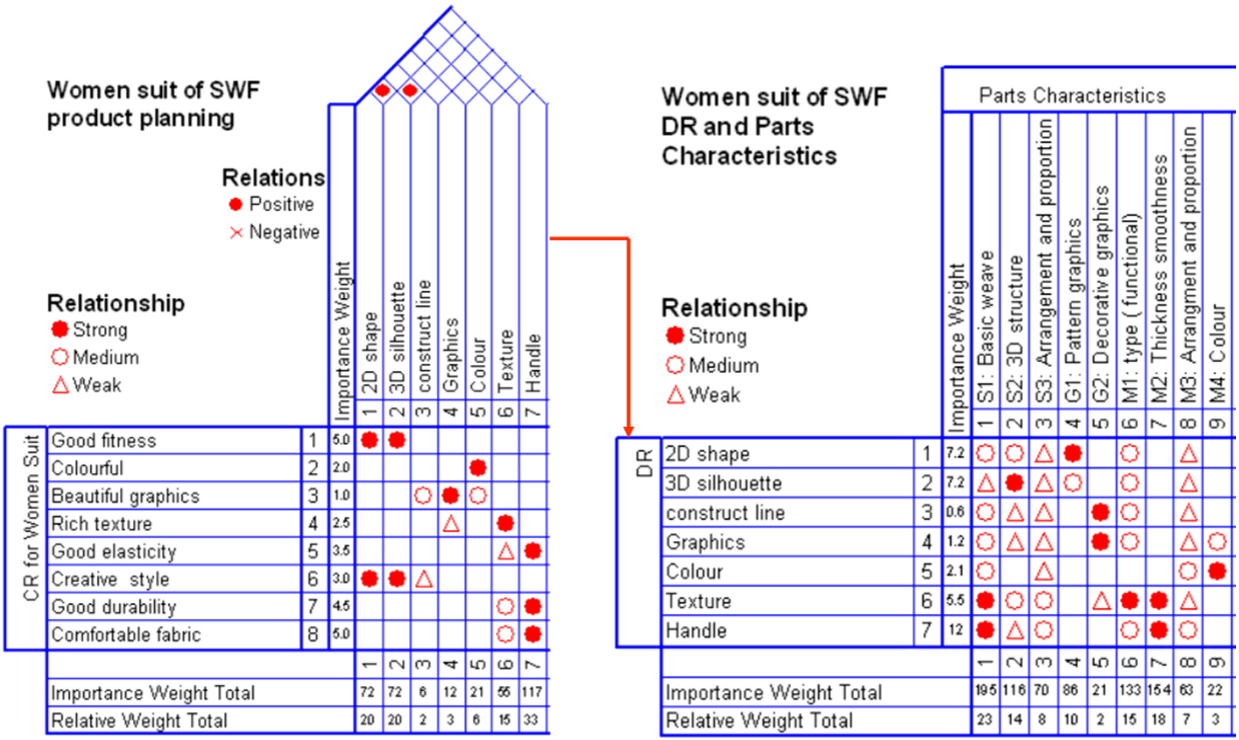
important technical parts which contributed to the success of the general SWF are ranked as "S1: basic weave"=20%, "S2: 3-D structure"=15%, "M1: yarn type"=15%,"M2: thickness smoothness"=14% respectively. This indicates that, although all undefined elements should be explored and be experimented, these four items are the emphasis of primary investigation and should be researched comprehensively.

Figure 6: QFD Analyses for General SWF (Exploratory stage).

During the prototype stage, some real "CR"s for the women suit of SWF had been obtained by surveys. Finally, the four corresponding most important parts are rated as "S1: basic weave"=23%, "M2: thickness smoothness"=18%, "M1: yarn type"=15% and "S2: 3-D structure"=14% respectively (See Fig. 7). In this case, in the light of the findings of technical parts during the exploratory stage, more attentions and designs should be put into S1 and M2 to enhance the customer satisfaction and complement the investigation of pre-design stage.

When compare these two kinds of different importance weights of design parts, as shown in Figure 8, it was found that these two lines are similar. Additionally, not included in this paper are some other prototypes for different SWF designs which also shown that, regardless of the clothing style, the two most important design parts are basic weave and 3-D structure.

Actually, several prototypes for a variety of SWF were designed. Difference customer requirements of different prototypes encouraged this study to improve some other design parts, and by doing so, all design elements can be decided to be studied gradually, which constitutes to a systematical design research of



SWF.

Figure 7: QFD Analyses for Women suit of SWF (Prototype stage).

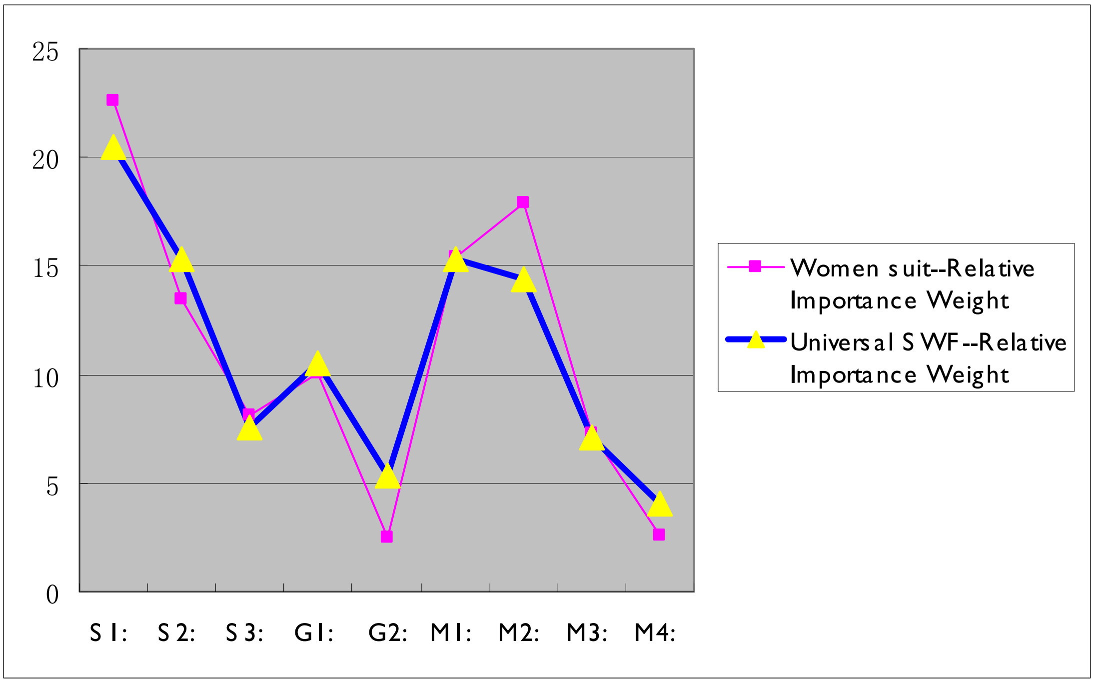


Figure 8: Comparing the importance weight of technical parts between Universal SWF and A detailed prototype.

5. CONCLUSION

Nowadays, designs in the fashion field are developed increasingly toward hybrid trends that integrate technologies and aesthetics. As a type of technology-based product design, this innovative SWF design adopted QFD as its research methodology.

This method contributed to the understanding between design objectives and design parts via diagrams, ranks, and formulas of QFD. QFD can identify the prior items from diverse technological possibilities, and dominate effectively the directions of the integrated fashion designs.

The decision-making processes at the exploration state guaranteed sufficient and universal design research of SWF, which would guide the emphasis in further technical studies. On the other hand, they fulfilled a complete and systematic research map at the state for different prototypes. The vital technical deployments for visual designs of the brand new fashion were thus well defined.

The QFD methodology has not been utilized to its full in this weaving technology-based fashion design project. It is envisaged that more powerful functions of QFD can be deployed in the third evaluation stage of the study to assess the final seamless fashion products.

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