Analysis and Application of Quality Assurance in User Centered Design: A case study

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Abstract: When discussing the topic of quality from a "modern" point of view, "customer satisfaction" is arguably one of the top criterion of high product / service quality, so that only companies whose output (be it a product or a service - or both) really satisfies end users are the ones with high quality. Traditional product design ideology and methodology is experiencing innovation and reformation. A new design ideology named "user-centered design" (UCD) is spreading and raising growing interest and recognition. Unlike conventional design approaches, UCD gives users top priorities throughout the whole design process, as its ultimate purpose is to meet users' requirements. The present work aims to propose a quality assurance process based on the UCD paradigm. The UCD process mainly includes three phases (namely pre-design planning, design presentation, design evaluation and implementation), and quality control of the product design is to be enforced throughout the whole UCD process. The proposed control process has been tested in a case study of portable photo printer design, using UCD for reference and Quality Function Deployment for technical means. The case study, which will be discussed in the paper, will show the application of a new, effective quality control model for product design. Thanks to the real application, based on a survey on customer needs, and applied to all stages of UCD process, feasibility of the suggested approach is validated. The paper will conclude with a critical discussion on the applicability of such methodology to different fields.

Keywords: User-Centered Design, Quality Function Deployment, Design Quality, Quality Assurance

1. Introduction

Quality has become a key factor for an enterprise to achieve success, as well as a significant issue in the economy evolution of each country (Fynes and De Burca, 2005) while the relationship between design quality and customer satisfaction and business performance is also addressed in several empirical studies in the fields of quality management and marketing (Karipidis, 2011). Dr. Joseph Juran - the famous quality management expert in America - predicted that the 21stcentury would be a century of quality, which would become not only the most effective weapon for companies to occupy market share, but also a powerful

driving force for the development and improvement of society(Han et al., 2007). There are a variety of perspectives from which quality is viewed according to the role it plays in the various parts of a business organization; in particular, the five perspectives singled out by Garvin (1984) in his seminal paper were the judgmental perspective, product-based perspective, User based perspective, value-based perspective, and manufacturing-based perspective. The "User Based" is a modern definition of quality, derived from Dr. Juran's viewpoint (Han et al., 2007): product quality is its "fitness for intended use", that is, basically "meeting or exceeding customers' expectations". That is also the definition of quality being accepted and applied in this article. This definition covers two aspects of implications: i) usage requirements and ii) satisfaction level. Users would always put forward some requirements for the quality of the products they are using, and those requirements may be influenced by some factors such as object, location, time and so forth. At the same time, user satisfaction with the product is reflected in terms of product performance, using effect, economic characteristics, etc. Failure to take into account the customers' view and needs during product design will result in low quality. Consequently, effective control on product quality in the early design phase from user's point of view would be one of the areas worthy of study (Lin, 2005). Quality engineering in design phase aims at grasping needs from market and users, and taking them into account in product design process. The concept of customer satisfaction means that the entire process of product development should be customer-centered and the requirement analysis should be carried out from customers' perspective. To help companies achieving such goals, tools – such as Quality Function Deployment (QFD) - and approaches – like User-Centered Design (UCD) – have been developed in the last decades.

As the core technique of quality engineering during product design stage, QFD has achieved great success in quality management and development of industrial products. Being regarded as a powerful weapon for companies to successfully implement the customer satisfaction strategy, QFD has attracted widespread concern by international quality academics. UCD is a design philosophy claiming that product strategy should consider meeting customers' needs as the basic motivation and ultimate purpose during the initial stages of product life cycle. As the core of usability engineering, UCD has become a hot topic in the field of computer interface all over the world (Hu, 2009). However, the concept of UCD is still quite "philosophical" when it comes to applications in the industrial world, as it has not been translated yet into clear guidelines giving specific directions for industrial product development.

Considering the relevance of the topic, along with said merits and limits of UCD, the present paper aims at providing a practical implementation of UCD in the case of a portable photo printer design, using the thoughts and ideas of UCD for reference and QFD for technical means. The paper is structured as follows: a literature review on main work topics in presented in section 2. Section 3 focuses on research objectives

and methodology, section 4 describes the quality control process adopted for the application case of section 5. The last section highlights merits and limits of the paper and indicates future research directions.

2. UCD, QFD and Kano Model

In an attempt to pursue customer satisfaction as a guarantee of long-term success, many firms are increasingly implementing quality management methodologies and tools, and embracing the Total Quality Management philosophy. Arguably, the most important, and often initial step when implementing TQM inspired initiatives – such as Six Sigma – is listening to the "Voice of the Customer", or VOC (Brun, 2011; Lai, 2003). Chen and Yan (2008) pointed out that especially during the early stages of product concept definition, the involvement of users plays a critical role: for a successful product development it is paramount to understand customer/user needs and to address them quickly and accurately (Hong et al., 2011). We can therefore define design quality as the degree to which a product meets the customer needs of a specific market segment (Freiesleben, 2010). In the following, we will analyze tools, philosophies and methodologies helping companies to guarantee design quality throughout the new product design process.

UCD is a design philosophy and a process in which the needs, wants, and constraints of (current and prospect) users of a product are given maximum attention at every phase of the design process. UCD can be characterized as a multi-stage problem solving process requiring designers to i) analyze and foresee how users are likely to use a product, and ii) test the validity of their assumptions with regards to user behavior in real world tests with actual users as well. UCD is typically deployed in three stages (Dong and Fu, 2003): a) strategy and user analysis, b) design and assessment, c) execution and assessment. At the beginning of product life cycle, users' needs satisfaction is strategically positioned to be the basic motivation and final objective; during the following design process and development, all the decision-making criteria are based on feedbacks coming from the users. In order to support practical implementation of UCD, a number of specific tools have been proposed. Consider, e.g., the *Star Life Cycle*, *Spiral* and *Waterfall* models, depicted in Figure 1 (Sharp et al., 2002): they fully reflect the characteristics of user-centered and suggest the central position of user in design.

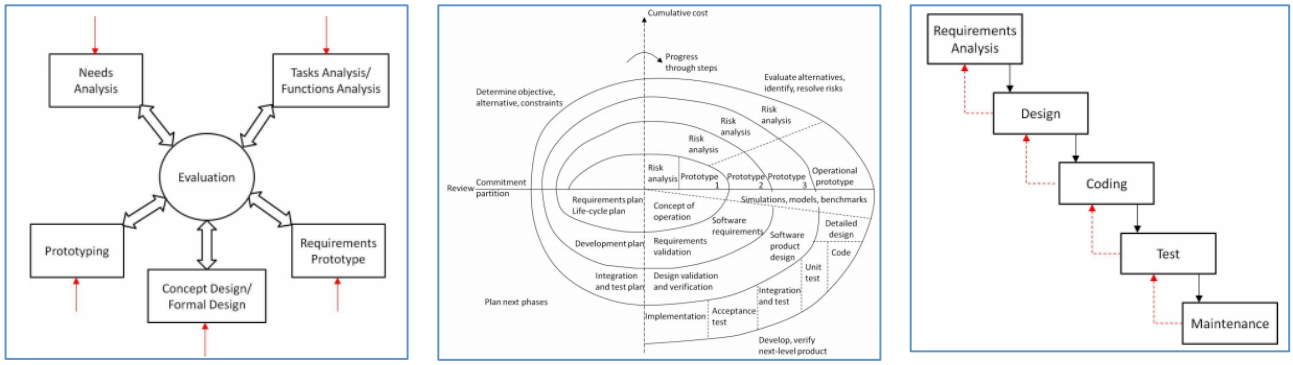

Figure 1: Star Life Cycle Model, Spiral Model, and Waterfall Model

QFD is a "method to transform user demands into design quality, to deploy the functions forming quality,and methods for achieving the design quality into subsystems and component parts, and finally to specify elements of the manufacturing process". It has the two-fold purpose "to assure that customer needs are properly deployed throughout the design, build and delivery of a new product and to improve the product development process itself" (Akao and Mazur, 2003). QFD transforms customer needs (i.e. the VOC) into design requirements, component characteristics, production and quality control requirements (Cristiano et al., 2000; Govers, 2001; Chang and Wu, 2002). The key success factors of the QFD methodology are that it is customer-centered and oriented towards customer satisfaction, supports systematic deployment of a product's function and characteristics, and fosters inter-departmental teamwork and collaboration. Three resolution models are widely acknowledged (Chang, 2006): i) Japanese QFD model (Xiong and Shindo, 1996), ii) ASI QFD model (Xu, 2003) and iii) Goal/QPC QFD model. QFD models proactively explore not only the requirements that customers explicitly conveyed, but also unspoken types of needs, so to maximize customer satisfaction and avoid dissatisfaction. Notwithstanding its many merits, QFD has some well-known limitations also, the main one being the underlying assumption that Customer Satisfaction improves linearly with the increase of the product performance. As not all the needs are showing the same linear behavior, specific methodologies (such as the Kano model and the Grey System Theory) have been developed to improve analysis and handling of customer needs.

Kano Model defines 3 types of user requirements (Kano, 1984): i) must-be requirements, ii) one-dimensional requirements and iii) attractive requirements (Figure 2). *Must-be requirements* are considered as the most "basic" product functions or services, often corresponding to unspoken customer needs. When must-be requirements are fulfilled, they contribute little to customer satisfaction while vice versa the customer will be very dissatisfied. *One-dimensional requirements* represent the "typical" product features, and contribute to customer satisfaction in a linear way. *Attractive requirements* are related to product attributes or service behaviors that totally go beyond users' expectations and thus make users surprised and excited. When the product doesn't have these features, users won't feel dissatisfied; but once these features exist, users would be very satisfied.

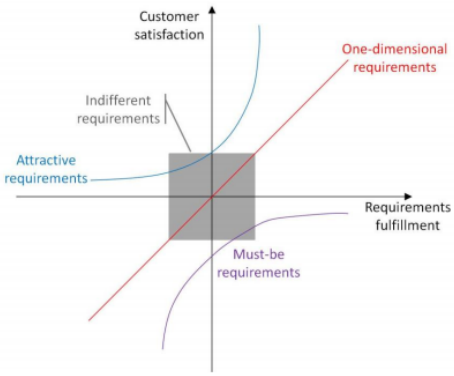

Figure 2: Kano Model

Kano model could be expanded with other types of requirements (Chen and Chuang, 2008): i) *indifferent requirements*, i.e. users are not interested in them; ii) *reverse requirements*, i.e. different users have different, or even diametrically opposite expectations towards one attribute; iii*) questionable requirements*, i.e. there are some misunderstanding from users or feedback mistakes, or the questions are put forward in a wrong stage. When user requirements have to be classified, two opposite questions (i.e. forward and reverse question) are set: customers are asked about their feeling and attitudes when the attribute exists or not. According to users' answers, user requirements can be classified according to the categories identified by Kano, e.g. using the widely adopted clustering approach advocated by Matzler and Hinterhuber (1998), shown in Table 1.

		User's feeling and attitude when the product doesn't have the certain attribute				
		I like it that way	It must be that way	I am neutral	I can live with it that way	I dislike it that way
User's feeling and attitude when the product has the certain attribute	I like it that way	Questionable requirements	Attractive requirements	Attractive requirements	Attractive requirements	One-dimensional requirements
	It must be that way	Reverse requirements	Indifferent requirements	Indifferent requirements	Indifferent requirements	Must-be requirements
	I am neutral	Reverse requirements	Indifferent requirements	Indifferent requirements	Indifferent requirements	Must-be requirements
	I can live with it that way	Reverse requirements	Indifferent requirements	Indifferent requirements	Indifferent requirements	Must-be requirements
	I dislike it that way	Reverse requirements	Reverse requirements	Reverse requirements	Reverse requirements	Questionable requirements

Table 1: Matzler and Hinterhuber Clustering Approach

3. Research objectives and methodology

UCD processes and models are mostly applied in software development and interactions design, yet also in industrial product design "User-centered" is showing a growing relevance and frequent adoption. With the present paper, we propose the introduction of a quality assurance process in a User-Centered product design context. Such a new methodology would support the design team in collectin g the VOC and at the

same time to take into account customer satisfaction as a measure of design quality, thus guided by the goal of developing products that meet user needs.

The development of our methodology is grounded on two underlying assumptions: i) “fit for purpose” / matching user needs is one of the most important success factors in new product development, and ii) insufficient market analysis is one of the most common causes of new product failure. Consequently, the process of product planning and design should be driven by customer needs. In order to obtain and maintain competitiveness, enterprises should carry out a rigorous market research, and continuously interact with users, to be able to design products better meeting customer requirements.

The proposed methodology will support companies willing to introduce the ideas and concepts of UCD into the design of industrial products. Based on the fact that UCD has been developed and proved to be beneficial in computer industry (Zheng, 2006), a UCD approach could be introduced in industrial design, and integrated with quality engineering, to develop a new approach to design. In this way, companies adopting the methodology could achieve benefits such as correctly understand user needs and seize market opportunities, and improve product design quality, ensure ultimate product quality.

The development of said methodology was based on an extended literature review, and supported by empirical evidence having been validated through a case study.

4. Development of quality control process in UCD

In the field of product design, some relatively frequently used UCD methods are: ethnography observation, user roles, user interview, survey questionnaire, focus group, QFD, scenario-based design, participatory design, usability test, eye-movement analysis, etc. The various tools provide similar benefits, supporting companies to: a) identify user needs; b) create a data collection system; c) speed up information access and interpretation; d) explore design opportunities from the perspective of end users; e) avoid judgmental decisions in design process (Hu, 2009).

The entire UCD process could be divided into three phases: pre-design planning, design presentation, design evaluation and implementation. In Figure 3, the entire process is depicted, and the specific steps in which the above mentioned tools could be used are highlighted.

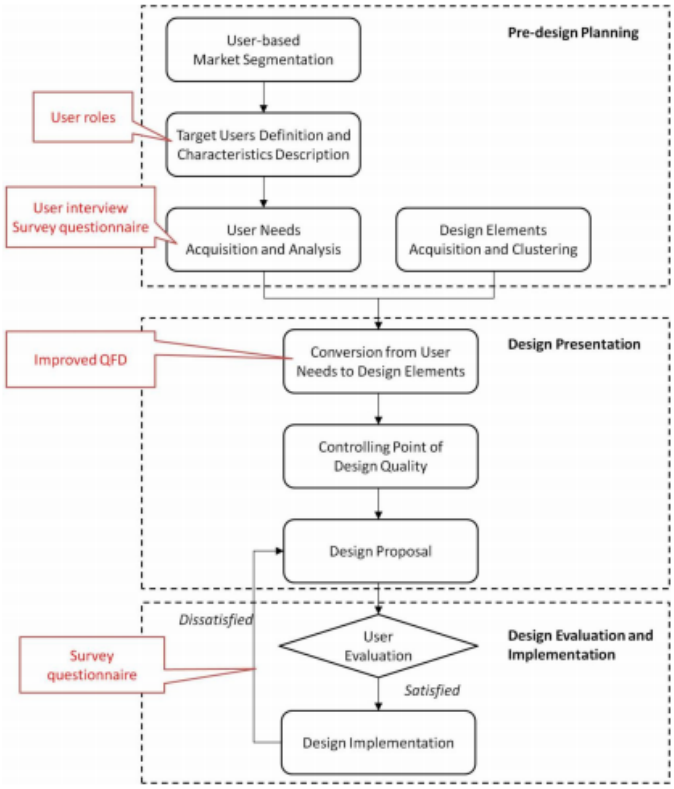

Figure 3: UCD process

Throughout the whole process, the degree to which user needs are fulfilled is typically regarded as a measure of design quality. Thus, correctly addressing the user needs at every step – as will be explained in details in the next subsection – is a mean to implement quality assurance in new product design.

4.1 User-Based Market Segmentation

Different users have different dominant needs, so the consumer market is not a unified homogeneous market, but can be divided into user group subsets with common requirements and characteristics. At present the approaches to market segmentation are mainly business perspective and user perspective (Xu and Tang, 2008). This work primarily studies the user-perspective-based market. The market segmentation variables based on users consist of 4 aspects (Gan, 2002): geographical factors, population statistical factors, psychological factors and behavioral factors characterized by some frequent variables (Freud, 1994).

4.2 Characteristics description of target users

Users should be classified through a set of characteristics. One frequently used classification model is based on the three elements of target users: a) age features; b) life attitude; c) fashion sensibility (Liao and Zhu, 2010); each triplet of age/attitude/sensibility representing one possible (virtual or actual) user group. Usually one product group could be targeted to several user groups at the same time.

4.3 Acquisition and classification of user needs

The acquisition and analysis of user needs is the most critical, and also the most difficult step in the quality control process in UCD impacting on the determination of design elements in QFD. Figure 4 presents the process of user needs recognition. The procedure for user needs acquisition starts from the definition of target users, followed by the selection and application of tools for needs recognition, such as interviews, focus groups, and observation of users behavior.

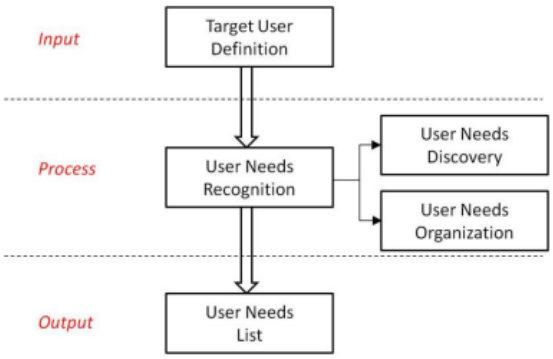

Figure 4: acquisition and classification of user needs

Griffin and Hauser (1993) showed that the needs revealed in a two-hour focus group discussion are equal to those obtained from two one-hour interviews, whereas the cost of interview is usually much lower than that of a focus group. This is the reason why the interview is the most frequently used user-needs-acquisition method, and we will therefore adopt it in our case study. User needs collected through interviews are then sorted and clustered using the Affinity Diagram technique. After the acquisition of valid user needs, an importance level is to be assigned to each of them. This is done through a questionnaire with five-point Likert scale answers.

4.4 Conversion from user needs to design elements based on QFD

Once the user needs have accurately been collected, QFD helps in: a) ranking the weight of user needs; b) calculating the correlation value between user needs and design elements. So QFD could be regarded as a conversion tool between user needs and design elements.

a. Ranking the weight of user needs

To introduce non-linear correlations needs and product performances into QFD, many scholars started to study how to integrate QFD and Kano model (Tan and Shen, 2000; Sauerwein et al., 1996; Sireli et al., 2005). In particular, we adopted the following approach to:

- Classify user needs according to Kano model, dividing them in: M (must-be needs), O (one-dimensional needs), A (attractive needs), I (irrelevant needs), R (reverse needs), and Q (questionable needs).
- For the i-th need, calculate the proportion of users considering it M, O, A and I (respectively U_i, V_i, $X_i$and Y_i), and calculate F_i (the increasing rate of user satisfaction when the attribute exists) and D_i (the declining rate without the attribute), and it can be obtained that

$$F_i = \frac{X_i+V_i}{X_i+V_i+U_i+Y_i}; D_i = \frac{U_i+V_i}{X_i+V_i+U_i+Y_i}$$

So the relative weight w_i of the i-th user need is:

$$w_i = max\left(\frac{F_i}{\sum_{i=1}^{m} F_i}, \frac{D_i}{\sum_{i=1}^{m} D_i}\right)$$

The user need will be classified applying the principle of "relative majority" (of users), but when the relative percentages of two classifications are equal (or very close to one another), and a clearly defined criteria is needed, we will adopt the relative user satisfaction coefficient ratio (expressed as F_i/D_i) and classify the need according to the threshold in Table 2.

F_i/D_i	Type of needs
>1.1	Attractive needs
0.9~1.1	One-dimensional needs
<0.9	Must-be-needs

Table 2: thresholds for the relative user satisfaction coefficient ratio

b. Calculating the correlation

The correlation value between user needs and design elements is calculated by collecting the opinion of several experts. In case of diverging opinions, methodologies such as Delphi or the Analytical Hierarchical Process (AHP) could be applied to find a converging answer.

4.5 Design proposal evaluation

After obtaining the "quality controlling points" of the design process, the designer team could generate several alternative design proposals; the various proposals will then be evaluated and the best one selected according to the users' perspective. Here the user needs satisfaction degree S_{Ki} is introduced with the aim to examine the degree to which the design proposal fulfills user needs. In particular, specific evaluation criteria are:

- Judgment of S_{Ki} according to the following table;

Degree to which design proposals fulfill user needs	S_{Ki}
Very well	1

Preferably	0.75
Fairly	0.5
Reluctantly	0.25
None	0

- Calculation of weighted evaluation score for user need D_i:

$$f_{Di} = \frac{W_i \sum_{k=1}^{m} S_{ki}}{m}$$

Where W_i is the weight of each use need, *m* is the number of target users who participate in the grading;

- Calculation of the total score $f_x$for design proposal *X:*

$$f_x = \sum_{i=1}^{n} f_{Di}$$

where *n* is the number of items which regard user needs as grading indicators.

The proposal with a higher score is the design that could better fulfill user needs on the whole, providing basis for proposals evaluation (even though other criteria, such as the cost of the different proposals, might be used to make the final decision).

5 Application in a real case

The proposed quality method in UCD is applied in a design project of a new portable photo printer through three steps: i) During pre-design phase, carry out elaborate analysis on target users and their needs, ii) convert user needs to design elements effectively, with explicit design quality controlling point in design process and iii) Determine preliminary product design proposal, show the product design effect to users in forms of draft and 2D sketch drawings, preparing foundations for subsequent design work.

Step 1. Market segmentation and user needs acquisition

Six factors are considered: Region, mobility, age, gender, occupation and income. In this way it is helpful to understand and grasp the consumer market as a whole, as well as position target user groups. In particular, the project team addressed two clusters of users:

1. Potential users: University students, the mighty and main consumption forces in the future, whose attitudes and tastes play a determinant role in the development direction of printer in the future;
2. Main target users: New graduates, office white collars, paying close attention to new products in digital market, seemed as the major consumer groups of portable photo printer.

User needs acquisition was performed through interviews to target user to understand the general features such as value concepts, expectations, beauty appreciation and preferences of users towards portable photo printers. In this way, the general requirements and expectations of users when they use or purchase portable photo printers was obtained. The interviewee selection was based on the previous definition of target users, regarding the youth men and women in cities of 19~30 years old relatively concerned on the fashion trend of digital products; having purchased or used portable photo printer, or relatively familiar with this kind of products. After that, the researchers had comprehensive awareness of the using conditions, use intentions, value positioning, expectation conditions and aesthetic standards of users for portable photo printers, and they were able to extract a list of user needs and organize it hierarchically (in the so-called "Critical to Quality tree", CTQ tree) using affinity diagram.

A further questionnaire was administered to users in order to calculate the relative weights of customer needs. Results (analyzed by means of the statistical software SPSS) are summarized in Table 3.

User Needs		Importance Degree	Relative Importance Degree %
Printing performance	1. Lifelike printing effect, fine particles	139.36	7.44
	2. Photos keep bright-colored for a long time	136.34	7.27
	3. Beautifully printed human faces	116.88	6.24
	4. High printing speed, instant service	130.19	6.95
Operability	5. Easy to use	135.48	7.23
	6. Able to intuitively preview and select photos	132.40	7.06
	7. Able to remotely transmit and manipulate	99.27	5.30
	8. Able to connect directly with cameras/memory cards	139.12	7.42
Appearance	9. Small size, portable	136.72	7.29
	10. Delicate and compact appearance	110.10	5.87
	11. Bright-colored, matching with the environment	109.12	5.82
Economy	12. Reasonable price for hardware equipment	135.54	7.23
	13. Reasonable printing cost (including photo paper, cartridge)	133.82	7.14
Interestingness	14. Multi-medium and specification printing (including calendar, postcard)	103.09	5.50
	15. Multi-model photos, free layout when printing multiple photos on one paper	117.12	6.25

Table 3: relative importance of needs, as resulting from market survey

Since the actual importance degree of user needs is not linear, it is necessary to revise the user needs importance degree combined with Kano model. First of all, the user needs are classified based on Kano model and the classification manner proposed by Matzler and Hinterhuber; results are shown in Table 4.

User Needs	Must-be Needs %	One-dimensional Needs %	Attractive Needs %	Indifferent Needs %	Needs Classification	Correction Coefficient
1. Lifelike printing effect, fine particles	31.25	43.18	11.36	14.20	One-dimensional	2.0
2. Photos keep bright-colored for a long time	17.05	28.41	45.45	9.09	Attractive	1.5
3. Beautifully printed human faces	18.75	23.30	47.73	10.23	Attractive	1.5
4. High printing speed, instant service	23.86	49.43	15.91	10.80	One-dimensional	2.0
5. Easy to use	44.89	35.23	10.23	9.66	Must-be	2.5
6. Able to intuitively preview and select photos	39.20	30.11	11.93	18.75	Must-be	2.5
7. Able to remotely transmit and manipulate	12.50	21.59	48.30	17.61	Attractive	1.5
8. Able to connect directly with cameras/memory cards	45.45	19.32	11.93	23.30	Must-be	2.5
9. Small size, portable	37.50	39.77	15.34	7.39	Must-be	2.5
10. Delicate and compact appearance	17.05	26.70	46.02	10.23	Attractive	1.5
11. Bright-colored, matching with the environment	6.82	19.89	51.14	22.16	Attractive	1.5
12. Reasonable price for hardware equipment	41.48	35.80	10.23	12.50	Must-be	2.5
13. Reasonable printing cost (photo paper, cartridge)	46.02	39.20	7.39	7.39	Must-be	2.5
14. Multi-medium and specification printing	23.30	38.64	21.02	17.05	One-dimensional	2.0
15. Multi-model photos (black and white), free layout when printing multiple photos on one paper	12.50	31.25	42.05	14.20	Attractive	1.5

Table 4: classification of needs following Matzler&Hinterhuber method

As is shown in Table, for the 9th item “Small size, portable”, the difference between the relative frequency percentages of “Must-be needs” and “One-dimensional needs” is very small, so the relative user satisfaction ratio is calculated as 0.71, which is less than 0.9, thus classifying this item into must-be needs. The other user needs of portable photo printer are classified according to their highest relative percentage.

Step 2. Conversion from user needs to design elements

The extraction of design elements is a very technical process requiring detailed knowledge in the field. This has been done involved professional printer designers, ergonomics professionals and other practitioners. The matrix of relationships between user needs and design elements has been determined in a panel session with the experts. Results are summarized in Table 4, where “◎” represents strong correlation degree (equals to 5), “○” represents medium correlation degree (equals to 3), and “△” means weak correlation degree (equals to 1).

User Needs / Design Elements	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Printer size					△			△	◎	◎	○	○			
2. Sculpting vision design					○			△	◎	◎	◎				
3. Power supply mode design					○		○		◎	○		○	◎		
4. Color and material									○	◎	◎				
5. Resolution ratio	◎	○	◎	◎								○	◎	○	△
6. Color gradation	◎	◎	◎	○		△						○	◎	○	△
7. Printing speed	△	○	△	◎			○					◎	○	△	△
8. Power	○			◎			○					◎	◎	△	
9. Printing size	○	△	△	○		○			◎	◎		△	△	◎	◎
10 .Printing media	○	◎	◎	△	△							△	◎	◎	◎
11. Interface design				○	○		◎	◎	△	○	△	△		△	△
12. Button design					◎	○	△	○			○	△		△	
13. UI display design					◎	◎	△	◎	△	○	○	○		△	○
14.Consumable replacement mode design				○	◎				△	○		△	◎	△	
15. Paper in/out design	△	◎	△	○	◎				○	◎	○			◎	
16. Carrying mode design					◎			○	◎	◎	○				
17. Card slot design					◎	○	○	◎	○	○	△	△		△	△
18. Ink catridge design	◎				◎				○	△		○	◎	△	
19. Wireless transmission support degree				○	△	○	◎	△				○	○		△
20.Operational system design				○	○	◎	◎	○						○	◎

Table 5: resulting QFD matrix for the portable printer

Step 3. Design plans evaluation of portable photo printer

According to the importance rank of design elements, the design team designed two portable photo printers (labeled as Plan A and Plan B) to choose from where 20 target users were selected as the evaluators. The designers elaborated the design concept, specification parameters, product characteristics and so on face to face, and the users gave their grades in accordance with whether the product met their needs, with the satisfaction degree divided into 5 levels, from “Very well” to “Not at all”. Table shows the final grade values of the two plans after the synthesis of weighting and averaging of user grading.

User Needs Indicator		Weight	Plan A		Plan B	
			Target Users Grating	Weighted Grade	Target Users Grating	Weighted Grade
Printing performance	1. Lifelike printing effect, fine particles	7.87	0.74	5.80	0.86	6.79
	2. Photos keep bright-colored for a long time	5.41	0.77	4.17	0.84	4.53
	3. Beautifully printed human faces	4.24	0.71	3.02	0.85	3.59
	4. High printing speed, instant service	7.81	0.76	5.96	0.85	6.65
Operability	5. Easy to use	10.05	0.77	7.76	0.79	7.91
	6. Able to intuitively preview and select photos	7.48	1.00	7.48	1.00	7.48
	7. Able to remotely transmit and manipulate	3.26	0.80	2.60	0.84	2.75
	8. Able to connect directly with cameras/memory cards	6.36	0.93	5.89	1.00	6.36
Appearance	9. Small size, portable	10.25	0.74	7.59	0.64	6.59
	10. Delicate and compact appearance	4.19	0.87	3.66	0.74	3.09
	11. Bright-colored, matching with the environment	3.43	0.85	2.90	0.82	2.81
Economy	12. Reasonable price for hardware equipment	9.47	0.90	8.56	0.52	4.55
	13. Reasonable printing cost	11.07	0.78	8.67	0.66	7.30
Interestingness	14. Multi-medium and specification printing	4.58	0.84	3.87	0.87	4.00
	15. Provide customized printing programs	4.54	0.76	3.46	0.90	4.10
Total			81.38		78.88	

Table 6: comparison between two alternative design proposals taking into account user view

As can be seen from the evaluating results, the overall grades of plan A is higher than that of plan B, even though the performance of A is not superior to that of B for every single factor. The comparison of the two plans in terms of various indicators is shown in Figure 6.

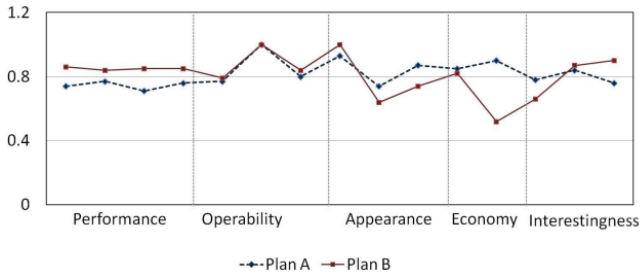

Figure 5: comparison between two alternative design proposals

The printing performance of plan B is superior to that of plan A, which can also be concluded from the specification parameters of the plans, since the configuration of the product B obviously exceeds that of product A, which, at the same time improves user satisfaction to some extent. This is coincidental with the classification that the performance-relevant user needs mostly belong to one-dimensional and attractive needs. Because of more advanced configuration, plan B has a higher market reference price than plan A, which affects user satisfaction to a great extent. This is because the target users are “University students of 19~30 year old and new graduates” who are relatively price-sensitive, which is closely related to the target

market being selected at the beginning. In addition, both the two plans have humanized design in terms of operability, with which the users are relatively satisfied. In the perspective of appearance, users prefer plan A, which gives them the feelings of “small, exquisite, fashion and succinct”. When it comes to interestingness, plan B is even better due to its advanced system configuration.

6 Conclusions and research outlooks

A modern quality definition has to take into account the user perspective; under this assumption, the UCD philosophy developed. Based on QFD, this work proposed an original methodology of quality control in product design. The whole process encompasses: pre-design planning, design presentation and design evaluation. It is always highlighted that the extent to which customer needs are satisfied is a measure of product design quality, aiming, on turn, at reaching high levels of customer satisfaction.

The following statements summarize our work:

- ✓ Discusses on why company willing to achieve good level of customer satisfaction has to ensure quality of the product design process, by using appropriate tools;
- ✓ Introduces the concept of UCD with a relevant literature review;
- ✓ We proposed a quality assurance process, based on the UCD paradigm, consisting in the application of several quality management tools in the 3 sub-processes of the User-centered product development;
- ✓ Kano Model is used to complement the well known QFD limitation, of assuming linear behavior of customer satisfaction;
- ✓ The methodology is tested and validated in a real case, regarding the development of a new portable photo printer. The process is used to direct and control the quality of the product design. In the light of the quality control points after analysis, design alternatives are mapped out. The final plan is determined after assessment judged by the extent that customer needs are fulfilled.

Although attempting to shed new light on the paramount topics of user based view of quality and measuring design quality, the present manuscript is to be considered a working paper as the research on the topic is still ongoing. Among the apparent limits of our work:

- first of all, taken independently, the methodologies adopted (QFD, Kano model, the Matzler and Hinterhuber method) are not innovative; it is the overall framework that is a somehow new contribution; for this reason, the selection of the specific techniques and tools is critical for the success of the overall methodology, and in the future probably other tools will be included in the framework and implemented;

- the application to one single case is not enough to prove that the methodology could actually work in different sectors and in different conditions – so several other application cases are required;
- finally, based on the single case study, we were not able to assess numerically the benefits coming from the methodology application.

Therefore, future research directions are devised: the overall framework will be expanded to include several other "classic" quality management tools; the methodology will be tested in a number of cases of design of new consumer goods. Furthermore, a tool to measure benefits resulting from the application of the methodology will be developed and applied to every single case study – it will measure benefits both in a qualitative way (increased customer satisfaction, perception of the design team of having been supported, …) and in a quantitative way (lower costs, shorter time to market, less failures, …).

As a future extension, the model could be applied not only to the design of new products but also to the interesting field of service design.

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