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# Constructing a evaluating model for Smartphone Green Design by VAHP and QFD

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**Abstract:** Industry and high-tech industries flourish in the current era. In addition to enhancing quality of life, they have caused plentiful harm to human beings and the environment. Some man-made pollution has destroyed the ecological balance. Environmental protection has thus become everybody's social responsibility. Many enterprises are beginning to actively concern themselves with sustainable business models and environmental protection issues. After continuous technological development in recent years, many new products have emerged to make human life more convenient. The smartphone is among the most popular of these products. The main aims of this study are to (1) analyze green smartphone requirements of consumers and designers; and (2) construct an assessment framework and checklist for smartphone green design. This study adopts voting analytic hierarchy process (VAHP) and quality function deployment (QFD) and constructs green design criteria through expert interviews.

Keywords: VAHP, QFD, HOQ

## 1. INTRODUCTION

### 1.1 Background and research motivation

Industrial and high-tech industry is flourishing, despite the quality of human life to improve, but also cause a lot of damage to humans and the environment in recent years, the smartphone market is continuing to expand, in the streets or in many public places, often see we bow to the use of smart phones, also expressed modern life adds a lot of convenience, new technology development is increasingly month, major mobile phone manufacturers have launched distinctive smartphone, however, the amount of R & D to the official Nissan's overall production process, tend to produce large electrical and electronic waste, if the industry can join the green design concept in the research and development, not only does the implementation of environmental protection concept also reduce the extent of the environmental damage. This study focused on green design of smartphone, the main purpose of the following : (1) Analyze the consumer's demand and the designer's concept of green design on smartphone. (2) Construct a design checklist of green design assessment and architecture.

### 1.2 Research Methodology:

This study applied VAHP (Voting Analytic Hierarchy Process), QFD (Quality Function Deployment), the architecture of quality finishing house to evaluate green design criteria smartphone for producers and consumers. Use VAHP criteria as the calculating base to obtain the factors of consumer's demand and the weights of engineering characteristics. Put the consumer's demand according to the result of VAHP model on the left of the house of quality and engineering characteristics above the quality of houses above and expand the relationship

matrix of consumer's demand and engineering characteristics. The process of constructing this house of quality can analyze and compare the differences between producers and consumers of design criteria for green products.

## 2. LITERATURE REVIEW

### 2.1 Green Design:

'We have not run out of water. We have simply run out of new streams to pollute' [6]. People lose the curiosity for different styling products gradually, nature-based design become the breakthrough point for development of design, and create a generation of green products. Green design projects achieved a higher proportion of exports (25% versus 19%), and a higher gross margin (40% compared with 37%.) It takes more time and more money to develop green designs (on average, three times as long.) But payback is still rapid and growth is strong. One company reported that their low-energy floodlight recovered costs in 2 years and went quickly to a rapid sales growth. Actually, most of the firms in the study did not set out to create designs with greater environmental benefit. They just committed to design, good design, and environmental aspects came up as reactions to the legislation. Unfortunately, financial institutions may still be hard to sell. In the U.K. this is especially so, enough that product innovators wish for European monetary union, so they can have access to German banks and their focus on the long-term of business. Burall explains that the environmental philosophy shall establish on "Reduce", "Reuse", "Recycle" and "Regeneration" which are the main concept of green design as following [2]:

(1) Reduce :During the green design process, designer must reduce the consumption of material and natural resource and remain features and quality of products.

(2) Reuse : Increase the reuse frequency of product, the amount of waste will also be reduced. If consumers are able to reusable products, the amount of waste will also reduce.

(3) Recycle : At the end of product life, if part of the value product can recycle, the amount of waste garbage will also reduce.

(4) Regeneration :Recycling of waste products of value through product recycling program will be of value in the re-manufacturing of waste materials or products of other available, although the cost of current technology, renewable recycled products uneconomic, but for the overall environment is indeed achieve the goal of environmental protection.

### 2.2 Voting Analytic Hierarchy Process, VAHP

Voting Analytic Hierarchy Process is a decision-making methodology based on Analytic Hierarchy Process. Narasimhan concludes some advantages as following [4] :

(1) Offer a more accurate judgment for managers as reference to make decision more accurately.

(2) Decision makers can operate sensitivity analysis by software.

(3) The result of AHP can be the basic for group decision-making and communication.

Although AHP has above advantages but still exist some deficiencies as following [5]:

(1) The simplification of the hierarchy may hide some of the important dependencies, and then over-simplify decision problems.

(2) AHP priority vector magnitude can't guarantee significant (Statistical Significance) to provide definitive results to decision makers.

Liu&Hai [3] develop VAHP based on AHP. VAHP is easier to understand than AHP and processes by three steps.

(1) Decision-makers can rank by assessing the importance of goals sorting to avoid both problems two relatively inconsistent

- (2) Find the weights through linear programming model
- (3) Calculate the total scores and complete the ranking.

### 3. RESEARCH DESIGN

#### 3.1 Questionnaire design

This study concludes the green design criteria of smartphone for producers are shown as Table 1.

**Table 1. The green design criteria of smartphone for producers**

Raw material selection and management	1	Selection of non-toxic substances
	2	Recycle valuable materials
	3	Consider the suitability of components
	4	Select non-radioactive material
	5	Select safe and recyclable material
Products assemble/disassemble	6	Foolproof design and positioning structure
	7	Simplified structure
	8	Modular Design
	9	Minimize the numbers and lengths of circuit
	10	Avoid pollution caused by adhesive
Packaging reduction and waste	11	Avoid redundant processing or coating treatment
	12	Use non-toxic packaging material
	13	Light the weight of packaging material
	14	Select the packaging material is easily decomposed
	15	Select paper with FSC or PEFC certified
Recyclable	16	Use environment-friendly ink
	17	Use compatible materials or components
	18	Easy to maintain and repair
	19	Use of repetitive components
	20	Recycle waste batteries
Permanent design	21	Highly safety of using mobile phone
	22	Extend the life-span of battery
	23	Low energy consumption
	24	Robust Design of mobile phone
	25	Lightweight of mobile phone

After discussing with experienced academics and deleting inappropriate criteria, the green design criteria of smartphone for consumer are shown as Table 2.

**Table 2. The green design criteria of smartphone for consumers**

Raw material selection and management	1	Selection of non-toxic substances
	2	Recycle valuable materials
	3	Consider the suitability of components
	4	Select non-radioactive material
Products assemble/disassemble	5	Select safe and recyclable material
	6	Foolproof design and positioning structure
	7	Simplified structure
Packaging reduction and waste	8	Modular Design
	9	Minimize the numbers and lengths of circuit
	10	Avoid pollution caused by adhesive
	11	Avoid redundant processing or coating treatment
Recyclable	12	Use non-toxic packaging material
	13	Light the weight of packaging material
	14	Select the packaging material is easily decomposed
	15	Select paper with FSC or PEFC certified
Permanent design	16	Use environment-friendly ink
	17	Use compatible materials or components
	18	Easy to maintain and repair
	19	Use of repetitive components
	20	Recycle waste batteries

#### 4. RESEARCH RESULTS AND DISCUSSION

This chapter will construct house of quality for smartphone green design. Firstly, select the green design assessment criteria for producers and consumers, secondly, VAHP establishes a systematic framework and identify the weights, then construct a house of quality for smartphone green design. Detailed steps described as follows:

##### 4.1 Capture smartphone green design criteria

Collect relative literature regarding smartphone and interviews with experts. Summarize green design five index of smartphone for producers and consumers such as "Raw material selection and management", "Products assemble/disassemble", "Packaging reduction and waste", "recyclable" and "Permanent design".

This study investigates and compares the smartphone green design criteria of similarities and differences between producers and consumers. VAHP questionnaires completed by interviews with experts, according to a five-point Likert scales Scale the importance of standards to conduct attainment score to pick out a suitable assessment criteria of green design.

Collecting consumer questionnaires via smartphones literature data, and then with the scholars in this field are discussed and VAHP questionnaire. After discussing the appropriateness and completeness of recognition criteria and academics, will be finishing VAHP completed questionnaires, according to the criteria of each five-point Likert Scale scales conduct importance degree score to pick out the right consumers green design assessment criteria

Questionnaires of smartphone green design for producers include 25 criteria, 30 experts give 1~5 score. According to the selection criteria scores level at the VAHP survey results. Based on the ANP principle, the average score is 2.967. Fourteen items exceed the average score and are shown as following Figure 3.

**Figure 3. The score of questionnaires of smartphone green design for producers**

Item	Contents	Total score	Average
19	Use of repetitive components	129	4.300
3	Consider the suitability of components	121	4.033
23	Low energy consumption	119	3.967
17	Use compatible materials or components	114	3.800
1	Selection of non-toxic substances	107	3.567
8	Modular Design	107	3.567
18	Easy to maintain and repair	107	3.567
21	Highly safety of using mobile phone	104	3.467
7	Simplified structure	101	3.367
22	Extend the life-span of battery	101	3.367
12	Use non-toxic packaging material	97	3.233
4	Select non-radioactive material	95	3.167
2	Recycle valuable materials	93	3.100
25	Lightweight of mobile phone	93	3.100
10	Avoid pollution caused by adhesive	83	2.767
24	Robust Design of mobile phone	81	2.700
13	Light the weight of packaging material	80	2.667
16	Use environment-friendly ink	79	2.633
6	Foolproof design and positioning structure	78	2.600
5	Select safe and recyclable material	75	2.500
20	Recycle waste batteries	74	2.467
9	Minimize the numbers and lengths of circuit	61	2.033
11	Avoid redundant processing or coating treatment	59	1.967
14	Select the packaging material is easily decomposed	52	1.733
15	Select paper with FSC or PEFC certified	49	1.633

Questionnaires of smartphone green design for consumers include 20 criteria, 30 experts give 1~5 score. According to the selection criteria scores level at the VAHP survey results. Based on the ANP principle, the average score is 3.467. Eleven items exceed the average score and are shown as following Figure 4.

**Figure 4. The score of questionnaires of smartphone green design for consumers**

Item	Contents	Total score	Average
16	Use environment-friendly ink	275	4.583
18	Easy to maintain and repair	269	4.483
1	Selection of non-toxic substances	258	4.300
3	Consider the suitability of components	255	4.250
17	Use compatible materials or components	248	4.133
19	Use of repetitive components	241	4.017
20	Recycle waste batteries	241	4.017
15	Select paper with FSC or PEFC certified	228	3.800
14	Select the packaging material is easily decomposed	223	3.717
8	Modular Design	218	3.633
10	Avoid pollution caused by adhesive	208	3.467
9	Minimize the numbers and lengths of circuit	203	3.383
2	Recycle valuable materials	199	3.317
12	Use non-toxic packaging material	194	3.233
7	Simplified structure	187	3.117
11	Avoid redundant processing or coating treatment	180	3.000
4	Select non-radioactive material	177	2.950
13	Light the weight of packaging material	155	2.583
5	Select safe and recyclable material	148	2.467
6	Foolproof design and positioning structure	141	2.350

## 5. CONCLUSION

Environmental awareness is valued by today's global , green design has become more than just enterprise development must require , more sustainable future product development is the mainstream , and even some developed countries have already developed a product design and production in the regulations environmental standards , such as the European Union from August 2005 to promote the waste Electrical and Electronic equipment Directive (WEEE), restriction of Hazardous Substances Directive (RoHS), as well as eco-design of energy using products Directive (EUP) and other three environmental directives , increasing emphasis on making the world green , so all enterprises in the development of new products , you must factor in environmental protection considerations into the development of new products among green product design to cope with the major environmental directives set for enterprises better application of green design methods and techniques of sustainable development strategy will be an integral part of the product , and also reached the social responsibility to protect the environment . Enterprises to implement green trend in this stock in sustainable development must be implemented in the management of the source , from the perspective of green design to development , application of effective innovation management tools and techniques to create a competitive advantage , to promote environmental protection and economic development to achieve a balance points to reach corporate sustainability goals and implement environmental win.

Therefore, this study of the smartphone industry and consumer use of smart phones as the main research object, producers and consumers on the importance of product design factors and style QFD voted constructed

using smartphones quality green product design planning house, using this method to provide guidelines for corporate conduct understand consumer attention smartphone green design, thus providing a combination of factors to consider when consumer demand for new product design and development, in order to design more in line with consumer demand for green intelligent Mobile.

After the order to establish smartphones green design voted type QFD model used in this study VAHP combined QFD computing smartphones green design criteria weights, assess each criterion through analyzed with producers and consumers scores and sorting is completed smartphones green design quality of houses constructed, Through this research found that summarized the following conclusions:

(1) This study has collected relevant literature, expert interviews and questionnaires to identify selection criteria for smart phone industry green design, green design elements to establish guidelines smartphone industry when making green design considerations

(2) After calculating the quality of housing architecture through VAHP analysis found that smartphone producer in the selection of green design, the order of importance criteria are: selection of non-toxic substances (0.1807), the use of recycled materials with economic value (0.1067), using non-toxic packaging materials (0.0822), the use of compatible materials or components of (0.0748), structural simplification (0.0714), high security mobile phone use process (0.0669) consider the suitability of components between (0.0655) , designed to extend the battery life of (0.0592), easy to maintain and repair design (0.0582), use of non-radioactive parts and materials (0.0562), the use of highly repetitive use of components (0.0495), low energy (such as energy efficiency standard Chapter) (0.0462), mobile lightweight design (0.0436), modular design (0.0389)

(3) Consumers in the selection of smartphones green design criteria were sequentially attention: selection of raw materials do not contain toxic substances (0.1137), mobile phone use during high security (0.1007), designed to be easy to maintain and repair (0.0928), mobile rugged design (0.0921), mobile lightweight design (0.092), the use of non-toxic packaging materials (0.0892), use of non-radioactive parts and materials (0.088), low energy (such as energy-mark) (0.0872 ), recyclable waste batteries (0.0831), use recyclable packaging materials (0.0828), designed to extend the battery life of (0.0784)

(4) Relationship matrix results weighted by the expert assessment, the results of this combined voices of consumers, the smartphone can be found in green design assessment framework producers and consumers of the top three most important criteria for the selection of non-toxic substances (1.4207) use non-toxic packaging materials (1.1205), high security mobile phone use process (0.7724), producers can thus sorting criteria to confirm the importance of

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