

# Utilizing Analytic Hierarchy Process to Analyze Consumers' Purchase Evaluation Factors of Smartphones

Yi-Chung Hu and Yu-Lin Liao

**Abstract**—Due to the fast development of technology, the competition of technological products is turbulent; therefore, it is important to understand the market trend, consumers' demand and preferences. As the smartphones are prevalent, the main purpose of this paper is to utilize Analytic Hierarchy Process (AHP) to analyze consumer's purchase evaluation factors of smartphones. Through the AHP expert questionnaire, the smartphones' main functions are classified as "user interface", "mobile commerce functions", "hardware and software specifications", "entertainment functions" and "appearance and design", five aspects to analyze the weights. Then four evaluation criteria are evaluated under each aspect to rank the weights. Based on an analysis of data shows that consumers consider when purchase factors are "hardware and software specifications", "user interface", "appearance and design", "mobile commerce functions" and "entertainment functions" in sequence. The "hardware and software specifications" aspect obtains the weight of 33.18%; it is the most important factor that consumers are taken into account. In addition, the most important evaluation criteria are central processing unit, operating system, touch screen, and battery function in sequence. The results of the study can be adopted as reference data for mobile phone manufacturers in the future on the design and marketing strategy to satisfy the voice of customer.

**Keywords**—Analytic Hierarchy Process (AHP), evaluation criteria, purchase evaluation factors, smartphone.

## I. INTRODUCTION

THE mobile phone markets are a swift and turbulent market environment due to the fast development of technology and increased competition and change. According to the international marketing institution, IDC's (International Data Corporation) analysis report shows that the world-wide smartphone shipments have grown 15% and reached 170 million in 2009 and furthermore the selling of smartphones will dramatically rise 55% by 2012. Therefore smartphones have shown the rapid growth and evolution.

Mobile phones have become a fundamental part of personal communication across the globe during the past ten years. After years of development and innovation, the mobile phone industry

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has evolved from voice phones to smartphones. Generally, a smartphone is the product of convergence of regular mobile phone and PDA (personal digital assistant); hence a smartphone not only comes with a telecommunication function but incorporates the functionalities of PDA, such as Personal Information Management (PIM), multi-media, program application, Internet, and e-mail service. As the mobile phone market is a typical technology push driven market where products are created ahead of the recognition of existing recognized consumer needs [1], in such a market environment, a smartphone selection becomes an important issue to a consumer. According to Woodruff [2], customers' needs can be satisfied with product characters and functions. If the product or service can increase the utility/value, then customers will purchase these products. Since more and more consumers consider the smartphone is convenient and necessary in their daily lives, the producers had started to develop their sale strategies based on consumer preferences over time [3]. As the smartphone has become one of the most desirable electronic products for consumers, it is important for smartphone manufactures to comprehend the evaluation factors of consumers. Based on consumers' needs, then the smartphone manufactures can plan the development strategy for satisfying the consumers' voice of sound. In such circumstances, the smartphone evaluation can be considered as a multiple criteria decision problem. One of the most outstanding MCDM (multiple criteria decision making) approaches is the Analytic Hierarchy Process (AHP) which has its roots on obtaining the relative weights among the factors. Therefore, in this study, we use the AHP to propose an evaluation model with five aspects (user interface, mobile-commerce function, software and hardware specifications, entertainment function, and appearance and design) and twenty criteria to understand consumers' choice and adoption behaviors.

The remainder of this paper is structured as follows. The related studies are reviewed in Section II. Then an evaluation framework of smartphones is proposed in Section III. The AHP method to evaluate criteria and compute the criteria weights in Section IV Finally, results and conclusions are presented in Section V and VI.

## II. BACKGROUND

Researchers have various perspectives towards smartphones, for instance, "There is a significant difference between

smartphones and traditional phones, and defined smartphones are progress and require integrating multiple requirements into one device". TRI's (2006) industry report: The product trend of a smartphone is not only business-oriented but also entertainment-oriented. Beside, slim and fashion modeling, high resolution touch screen, high battery efficiency etc.

The related literature studies are to investigate what is the importance of the smartphone feature preferences for consumer. Han et al. [4], Chuang et al. [5], Han and Hong [6] attempted to investigate the relationship between user preferences of mobile phones and their design elements. User satisfaction depends on the product design and they build relationship models based on experimental data to predict user satisfaction and to provide significant remedies for design change. Chuang, Chang, and Hsu [5] analyzed the preference impression of design trend and design elements for mobile phones by the morphological analysis method, then defined the soft critical design elements to evaluate the suitable design solution of mobile phone. Isiklar and Buyuközkan [7] developed a multi-criteria decision making (MCDM) approach to evaluate the mobile phone options in respect to the users' preferences order.

Some researches concentrate on the mobile phone attributes and usage. It is well known that usability is a significant quality attribute of mobile phones and thus usability evaluation is becoming increasingly important in the mobile phone industry [8]. A research of product design for mobile phone considered product form features should include body (length, width, thickness, volume, and type), function button (type, style), number button (shape, arrangement) and panel (detail treatment). They analyzed the customer' needs of product designs for different styles users (plain, sports, female, simplicity and business) [9]. Chang, Chen and Zhou [10] identified nineteen features for the ideal smartphone and suggested eleven "must-have" and eight "desirable-to-have" features. Tetard and Collan [11] argued that users are in principle lazy and they are reluctant to make extra effort in complex situation-like choosing service that fits their needs.

AHP is a Multiple Criteria Decision Making (MCDM) method and has been widely used in weighing user requirements and preferences in many studies [12], [13]. Isiklar and Buyuközkan [7] have also used AHP as their research approach to evaluate users' preferences toward different mobile phone alternatives. Nikouand Mezei [14] evaluated the mobile services and substantial adoption factors with AHP.

### III. AN EVALUATION FRAMEWORK FOR SMARTPHONE MARKET

It is evident that the mobile phones are deeply rooted in every person's everyday life and enable undertaking of many tasks, therefore, the smartphone's great market potential and its popularity in telecom world can't be neglected.

AHP techniques enable to structure the problem explicitly and systematically. With the characteristics, decision makers can easily examine the problem and scale it in compliance with their requirements. Therefore, we utilize AHP approach to analyze consumers' purchase evaluation factors of smartphones.

The evaluation procedure of this study consists of three main steps and summarized in Fig. 1.

Step 1. Identifying the smartphone evaluation aspects and criteria that are considered important for the users.

Step 2. Constructing the evaluation criteria hierarchy and calculating the criteria weights.

Step 3. Finding out the final ranking results.

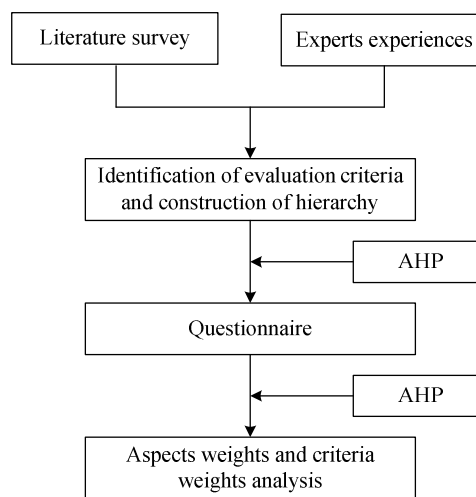


Fig. 1 The evaluation procedure

The primary objective is to understand the importance of factors affecting consumers' preferences related to smartphones. In order to propose the most reasonable aspects and criteria, we combine literature surveys and the experiences of related telecommunication experts to build five aspects and twenty criteria to evaluate the purchase factors of consumers. In compliance with the construction of hierarchy, the AHP questionnaire is designed. The evaluation aspects and criteria are shown in Table I. The User interface which is one of the aspects includes the criteria of the touch screen, easy to internet access, the high quality screen and the operation platform. The next aspect is the mobile-commerce function of a smartphone involving the criteria of the word processing, e-mail service, personal information manager (PIM), and global positioning system (GPS). The third aspect is the software and hardware specifications which consist of the criteria of the battery life, high-speed Internet access, build-in memory and central processing unit (CPU). The entertainment function is another aspect that comprises the criteria of the photograph function, multimedia, sound recording and mobile TV. The last aspect is the appearance and design which contains the criteria of the style design, cover material, screen size and its weight. The questionnaire has been designed to evaluate consumers' purchase factors of smartphones and paper-and-pencil questionnaire was used in this study. The respondents are comprised of the teachers and the graduate students of two universities in Taiwan.

TABLE I

EVALUATION ASPECTS AND CRITERIA	
Aspect	Criteria
User interface	Touch screen Easy to internet access High quality screen Operation platform
Mobile-commerce function	Word processing E-mail service Personal information manager (PIM) Global positioning system(GPS)
Software and Hardware specifications	Battery life High-speed Internet access Build-in memory Central processing unit (CPU)
Entertainment function	Photograph function Multimedia Sound recording Mobile TV
Appearance and design	Style design Cover material Screen size Weight

#### IV. AHP METHODOLOGY

The Analytic Hierarchy Process(AHP) is a multiple criteria decision making method proposed by Saaty [15]-[17], AHP was applied to uncertain decision problems with multiple criteria, and has been widely used in solving problems of ranking, selection, evaluation, optimization, and prediction decisions. AHP is a comprehensive framework designed to deal with the intuitive, rational response when we make multi-objective, multi-criteria, and multi-factor decisions with and without certainty for any number of alternatives.

The AHP includes four steps as follows:

Step 1. Develop the hierarchy structure

Decompose the analytic hierarchy of the decision problem. In order to ensure the consistency test, the analytic hierarchy does not exceed 7 in one level.

Step 2. Construct the pair-wise comparison matrix

Pair-wise comparison of the relative importance of factors/criteria and obtain an  $n \times n$  pair-wise comparison matrix, n means the number of criteria.

Step 3. Test consistency

AHP calculates the judgment consistency using the consistency index (C.I.) and consistency ratio (C.R.). The C.I. value is defined as  $C.I. = (\lambda_{max} - n)/(n - 1)$ , and the  $\lambda_{max}$  is the largest eigenvalue of the pair-wise comparison matrix. The C.R. value is defined as  $C.R. = C.I./R.I.$  (R.I.: random index). The R.I. value is decided by the value of n. In general, the values of C.I. and C.R. should be less than 0.1.

Step 4. Synthesis of the results to obtain a final ranking

Use the normalized eigenvector of the largest eigenvalue ( $\lambda_{max}$ ) as the factor weights and obtain a ranking, as shown in Table III and Table IV.

In the decomposition step, the components of the problem are organized in a hierarchical structure as shown in Fig. 2. The main goal of determining the most influential factors of purchasing a smartphone can be considered by evaluating the aspects of user interface, mobile-commerce function, software and hardware specifications, entertainment function and appearance and design. These aspects can be decomposed four criteria respectively.

After the hierarchical tree is constructed, pairwise comparisons are made in terms of importance for all combinations of elements. When comparing a pair of criteria, a ratio of relative importance expressed on a verbal scale is generally used as shown in Table II.

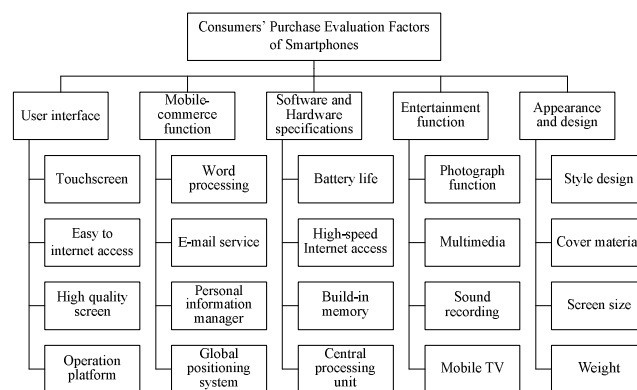


Fig. 2 The hierarchical structure of the problem

TABLE II

THE LINGUISTIC DESCRIPTION OF THE NUMERICAL SCALE IN AHP	
Numerical assessment	Linguistic meaning
1	Equal important
3	Moderately more important
5	Strongly more important
7	Very strongly important
9	Extremely more important
2,4,6,8	Intermediate values of importance

Consistency index (C.I.) and consistency ratio (C.R.) are used to evaluate the consistency of the pair-wise comparison matrix. The results of C.I. and C.R. are depicted in Table III.

TABLE III

THE TESTING OF CONSISTENCY	
$C.I. = (\lambda_{max} - n)/(n - 1)$	0.00
The threshold value	0.1
$C.R. = C.I./R.I.$	0.00
The threshold value	0.1

For the following part, the eigenvalues of the matrix are needed to be calculated which would give the relative weights of aspects and criteria. The aspect weights (pre and post normalization) and priority rankings are shown in Table IV and V. The data of all criteria weights and priority rankings are also shown in Table VI.

TABLE IV

ASPECT WEIGHTS (PRE-NORMALIZATION)		
Aspect	Pre-normalization	Ranking
User interface	0.337	2
Mobile-commerce function	0.127	3
Software and Hardware specifications	0.341	1
Entertainment function	0.077	5
Appearance and design	0.119	4

TABLE V

ASPECT WEIGHTS (POST-NORMALIZATION)		
Aspect	Post-normalization	Ranking
User interface	0.320	2
Mobile-commerce function	0.130	4
Software and Hardware specifications	0.332	1
Entertainment function	0.083	5
Appearance and design	0.135	3

TABLE VI  
CRITERIA WEIGHTS

Criteria	Weight	Ranking
Touch screen	0.0931	3
Easy to internet access	0.0465	9
High quality screen	0.0569	5
Operation platform	0.1230	2
Word processing	0.0307	14
E-mail service	0.0410	10
Personal information manager (PIM)	0.0317	12
Global positioning system(GPS)	0.0269	16
Battery life	0.0684	4
High-speed Internet access	0.0520	7
Build-in memory	0.0549	6
Central processing unit (CPU)	0.1565	1
Photograph function	0.0302	15
Multimedia	0.0193	18
Sound recording	0.0116	20
Mobile TV	0.0220	17
Style design	0.0383	11
Cover material	0.0315	13
Screen size	0.0477	8
Weight	0.0177	19

## V.RESULT

The problem of evaluating factors consists of three levels: the high level is the objective, the evaluating aspects are listed in the second level and the last level is the criteria.

The AHP methodology constructs the pair-wise comparisons of the aspects and the criteria in order to determine their weights. According to the aspect weights, Table V shows the aspect of software and hardware specifications play a main role with an overall weight of 33%. The weight of the user interface is 32%. The third ranking is the appearance and design of a smartphone, its weight is 13.5%. The following aspect is the mobile-commerce function which weight is 13%. The last aspect is the entertainment function.

The priority rankings and weights in Table VI were obtained for the criteria. We sort the weights of all criteria in order and the result is shown in Table VII. The respondents think the central processing unit (CPU) as the most important criterion. The operation platform ranked as the 2<sup>nd</sup> most important criterion. The touch screen and battery life criteria were ranked as the 3<sup>rd</sup> and 4<sup>th</sup>, while multimedia (0.019), weight (0.018), and sound recording (0.012) were ranked as the last 3 criteria

respectively.

The analysis of consensus degree can demonstrate the consistency of respondents in evaluation aspects and criteria. The indicator of consensus degree is the coefficient of variance (CV). If the coefficient of variance (CV) is smaller, the consistency of respondents' evaluations is higher. The consensus degree of aspects is shown as Table VIII. According to Table VIII, the highest coefficient of variance (CV) is the aspect of entertainment function which means the entertainment function has the lowest degree of consensus. The highest degree of consensus in aspects is the user interface as the aspect of user interface has the lowest coefficient of variance (CV). Furthermore, the consensus degree of criteria is shown as Table IX. In the first aspect of user interface, the highest degree of consensus is the criterion of operation platform. In the second aspect of mobile-commerce function, the highest degree of consensus is the criterion of e-mail service. Among the criteria of the next aspect of software and hardware specifications, the criterion of photograph function has the highest degree of consensus. In the last aspect of appearance and design, the highest degree of consensus is the criterion of screen size.

The scree plot of criteria weights ranking (Fig. 3) indicates that all the criteria can be divided into three groups. As shown in Fig. 3, the horizontal axis is the evaluation criterion and the vertical axis is the criterion weight. It is illustrated that the major and the minor factors which consumers consider to purchase smartphones. The first group consists of the first four criteria in the priority ranking. We can understand the most important evaluation criteria of consumers purchase smartphones. The second group includes seven criteria--the high quality screen, build-in memory, high-speed internet access, screen size, easy to Internet access, e-mail service and style design. The other nine criteria are the least important factors based on the respondents' opinions.

TABLE VII  
CRITERIA WEIGHTS AND PRIORITY RANKING

Criteria	Weight	Priority Ranking
Central processing unit (CPU)	0.1565	1
Operation platform	0.1230	2
Touchscreen	0.0931	3
Battery life	0.0684	4
High quality screen	0.0569	5
Build-in memory	0.0549	6
High-speed Internet access	0.0520	7
Screen size	0.0477	8
Easy to internet access	0.0465	9
E-mail service	0.0410	10
Style design	0.0383	11
Personal information manager (PIM)	0.0317	12
Cover material	0.0315	13
Word processing	0.0307	14
Photograph function	0.0302	15
Global positioning system(GPS)	0.0269	16
Mobile TV	0.0220	17
Multimedia	0.0193	18
Weight	0.0177	19
Sound recording	0.0116	20

TABLE VIII  
DEGREE OF CONSENSUS IN ASPECTS

Aspect	coefficient of variance (CV)
User interface	0.4940
Mobile-commerce function	0.6507
Software and Hardware specifications	0.5634
Entertainment function	1.2438
Appearance and design	0.9846

TABLE IX  
DEGREE OF CONSENSUS IN CRITERIA

Aspect	Criteria	CV
User interface	Touchscreen	0.6890
	Easy to internet access	1.0123
	High quality screen	0.8572
	Operation platform	0.4823
Mobile-commerce function	Word processing	0.9436
	E-mail service	0.6470
	Personal information manager (PIM)	0.8501
	Global positioning system(GPS)	0.7369
Software and Hardware specifications	Battery life	0.7916
	High-speed Internet access	0.8379
	Build-in memory	0.8015
	Central processing unit (CPU)	0.5191
Entertainment function	Photograph function	0.4273
	Multimedia	0.4920
	Sound recording	0.9020
	Mobile TV	0.9783
Appearance and design	Style design	0.7248
	Cover material	0.8972
	Screen size	0.4978
	weight	0.8439

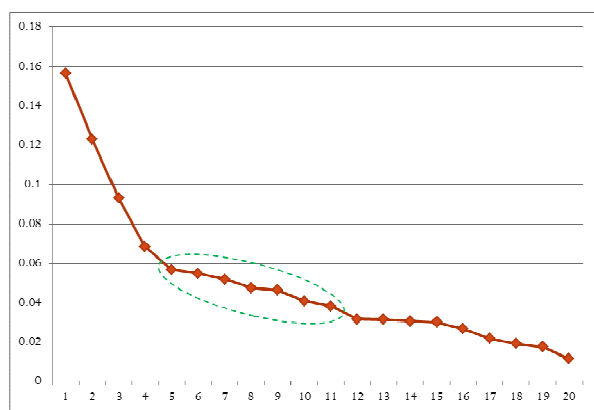


Fig. 3 The scree plot of criteria weights ranking

## VI. CONCLUSION

The advances in technology directly influence consumers' evaluation towards the smartphones. In this study, in order to realize the tendency of consumers' choosing factors, we utilize the Analytic Hierarchy Process (AHP) method to construct the hierarchical structure of consumers' evaluation. According to the aspects and criteria of the hierarchical structure, the model built to evaluate the main factors of purchasing smartphones.

The results indicate that the main choice factor of smartphones is software and hardware specifications. The first four most important criteria are central processing unit (CPU), operation platform, touch screen and battery life. Furthermore, it can use the coefficient of variance (CV) to judge the degree of consensus. The high consensus aspect and criterion are user interface and photograph function respectively.

We can learn consumers' chief considerations through AHP evaluation model. To expand the market share, the enterprises must create the features and services that meet consumer needs. As the development condition of the smartphone market is presented, the analysis can assist operators to find their improvement strategies of products and services for the smartphone market.

The investigation demonstrates that consumers hold a high level of expectations with the usefulness of smartphones. Such results reflect why the functions of smartphones and other technology products must be continuously enhanced. Therefore, to meet the needs of consumers, the improvement of the smartphone's functional dimension can facilitate conveniences of work and life. The research findings have also some practical implications, for example, designs of products and service, the development for application and the adoption of marketing strategies should take notice of consumers' preferences.

The proposed framework in this study is illustrated with respect to the perspectives of Taiwanese smartphone users; it can extend to explore the users' preferences of different countries and compare the results in the future research.

## REFERENCES

- [1] O. Gerstheimer, and C. Lupp, "Needs versus technology—the challenge to design third-generation mobile applications," *Journal of Business Research.*, vol. 57, no. 12, 2004, pp. 1409–1415.
- [2] R. B. Woodruff, "Customer value: The next source for competitive edge," *Journal of the Academy of Marketing Science.*, vol.25, no.2, 1997, pp. 139-153.
- [3] P. Mahatanankoon, H. J. Wen, and B. Lim, "Consumer-based m-commerce: exploring consumer perception of mobile applications," *Computer Standards & Interfaces.*, vol. 27, no. 4, 2005, pp. 347-357.
- [4] S.H. Han, K.J. Kim, M.H. Yun, S.W. Hong, and J. Kim, "Identifying Mobile Phone Design Features Critical to User Satisfaction," *Human Factors and Ergonomics in Manufacturing.*, vol. 14, no. 1, 2004, pp. 15-29.
- [5] M.C. Chuang, C.C. Chang, and S.H. Hsu, "Perceptual factors underlying user preferences toward product form of mobile phones," *International Journal of Industrial Ergonomics.*, vol. 27, 2001, pp. 247-258.
- [6] S.H. Han, and S.W. Hong, "A systematic approach for coupling user satisfaction with product design," *Ergonomics.*, vol.46, 2003, pp. 1441-1461.
- [7] G. Isklar, and G.B'uy'uk'ozkan, "Using a multi-criteria decision making approach to evaluate mobile phone alternatives," *Computer Standards and Interfaces.*, vol. 29, no. 2, 2007, pp. 265–274.
- [8] H.B.-L. Duh, G. C. B. Tan, and V.H.-h. Chen, "Usability evaluation for mobile device: a comparison of laboratory and field tests," *In: Proceedings of the 8th Conference on Human-Computer Interaction with Mobile Devices and Services*, Helsinki, Finland, 2006, pp. 181-186.
- [9] M. D. Shieh, and C. C. Yang, "Classification model for product form design using fuzzy support vector machines," *Computers & Industrial Engineering.*, vol. 55, 2008, pp. 150-164.
- [10] Y.F. Chang, C.S. Chen, and H. Zhou, "Smart phone for mobile commerce," *Computer Standards and Interfaces.*, vol.31, 2009, pp. 740-747.

- [11] F. Tetard, and M. Collan, "Lazy user theory: A dynamic model to understand user selection of products and services," *In: Proceedings of the 42<sup>nd</sup> annual Hawaii international conference on system sciences.*, 2009, pp. 1-9.
- [12] Y. Chou, C. Lee, and J. Chung, "Understanding M-commerce Payment Systems through the Analytic Hierarchy Process," *Journal of Business Research.*, vol.57, 2004, pp.1423-1430.
- [13] D. I. Giokas, and G. C. Pentzaropoulos, "Efficiency ranking of the OECD member states in the area of telecommunications: A composite AHP/DEA study," *Telecommunications Policy.*, vol. 32, 2008, pp. 672-685.
- [14] S. Nikou, and J. Mezei, "Evaluation of Mobile Services and Substantial Adoption Factors: with Analytic Hierarchy Process (AHP)," *Telecommunications Policy*, vol. 15, DOI: 10.1016/j.telpol.2012.09.007.
- [15] T. L. Saaty, "Exploring the interface between hierarchies, multiple objectives and fuzzy sets," *Fuzzy Sets and Systems.*, vol. 1, no. 1, 1978, pp. 57-68.
- [16] T. L. Saaty, "Decision-making with the AHP: Why is the principal eigenvector necessary. European," *Journal of Operational Research.*, vol. 145, no. 1, 2003, pp. 85-91.
- [17] T. L. Saaty, "Rank from comparisons and from ratings in the analytic hierarchy/network processes," *European Journal of Operational Research*, vol. 168, no. 2, 2006, pp. 557-570.