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Smartphone Market Analysis Using Dynamic Multi-Criteria Decision Methods

Ruey-Chyn Tsaur, I-Fei Chen and Yin-Cheng Chen

Tamkang University

Abstract

The iPhone introduced an innovative multi-touch interface to satisfy customers' attractive requirements. Thereafter, most smartphone manufacturers begin to mimic this innovation in their new generation products for a dramatically increasing demand market. Although the smartphone market includes many types and functions of products, there are no smartphone selection methods to support customers to select an effective smartphone. In order to cope with such a problem, this paper proposes a multi-criteria selection method to evaluate operating systems and hardware and software specifications using AHP and SMART-ROC, respectively. For illustration, this paper uses the proposed methods to analyze the customer utility and benefit-cost of 24 popular smartphones in the market. The results show that the most popular smartphone does not have the best cost-benefit. This paper suggests customers select smartphones by referring to the cost-benefit approach except when they are looking for a communications product for a special purpose.

Keywords: Smartphone, AHP, SMART-ROC, cost-benefit analysis.

1. Introduction

In 2007, Apple launched the intelligent iPhone handset, which consumers lined up to purchase. With its simple and easy-to-use user interface and its strong application platform, it has forced other smartphone manufacturers to transform and be more innovative in order to be competitive. Today, smartphones have many functions that conventional personal computers used to provide, such as Web browsing, email, dynamic community updating, and even video conferencing [1]. Consequently, smartphones have greatly increased their penetration ratio and acceptability for most users. As smartphone technologies continuously evolve, the definition of a smartphone is becoming ambiguous. Hsu [8] claims that it is too narrow to define the smartphone only using hardware specifications and functions; and he suggests that the definition should be based on the degree of "smartness". Therefore, in addition to voice communication, the smartphone should be equipped with an open operating system (OS) and sufficient computational capability. The user can select application software to extend the smartphone's capacity to almost limitless functions. Litchfield [10] re-visits the five publicly known definitions of the smartphone, and finds that the boundary between a smartphone and a feature phone is unclear. Advanced technology allows a feature phone to have the functions of a smartphone, such as a touch screen and an OS. Chen et al. [2] argue that a manufacturer standard for smartphones does not exist. The open platform of a smartphone's OS allows customers to download a variety of application software programs (apps), and install and delete them to customize their own handsets. With the trend of strong development of the global communication industry, wireless communication capability has become the most important factor of mobile technology [7]. Supported by hardware, software, and network technology, communication products have become more mature, which has led to a change in consumers' lifestyles. Generally, younger, educated, and wealthy individuals tend to use smartphones and smartphone applications to a greater extent; and females tend to use smartphones, e-commerce applications, and relational applications more than males [9]. The usage range of mobile phones has changed from the previous consumer network usage mode of a simple voice communication function to network-connected and multimedia interactive functions. Consumer's usage time and dependence on networks have increased. This implies that mobile phones have changed to a new form and will become increasingly intelligent. The phone manufacturers and smartphone software and hardware developers all offer a variety of functions that make smartphone so diverse. In such a situation, after scanning all the commonly available features of smartphones in the market, this paper defines a smartphone as a phone having the following three features:

(1) A larger touch screen than feature phones with the basic mobile phone functions retained, such as video-audio communication, short message, camera, and video-audio recording and playback.
(2) Capability to connect to a network, Wi-Fi compatibility, ability to sync to a personal computer for correspondence, a work schedule, and a notebook.
(3) Equipped with a built-in multi-tasking central processing unit (CPU) that has powerful computational capability.

In the smartphone market, with its diversity of products, most customers find it difficult to select the best smartphone. For example, assorted smartphone brands have flooded the Taiwanese market, including the local HTC series, the Apple iPhone, the Samsung series, and many others. How to assess the quality of smartphones has become an important issue for consumers. In the past, research focused on the comparison and evaluation of smartphone infrastructure systems ([14], [12], [4], [15]). However, from the customer point of view, they hope to select a cost- or function-effective smartphone for themselves. Therefore, in this study, we attempt to focus on smartphone OSs and analyze and compare the attributes of hardware from most of the smartphones in the Taiwanese market. The traditional multi-attribute decision-making (MADM) analysis is a good tool for this analysis, but it tends to be static. As smartphone providers continuously launch new models with new functions over time, a dynamic evaluation approach has become important to consumers. We first investigate the research background and provide a through literature review in which we identify the research gap to generate our research problem and research objective. Second, a suitable research tool for problem analysis is identified and a model consumers can assess is constructed using simple multi-attribute rating technique (SMART) and analytical hierarchy process (APH) tools. Third, an empirical study is conducted using surveys and the results are analyzed based on benefit-cost performance. Finally, a discussion and conclusion is provided. This paper is organized as follows. Section 2 reviews the MADM methods used in this paper. Then, Section 3 presents the proposed concept for this study. In Section 4, an illustrative example analyzes consumers' purchasing strategy in the Taiwanese smartphone market. Finally, Section 5 draws conclusions and provides suggestions for future research.

2. Review of MADM Methods

2.1 SMART method

Decision-making analysis is important because a good analytical method can really help decision makers cope with uncertain problems. With respect to a multiple-criteria evaluation problem, we define and evaluate each attribute independently, and then the total value required to evaluate the alternatives can be obtained by simply summing up the criteria values. Chien [3] points out that a simple decision-making method is better than complex method in supporting a decision maker to make a better choice. There are many multi-criteria decision methods; Edwards [5] developed SMART and proposed 10 steps for the model, as follows:

(1) Identify who is the decision maker to decide whose value should be considered.
(2) Confirm decision factors and objectives.
(3) Identify selectable cases.
(4) Identify the related evaluation attributes.
(5) Rank the attributes by degree of importance.
(6) Assign a weight to each attribute according to its degree of importance.
(7) Standardize the weights obtained in step 6.
(8) Calculate the value of each case for each attribute.
(9) Calculate the total value of the case by summing up the values obtained in step 8.
(10) Select the best case.

Although SMART is simple and easily applied in management and engineering, many researchers have encountered challenges using it. Therefore, Edwards and Barron [6] developed SMART-ROC and SMARTS to derive better weighting methods for the choice criteria. SMART-ROC improves steps 6 and 7 of SMART, and uses average value as the weights of multiple criteria, called the ROC weighing method. The key considerations of SMART-ROC are the quantity of criteria and the ranking of weights.

If the ranking sequence of all the criteria is $R_1, R_2, \ldots, R_n$, and the relative weighing sequence is $W_1, W_2, \ldots, W_n$, meeting the condition $1 > W_1 \geq W_2 \geq \ldots \geq W_n > 0$, then the weight for each criterion i can be obtained as follows:

$$W_i = \frac{1}{n} \sum_{k=1}^{n} \frac{1}{k} \tag{1}$$

Next, SMARTS starts from the perspective that the total value will be changed if the weights change. Comparatively, it can better reflect the preferences of the decision maker. The weight exchange method assigns the weights based on this perspective.

2.2. Analytical hierarchy process

Saaty [16] developed the analytical hierarchy process (AHP) to solve the problem of multiple criteria decision making in uncertain situations. The purpose of AHP is to systemize a complex problem by utilizing a hierarchical structure from the top level to the lower level of the hierarchy, so that the problem can be resolved in stages. Because many complex problems can be easily solved using the AHP method, many researchers have devoted themselves to the field of AHP. For example, Partovi and Burton [13] pointed out that AHP is a decision support tool used to handle complex, unstructured, and multiple attribute problems. Vaidya and Kummar [18] deemed AHP a decision-making analytical method that solves qualitative problems with a quantitative approach. Sedzro et al. [17] described AHP as an analytical method for decision making that deals with subjective and difficult-to-quantify elements.

As a whole, AHP is applied to the problem of multiple criteria under uncertain conditions. A simple and clear hierarchical system is built first. Through expert interviews, the decision maker's opinions are collected to select the proper evaluation indicator. Pairwise comparisons among factors are conducted using nominal scale to calculate the eigenvector and obtain the weight relationship. The weights help the decision maker to rank the priority sequence of hierarchical factors and lower the risk of making the wrong decision. The AHP method can be conducted with the following steps:

(1) Build the hierarchical structure. For a complex problem, key dimensions are dissolved into criteria at the next lower level to form a hierarchical structure. The targeted layer is developed last.

(2) Build the pairwise comparison matrix. Any two criteria on the same level are compared using the relative importance r of criteria evaluation with respect to a higher level. The values of the pairwise comparison of n criteria are placed in the upper triangular area, where a_{ij} stands for the relative importance of criterion i to criterion j. The values in the lower triangular area are the inverse of those in the upper triangular area, that is, $a_{ij} = 1/a_{ji}$. The values along the diagonal of the matrix are

all 1 because the indicators are compared to themselves.

$$A = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ 1/a_{12} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ 1/a_{1n} & 1/a_{2n} & \cdots & 1 \end{bmatrix}. \quad (2)$$

(3) Calculate the maximum eigenvalue and eigenvector. After the pairwise comparison matrix is obtained, we can derive the eigenvalue using the concept of linear algebra. Let w_i and w_j be the weights of criteria A_i and A_j, respectively. Assign $a_{ij} = w_i/w_j$, and the pairwise comparison matrix can be obtained as follows:

$$\mathbf{A} = [a_{ij}] = \begin{bmatrix} w_1/w_1 & w_1/w_2 & \cdots & w_1/w_n \\ w_2/w_1 & w_2/w_2 & \cdots & w_2/w_n \\ \vdots & \vdots & \vdots & \vdots \\ w_n/w_1 & w_n/w_2 & \cdots & w_n/w_n \end{bmatrix}. \quad (3)$$

Let W be the weight vector of n criteria, that is, $\mathbf{W} = [w_1, w_2, \ldots, w_n]^T$; then, the inner product of **A** and **W** can be derived as follows:

$$\mathbf{A} * \mathbf{W} = \begin{bmatrix} w_1/w_1 & w_1/w_2 & \cdots & w_1/w_n \\ w_2/w_1 & w_2/w_2 & \cdots & w_2/w_n \\ \vdots & \vdots & \vdots & \vdots \\ w_n/w_1 & w_n/w_2 & \cdots & w_n/w_n \end{bmatrix} \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{bmatrix} = \begin{bmatrix} nw_1 \\ nw_2 \\ \vdots \\ nw_n \end{bmatrix} = n * \mathbf{W}. \quad (4)$$

Because a_{ij} indicates the subjective ratings given by the decision maker, there must be a distance between it and the actual values w_i/w_j. Thus, $\mathbf{A} * \mathbf{W} = \mathbf{n}{*}\mathbf{W}$ cannot be calculated directly. Therefore, Saaty [16] suggested using the maximum eigenvalue, $\lambda_{\max}$, of the solution of matrix **A** to replace n; then:

$$\mathbf{A}{*}\mathbf{W} = \lambda_{\max}{*}\mathbf{W}. \quad (5)$$

(4) Weight vector **W** is a non-null vector that satisfies $w_1 + w_2 + \cdots + w_n = 1$. Then, the maximum eigenvalue $\lambda_{\max}$ and weight vector can be solved.

(5) Check the consistency ratio (C.R.). Consistency means the process is reasonable and has no obvious conflict throughout the whole evaluation process. C.R. is used to check if the consistency is satisfied. In general, the consistency can be guaranteed when the C.R. value is less than or equal to 1. C.R. = CI∗RI. R.I. stands for random index. Table 1 is the random index list when there are m decision-making factors.

Table 1: Random Index List.

Level	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
R.I.	N.A.	N.A.	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.58

3. Smartphone Evaluations

This study aims to construct a smartphone selection and evaluation process in the Taiwanese smartphone market. Based on the smartphone evaluation criteria collected from a report by MyPhoneDeals [19], we investigate most smartphones in the market. Because smartphones have the characteristics of a short life-cycle and fast technology evolution, most smartphone providers have to consider how to create the next generation of smartphones and what kind of competitive advantage can attract more customers' attention to use their products, that is, what functions and unique features consumers would consider in selecting a handset. Therefore, we use SMART and AHP evaluation techniques as the base, utilize expert comments as the niche, and analyze in detail the integrated combination of hardware, software, and contents to induce the confirmed decision making factors. After discussing with experts, the high-priority factors qualified for consumers' consideration in selecting a handset are obtained; these includes smartphone internal and external factors such as OS, external appearance and usage experiences, hardware, advertisement, and service.

3.1 The evaluation equation

This study first analyzes the most popular OSs in the smartphone market. These include iOS, used by iPhone 5; Android, used by HTC One X and Samsung Galaxy S3; and WP, used by Nokia Lumia 20. Then, 24 models of smartphones available in the market are selected for priority analysis and comparison for the cost-benefit analysis. As mentioned, the qualified evaluation factors are: (1) external appearance and usage experience, (2) hardware, (3) advertisement, and (4) service. The smartphone evaluation hierarchy is shown in Figure 1. We know the OS is the system that manages mobile hardware and software resources and provides common services for programs. Because the OS plays a specific role in a smartphone, different OSs have different performance values; thus, we derived evaluation information from experts using the AHP method. Next, the SMART method was used to evaluate the performance of hardware and software resources for the selected smartphones. If we define the evaluated normalized score of hardware and software resources as $X_1, X_2, \ldots, X_N$ ranged in $[0, 1]$ for M smartphones, then we can sum up the intercept value a_{ij} and evaluate the score of the hardware and software as follows:

$$Y_i = a_{ij} + a_1 X_{i1} + a_2 X_{i2} + \cdots + a_N X_{iN} = a_{ij} + \boldsymbol{a}\boldsymbol{X}_i; \quad i = 1, 2, \ldots, M, \quad j = 1, 2, 3 \tag{6}$$

where $a_1, a_2, \ldots, a_N$ are weights for N hardware and software resources, respectively.

For the ith smartphone with the jth OS, a_{ij} is the intercept for equation (6); different OSs have different intercepts. In equation (6), the value of a_{ij} for the ith smartphone with the jth OS is evaluated by experts using AHP because experts have sufficient experience in evaluating the advantages of OSs. Consequently, the OS with better performance has a larger intercept in equation (6), and thus a specific smartphone's evaluation Y_i might be larger than those of the others whose intercepts are smaller. Further, the utility

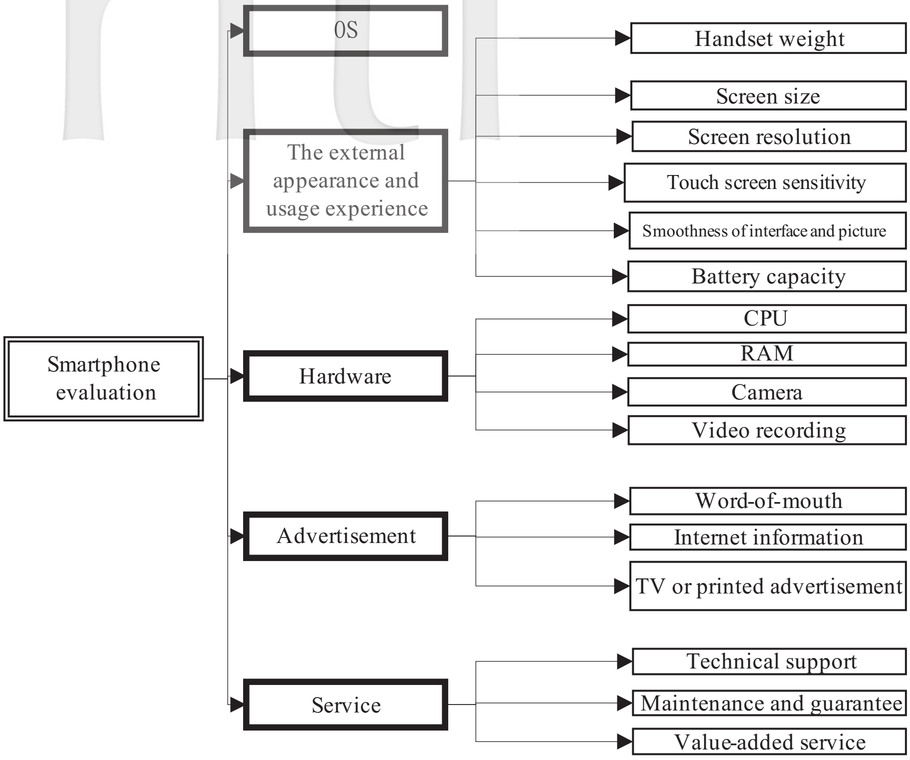

Figure 1: The hierarchical analysis for smartphone evaluation.

$\boldsymbol{aX_i}$ of the ith smartphone is evaluated using the SMART method and the hardware and software are evaluated using questionnaires or testing results from some hardware-testing websites. As shown in Figure 2, the second OS, the performance of which is a_{i2}, which is less than the a_{i1} performance of the first OS; thus, most smartphones using the second OS are lying near Y_2, with performance less than that of smartphones lying near Y_1—except some smartphones, which have excellent hardware and software performance.

3.2. Cost-benefit analysis

In most enterprises, all staff, including the CEO, managers, and even technicians, have to consider improvement, problems, planning, and decision making. The problems range from daily operations to long-term planning. In general, a decision maker chooses the best performance alternative to manage and overcome difficulties. In order to allocate limited resources, decision making to solve management problems is usually based on an evaluation of the economic performance, after which the best alternative is selected. The benefit-to-cost ratio (B/C ratio) is a financial term that describes the comparison of the amount of benefit made through the production of an item versus the costs incurred during the production process. Businesses must evaluate the B/C ratio to make sure

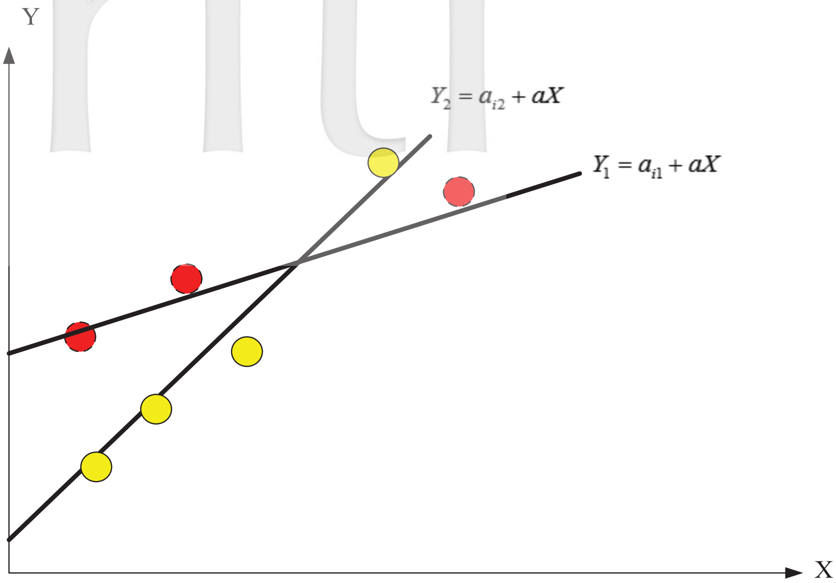

Figure 2: Evaluation results for the selected smartphones.

that production is profitable. If the costs outweigh the benefit, then it is no longer profitable for a company to produce the item under the same set of circumstances. Based on this B/C concept, in the smartphone-ranking analysis, our analysis of the B/C ratio involves systematically comparing smartphone performance with the corresponding prices to assess the relative value of each smartphone. This study adopts the conventional B/C ratio as follows:

$$\frac{B}{C} = \frac{\text{Evaluated performance of a smartphone}}{\text{Price of a smartphone}} = \text{the relative value of each smartphone} \tag{7}$$

where B is the normalized performance for the selected smartphone, and C is the normalized price for the selected smartphone. If B/C ≥ 1, then the normalized performance exceeds or equals the normalized price for the selected smartphone. Conversely, B/C < 1 means that the normalized price exceeds the normalized performance.

4. Empirical Study

This study aims to construct an evaluation process for smartphone selection in the Taiwanese smartphone market. We first use the AHP method to analyze OSs for most smartphones in the Taiwanese market, including iOS, Android, and Windows Phone, between the period of 10/01/2012 and 05/31/2013. Then, 24 models of smartphones available in the market are selected and analyzed using the SMART method. The qualified evaluation factors are: (1) the external appearance and usage experience, (2) hardware, (3) advertisement, and (4) service. Then we sum up the performance of the selected smartphones using AHP and SMART to obtain the total performance. Finally, we compare the selected smartphones using the cost-benefit method.

4.1. Step 1: OS evaluation using the AHP analytic process

Malykhina [11] deems the OS to be the heart of a smartphone. Because the hardware specification competition has almost reached its limits, the most important issue is to develop OS extensions for smartphone innovation. Hence, smartphone providers need to offer firmware updates at certain points in time to allow consumers to have different usage experiences and feelings. The main criteria for evaluating the OSs are classified as general functions, multimedia and gaming, and Internet connectivity. Based on the three criteria, we design a questionnaire to compare the three Oss, that is, Apple's iOS, Google's Android, and Windows Phone, to identify their differences. Table 2 lists the attributes and the considerations.

Table 2: Factors of AHP Evaluation Criteria.

Evaluated Attributes	**Main Considerations**
Application program (apps)	Quantity and quality of apps and free apps ratio
Usability and design	Does the OS support multi-function tasks in its operating interface design?
Web browsing	Smoothness of browsing, support for Flash
Email and messaging	Is there any integrated software (e.g., iMessage, Gmail, community capability) or voice control?
Photos and videos	How is the photo quality or human-based design for photo taking?
Music	Is there any music integrated software, sync function, or movie play software?
Gaming	Integration with game box with better quantity and quality of games
Syncing and backup	Can wireless sync and cloud backup be used easily?
Customization	Is the platform open or customized for choice (e.g., change of usage interface)
Social and other integration	Is a built-in community integrated (Facebook, Twitter, etc.)?
Updating	Update online, auto update notification
Live data	Dynamic real-time data notification received on interface, or tools available

The evaluated attributes and main considerations are obtained by consolidating expert opinions through interviews and brainstorming based on the three main criteria. The three main criteria are placed on the first level. The evaluated attributes associated with each criterion are then placed on the secondary level. The target OSs to be compared and selected are placed on the third level. The resulting hierarchical diagram is shown in Figure 3. The questionnaire is designed based on the main considerations of the evaluated attributes listed in Table 2 or the secondary level of Figure 3. To conduct the survey, questionnaires are distributed to the heads or managers of the top 10 most popular handset stores. The collected data are run through the Expert Choice 2000 software tool to compute the weights of the factors on each level. The consistency ratio is also checked with the same software tool. As mentioned above in the section on smartphone OS function selection, three criteria are selected: general, multimedia, and Internet connection. Each criterion contains several attributes. Then, the overall comparison matrix is generated. Finally, the weights, consistency ratio, attribute influence degree, and ranking are calculated and listed in Table 3. As shown in Figure 4, Apple's iOS has best performance, Google's Android is second, and Windows Phone is third. This means that iPhone has the competitive advantage with respect to the higher performance of iOS.

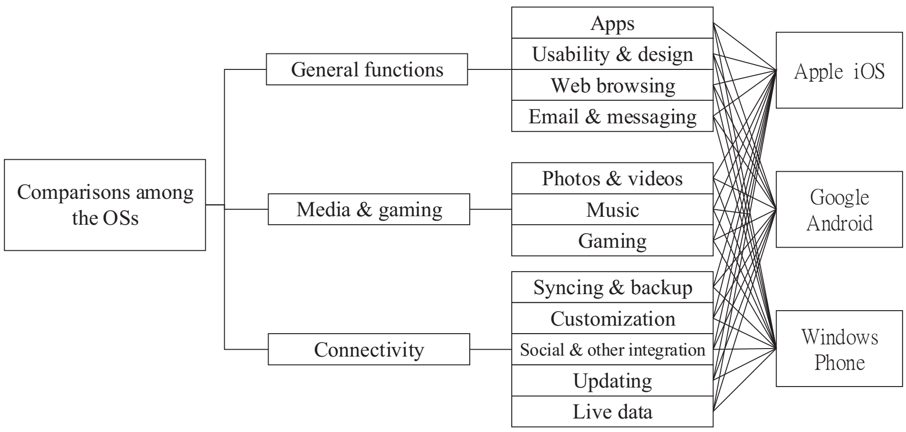

Figure 3: AHP Hierarchical Diagram.

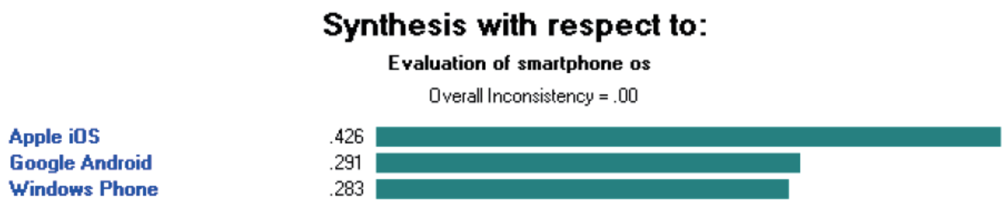

Figure 4: Smartphone OS evaluation.

Table 3: Values of Criteria Dimension Weights, Indicator Weights, and Ranking.

Criteria	Criteria Weights	Subcriteria	Subcriteria Weights	Overall Weight	Overall Ranking
General	0.341	Apps	0.405	0.138	1
		Usability and design	0.386	0.132	3
		Web browsing	0.128	0.044	8
		Email and messaging	0.081	0.028	11
Multimedia	0.188	Photos and videos	0.283	0.134	2
		Music	0.111	0.021	12
		Gaming	0.198	0.037	10
Internet connectivity	0.472	Syncing and backup	0.283	0.134	2
		Customization	0.086	0.041	9
		Social and other integration	0.170	0.080	7
		Updating	0.255	0.120	5
		Live data	0.206	0.097	6

4.2. Step 2: The result of SMART analysis

In this step, we use SMART-ROC to evaluate the scores for the selected smartphones for the main criteria shown in column 1 of Table 4. The subcriteria for each main criterion are shown in column 2 of Table 4. This paper uses the SMART-ROC method as the core of the analysis, where the order for the main criteria is external appearance, hardware, service, and advertisement with corresponding weights of 0.5208, 0.2708, 0.1458, and 0.0625, respectively. Clearly, in Table 4, all of the subcriteria can be classified into quantitative and qualitative categories. Quantitative attributes are measured by quantitative indicators such handset weight and screen size. Qualitative attributes such as touch screen sensitivity, interface and picture smoothness are measured by conducting a questionnaire survey using a seven-point Likert scale, except for the subcriterion of technical support, which is measured with a five-level scale because setting too narrow a specification is difficult for experts with a non-engineering background. In addition, some quantitative attributes must be measured based on the decision maker's subjective cognition, such as maintenance and guarantee, and value-added service.

For different subcriteria with different scales, we need to normalize all the subcriteria values to avoid some criteria in larger numeric ranges dominating those in smaller numeric ranges; another advantage is that this avoids numerical difficulties during the calculation. However, the normalized number n_{ij} (the rating of main criterion i with respect to subcriterion j) is linearly scaled to the range $[0, 1]$, which usually has a small gap where loss of information for ranking the derived numbers is possible. In order to cope with this problem, we enlarge the normalized value to be as large as possible, and make the lower value as small as possible. The normalized function is defined as follows:

$$n_{ij} = \Big\{\Big[\frac{\max_i\{x_{ij}\} + \rho_1) - x_{ij}}{(\max_i\{x_{ij}\} + \rho_1)(\max_i\{x_{ij}\} - \rho_2)}\Big]\Big\} \times 100 \tag{8}$$

where x_{ij} is the value of main criterion i with respect to subcriterion j, and ρ_1, ρ_2 are two given proper values for adjusting the possible range to cover some possible unknown information or trend for the subcriterion. In this study, we derive the range of all main criteria with respect to their corresponding subcriteria in column 3 of Table 4. Then, using the information in Table 4, the evaluation values of these 24 models of smartphones are obtained from the expert point of view or hardware specifications. Next, the weights of all the main criteria are shown in column 3 of Table 5 using the SMART-ROC method. This study selects four kinds of smartphone models with respect to three types of OS, including iOS, Android, and Windows OS, and then we use AHP to extract the expert opinions to obtain the ranking of the OSs. After summing up the value to multiply the weight value and criteria value for each smartphone, the utilities of all 24 models of smartphone are shown in Table 6. For example, in order to obtain the ranking of iPhone 4, we sum up the total criteria value, obtained as $56.9 \times 0.5208 + 21.8 \times 0.2708 + 76.7 \times 0.0625 + 73.3 \times 0.1458 = 51.3$, ranking it 21st among the selected smartphones. Obviously, in Table 6, the HTC One X+, Samsung Galaxy S3, and iPhone 5 are ranked as the first three. We know that they are the top smartphones for HTC, Samsung, and Apple, respectively. However, according to most users' impression, the iPhone series always dominates the other smartphones. Therefore, we need to consider the OS differences among iOS, Android, and Windows using the AHP method.

4.3. Step 3: Sum up the evaluation results for the selected smartphones

Because the OS is the main smartphone support factor, and the main criteria (i.e., external appearance and usage experience, hardware, advertisement, and service) make the smartphone valuable, we consolidate the handset OS and the other four evaluation criteria to sum up the evaluated score for the selected smartphones using the concept of a multiple regression equation, defined as follows:

$$y_i = \alpha + \beta\Big[\sum_{k=1}^{6}\frac{n_{i1k}}{6}\Big] + \gamma\Big[\sum_{k=1}^{4}\frac{n_{i2k}}{4}\Big] + \tau\Big[\sum_{k=1}^{3}\frac{n_{i3k}}{3}\Big] + \rho\Big[\sum_{k=1}^{3}\frac{n_{i4k}}{3}\Big] \tag{9}$$

where α is the OS score; $\beta, \gamma, \tau, \rho$ are the weights for the main criteria, respectively; and n_{ijk} is the normalized score of the ith smartphone for the jth main criterion with respect to the kth subcriterion, $j = 1, 2, 3, 4$; $k \geq 1$. Then, the total value for the selected smartphone can be obtained using equation 9, as shown in column 4 of Table 7.

In Table 7, we can see that the iPhone 5, HTC One X+, iPhone 4S, Samsung Galaxy S3, and HTC WP 8X, all of which are popular and high performance smartphones, are ranked numbers one to five, respectively. Some medium and lower performance

Table 4: Criteria and their Defined Ranges.

Main Criteria	Subcriteria	Range Defined for the Attribute
External appearance and usage experience	Handset weight	max = 185 gram, min = 112 gram, $\rho_1 = 15$, $\rho_2 = 10$
	Screen size	3.5 − 5.5 inch, $\rho_1 = \rho_2 = 0.5$
	Screen resolution	max = 332 PPI, min = 306 PPI, $\rho_1 = 100$, $\rho_2 = 100$
	Touch screen sensitivity	7-point Likert scale, $\rho_1 = 1$, $\rho_2 = 1$
	Smoothness of interface and picture	7-point Likert scale, $\rho_1 = 1$, $\rho_2 = 1$
	Battery capacity	max = 12 (hr), min = 8 (hr), $\rho_1 = 10$, $\rho_2 = 2$
Hardware	CPU	max = 1628, min = 1505, $\rho_1 = 500$, $\rho_2 = 1000$, score based on the Geekbench testing software
	RAM	max = 2 (GB), min = 1 (GB), $\rho_1 = 2$, $\rho_2 = 0.5$
	Camera	max = 8.7 mega-pixels, min = 8 mega-pixels, $\rho_1 = 4$, $\rho_2 = 3$
	Video recording	Give 1080 the highest score (80) and 720 the lowest score (60)
Advertisement	Word-of-mouth	7-point Likert scale, $\rho_1 = 1$, $\rho_2 = 1$
	Internet information	7-point Likert scale, $\rho_1 = 1$, $\rho_2 = 1$
	TV or printed advertisement	20 million dollars and above, evaluated by experience scores between 0 and 100
Service	Technical support	5-point Likert scale, $\rho_1 = 1$, $\rho_2 = 1$
	Maintenance and guarantee	User experience scores between 0 and 100
	Value-added service	User experience scores between 0 and 100

Table 5: Main Criteria Weights Derived Using the SMART-ROC Method.

Main Criteria	Ranking Order	Weight
External appearance and usage experience	1	0.5208
Hardware	2	0.2708
Advertisement	4	0.0625
Service	3	0.1458

smartphones follow. Comparing the iPhone 5 and HTC One X+, we find that HTC One

Table 6: Ranking Smartphones by Summing Criteria Weight and Evaluated Value.

Selected Smartphones	External Appearance and Usage Experience	Hardware	Advertisement	Service	Criteria Score	Ranking
iPhone 5	72.6	50.2	73.3	76.7	67	3
HTC One X	71.2	48.7	62.4	85	66.6	4
Samsung Galaxy S3	69.5	57.8	86.7	76.7	68.4	2
Nokia Lumia 920	63.6	51.5	74.3	93.3	65.3	5
iPhone 4S	57.5	35.1	73.3	76.7	55.2	13
iPhone 4	56.9	21.8	73.3	76.7	51.3	19
HTC One X+	75.4	51.7	62.4	85.0	69.6	1
HTC One SC	60.6	39.5	62.4	85.0	58.5	10
HTC J	64	48.8	62.4	85.0	62.8	6
HTC One V	54.8	15.1	62.4	85.0	48.9	24
HTC One S	62.3	49.6	62.4	85.0	62.2	7
HTC Desire X	60.7	19.2	62.4	85.0	53.1	18
HTC Desire V	55.8	15.5	62.4	85.0	49.6	22
HTC Sensation XL	51.4	29.4	62.4	85.0	51.0	20
HTC Sensation XE	55.8	36.0	62.4	85.0	55.1	14
Samsung Galaxy S2	58.0	43.0	86.7	76.7	58.4	11
Samsung Galaxy Note 2	48.5	62.7	86.7	76.7	58.9	8
Samsung Galaxy Note	49.6	44.8	86.7	86.7	54.6	16
Samsung Galaxy S Advance	56.2	22.4	86.7	76.7	49.6	22
Samsung Galaxy Nexus	61.6	31.7	86.7	76.7	51.0	20
Samsung Galaxy R	56.9	33.5	86.7	76.7	55.1	14
Nokia Lumia 820	57.3	49.2	74.3	93.3	58.4	11
Nokia Lumia 900	51.5	31.8	74.3	93.3	58.9	8
HTC WP 8X	76.1	51.1	62.4	78.3	54.6	16

X+ has a better criteria score than iPhone 5, which means the HTC One X+ is evaluated significantly for external appearance and usage experience, hardware, advertisement, and

Table 7: Final Results of Analysis.

Smartphone Model	Utility and OS Weight			Ranking
	Criteria Scores	OS Weight	Total Value	
iPhone 5	67.1	42.6	113.3	1
HTC One X	66.6	29.1	95.7	6
Samsung Galaxy S3	68.4	29.1	97.5	4
Nokia Lumia 920	65.3	28.3	93.6	8
iPhone 4S	55.2	42.6	97.8	3
iPhone 4	51.3	42.6	93.9	7
HTC One X+	69.6	29.1	98.7	2
HTC One SC	58.5	29.1	87.6	13
HTC J	62.8	29.1	91.9	9
HTC One V	48.9	29.1	78.0	24
HTC One S	62.2	29.1	91.3	10
HTC Desire X	53.1	29.1	82.2	19
HTC Desire V	49.6	29.1	78.7	23
HTC Sensation XL	51.0	29.1	80.1	22
HTC Sensation XE	55.1	29.1	84.2	17
Samsung Galaxy S2	58.4	29.1	87.5	14
Samsung Galaxy Note 2	58.9	29.1	88.0	12
Samsung Galaxy Note	54.6	29.1	83.7	18
Samsung Galaxy S Advance	51.9	29.1	81.0	21
Samsung Galaxy Nexus	57.3	29.1	86.4	15
Samsung Galaxy R	55.4	29.1	84.4	16
Nokia Lumia 820	61.4	28.3	90.5	11
Nokia Lumia 900	53.7	28.3	82.0	20
HTC WP 8X	68.8	28.3	97.1	5

service. However, the iOS has greater weight than Android in system evaluation using AHP, which means iOS's uniform design elements are sometimes seen as being more user-friendly than those of Android. Although Android is now the world's most commonly used smartphone platform and is used by many different phone manufacturers, while iOS is only used on Apple devices, most experts still have a higher evaluation of iOS.

4.4. Step 4: B/C ratio analysis and perceptual map

The best smartphone in our selected models is the iPhone 5, but we know that many users select their smartphones based on their budget without considering performance. We believe that some consumers have limited resources or budget when selecting a suitable or usable smartphones for themselves. B/C ratio analysis is a kind of evaluation method used to maximize the benefit of resources with respect to cost. The consumer always hopes to use his or her limited disposable income to purchase the best product or service for him or herself. This paper uses this concept in combination with a perceptual map to provide consumers with good propositions for purchasing smartphones. The analysis results for the selected smartphone are shown in Table 8 and Figure 5. From the analysis results, we find that the HTC One V is the best smartphone choice, rather than the iPhone 5, because the price of the iPhone 5 is too high to reduce its B/C ratio. If a consumer just wants a basic smartphone, without considering brand loyalty, a low-end segment smartphone like the HTC One V can be selected from the diversity of products in quadrant IV. Further, in quadrant IV of Figure 5, the products have a higher B/C ratio but lower price, which can attract some customers who prefer the market segmentation between functional orientation and lower price. By contrast, the top smartphones in quadrant II from different manufacturers have lower B/C ratios with higher prices. Clearly, when the top smartphones cannot continue their dominant advantages, or a new generation of smartphone is promoted in the market, consumers might shift to the mid-priced models in the range of quadrant III. Finally, when the smartphone market becomes mature, the top smartphones from famous manufactures will be priced lower and maintain higher performance than the top models in the range of quadrant I.

5. Conclusion and Propositions for Future Research

Information technology evolves very fast. The time interval to launch new smartphone models is becoming shorter and shorter. No sooner than a consumer purchases a new model, newer models come out. The consumer wishes to obtain useful information from experts to evaluate a smartphone when facing so many handsets. This paper uses AHP and SMART approaches to make a combination analysis of OS, hardware specifications and usage experience, advertisement, and service. We believe that the key issue for a smartphone is the OS. Under the current level of technology, the development of hardware has reached its limitation. From the analysis of the first stage, it is found that the user may have difficulty sensing the difference, even when there is a small improvement or progress in hardware. From the perspective of smartphone providers, the specifications of the hardware of the current flagship smartphone models do not have many differences. The future winning points for smartphones should involve software.

Table 8: B/C Analysis for the Selected Smartphones.

Selected Smartphones	Total Performance	B	Average Price	C	B/C	Ranking
iPhone 5	113.3	1.00	25500	1	1	22
HTC One X	95.7	0.84	15000	0.59	1.44	12
Samsung Galaxy S3	97.5	0.86	16800	0.66	1.31	15
Nokia Lumia 920	93.6	0.83	21900	0.86	0.96	23
iPhone 4S	97.8	0.86	20400	0.80	1.08	19
iPhone 4	93.9	0.83	19800	0.78	1.07	20
HTC One X+	98.7	0.87	20900	0.82	1.06	21
HTC One SC	87.6	0.77	15000	0.59	1.31	14
HTC J	91.9	0.81	14100	0.55	1.47	11
HTC One V	78.0	0.69	6700	0.26	2.62	1
HTC One S	91.3	0.81	11600	0.45	1.77	7
HTC Desire X	82.2	0.73	8600	0.33	2.15	2
HTC Desire V	78.7	0.69	8700	0.34	2.03	5
HTC Sensation XL	80.1	0.71	10600	0.42	170	8
HTC Sensation XE	84.2	0.74	11600	0.45	1.63	9
Samsung Galaxy S2	87.5	0.77	12700	0.50	1.55	10
Samsung Galaxy Note 2	88.0	0.78	21900	0.86	0.90	24
Samsung Galaxy Note	83.7	0.74	16300	0.64	1.16	18
Samsung Galaxy S Advance	81.0	0.71	8700	0.34	2.10	3
Samsung Galaxy Nexus	86.4	0.76	9300	0.36	2.09	4
Samsung Galaxy R	84.4	0.74	9900	0.39	1.92	6
Nokia Lumia 820	90.5	0.80	16300	0.64	1.25	16
Nokia Lumia 900	82.0	0.72	15300	0.60	1.21	17
HTC WP 8X	97.1	0.86	16600	0.65	1.32	13

In general, smartphone software can be divided into two categories. The first one is the software built into the smartphone and provided by the original manufacturer, including the OS and the user interfaces. The other is the apps provided by third-party software developers. The OS is the interactive channel between the user and the smartphone.

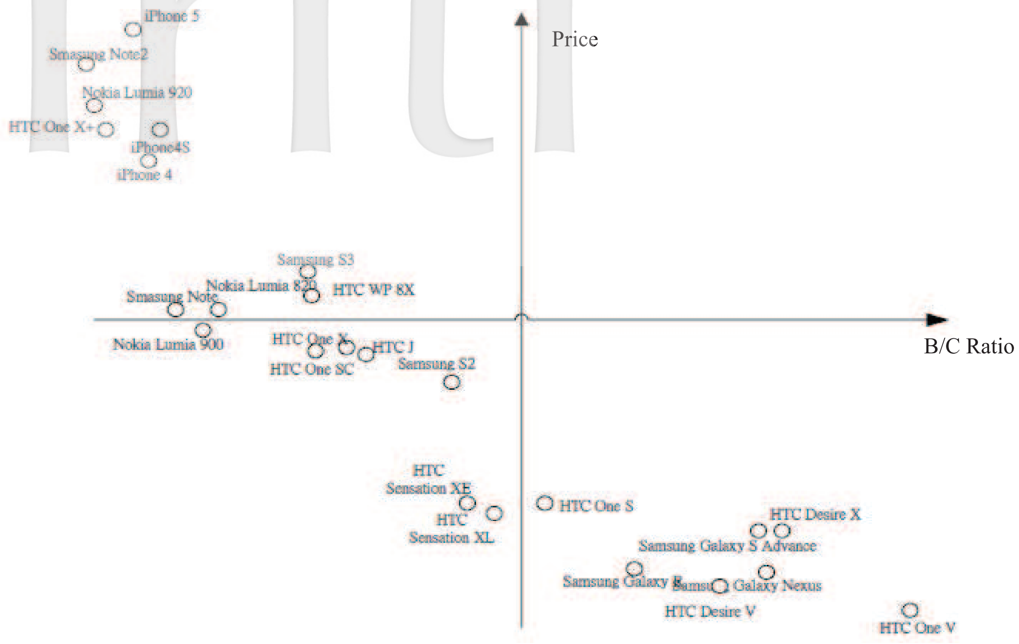

Figure 5: Perceptual Map of 24 Smartphone Models.

The smartphone provider can increase competitiveness by providing a better usage experience. From the AHP analysis of this paper, the top three indicators in the weight ranking of OSs are apps, sync and backup, and usability and design, with respective overall weights of 0.138, 0.134 and 0.132. Apps are so important because consumers can download the apps needed to optimize their own smartphones according to their own needs. Therefore, to attract consumers, providers must be able to provide what customers need, improve the quality of apps, and protect consumers' personal data. This paper proposes that smartphone providers improve the three indicators mentioned so that the OS can be differentiated from competitors.

From the perspective of cost-benefit analysis, most current users are pursuing so-called external utility, that is, hardware specifications, and neglecting the so-called internal experience, that is, the software aspect. In the perceptual map of this paper, the upper-left cluster contains the iPhone 5, Samsung Galaxy Note 2, Nokia Lumia 920, HTC One X+, iPhone 4S, and iPhone4. The models mentioned in this cluster are currently those having better external performance. This is the main cluster that consumers are pursuing. However, these models are comparatively more expensive in price and thus create less value per unit price. In contrast, the lower-right cluster, which includes models such as the HTC Desire X, HTC Desire V, Samsung Galaxy S Advance, and Samsung Galaxy R, includes smartphones with ordinary external performance. They belong are in the middle or lower-priced cluster. The models in this cluster highlight their easy-to-accept price, but the value created by each unit price is much higher than that in the upper-left cluster. Therefore, it is proposed that consumers should select middle-priced smartphones to get the highest benefit. If the consumer does not need any special function, this would be the optimal solution.

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Department of Management Sciences, Tamkang University, No. 151, Yingzhuan Rd. Tamsui District, New Taipei City 25137, Taiwan R.O.C.

E-mail: rctsaur@yahoo.com.tw

Major area(s): Multicriteria decision making, fuzzy set theory, business forecasting, and green supply chain management.

Department of Management Sciences, Tamkang University, No. 151, Yingzhuan Rd. Tamsui District, New Taipei City 25137, Taiwan R.O.C.

E-mail: enfa@mail.tku.edu.tw

Major area(s): Retailing management, customer relationship management, machine learning and its applications.

Department of Management Sciences, Tamkang University, No. 151, Yingzhuan Rd. Tamsui District, New Taipei City 25137, Taiwan R.O.C.

E-mail: mac62077@hotmail.com

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