Kim, T., Okudan, G. and Ertek, G. (2009) "Innovation in product form and function: customer perception of their value." In: ASME 2009 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference (IDETC/CIE 2009), San Diego, CA, USA

INNOVATION IN PRODUCT FORM AND FUNCTION: CUSTOMER PERCEPTION OF THEIR VALUE

Taehyun Kim and Gül Okudan
Pennsylvania State University
University Park, Pennsylvania, USA

Gürdal Ertek
Sabanci University
Istanbul, Turkey

ABSTRACT

The goal of product design is to obtain the maximum effect with minimum cost in functionality and aesthetic beauty. Consumers are attracted to the designs that reflect their use behaviors and psychological responses more than they are to the simple visual representations. When product functions and qualities are similar across products, customers make their purchasing decision upon aesthetic form. Form presents a significant competitive factor that improves the value of a product. Overall, the purpose of this study is to examine the most important product design factors that affect the market share trends of mobile phone companies. Study uses product characteristics for 1,028 mobile phones released between 2003 and 2008 as a case study. The multiple linear regression analysis is used to select highly correlated variables that influence the market share, and Mallow's Cp method is used to determine the best-fitting model. The Partial Regression Coefficients are used to evaluate the relative importance of design criteria. The nine mobile phone design features that affect the market share were identified, and the block form style is determined as the most important design factor. Using these approaches, this study demonstrates how investments should be directed in the next mobile phone design process.

1. INTRODUCTION

Good design can be interpreted in various ways by designers, engineers, producer, and consumers. It can be defined as a design that is comfortable to use, looks beautiful, or makes you happy [1]. Some consumers may prefer utility to appearance while other consumers may prefer price to utility. Even though consumers' preferences differ in determining good designs, the best selling product can be seen as a good design as per its success in the market. Enabled by the profits of the best selling product, manufacturers can provide good work environments and a competitive operation which improve the product offerings.

Traditional design process is mostly focused on functionality of the product, and accordingly, most companies opt to provide a set of features and functionality with competitive prices. When product functions and qualities are similar across products, however, customers make their purchasing decision upon aesthetic form [2]. Product aesthetics is the effective evaluation criterion when

consumers have trouble choosing a product from alternatives in the market [3]. Form, then, plays a significant role as a competitive factor improving the value of a product. Ideal product form reflects consumers' behavioral response, and will change design trends in the market place [2]. Moreover, consumers are interested in product design to motivate intuitive psychological responses more than visual impression [1]. Accordingly, achieving good design should mean obtaining the maximum effect with minimum cost in terms of functionality and aesthetic beauty [1].

Mobile phone manufacturers are increasingly interested in capturing consumers' preferences to stay competitive. As the relative importance of form design grows, designers are required to better understand consumers' opinions through effective communication. Communication not only plays a bridge role between the present and the future design variants but also provides input to improve the design process.

Early mobile phone models were used as a means of communication. Voice clarity was significant to distinguish among competitive global companies. With technological improvements, a high quality network system provided stable voice tone, and mobile phone manufacturers incorporated additional functions such as text messaging for arousing consumers' curiosity. Moreover, overall product value in mobile phones was extended by multimedia functions (e.g. camera, mp3 player, and games). At that time, Korean mobile phone manufacturers (LG and Samsung) gained significant market shares by exploiting the customer curiosity towards multimedia functionality. As technology matured, mobile phones became slimmer, lighter, and more colorful. Slim size preferences seem to have influenced the menu navigation and screen sizes to reflect user's behavior and perceptions [4]. However, consumer preferences change quickly.

Accordingly, in order to stay competitive mobile phone manufacturers release new models every three months. In this competitive environment, it is crucial for a company to know how to manage design budgets. As such, in this paper, based on real data we investigate the relative importance of form and function in mobile phone designs.

2. LITERATURE LIVIEW

The design form perception of users' plays a role in recent design trends, and it has been a subject of study with increasing importance. To understand users' perception and understanding of product form, the semantic differential (SD) method has been useful to measure connotative meaning [5]. In this method, users' perception about a product image is evaluated by using meaning words, and a scale is constructed of contrasting adjective pairs like good-bad. This method is used to evaluate preference on form, style, and color in order to elicit the personal attitude towards the design. For example, Hsu et al. [6] investigates cognitive preferences between users and designers, and users' preferred telephone samples are used to find optimal design factors. Likewise, Zhu et al. [7] conducted a study on mobile phones to examine designers' color perception. A color image scale approach helped to guide influential color factors in the product market. Designers can make appropriate color selection for mobile phones of different styles, and thereby save time through the use of color image scales. Chuang et al. [8] evaluated user preference perception in form designs, and mobile phones as the example selected to indentify design trends based on important design components. The Multidimensional scaling (MDS) [9] method was used to investigate consumers' subjective assessment and identify their preference information with respect to new product design.

Beyond identifying if something (a form or a feature) is important for the user, understanding the relative importance of a set of characteristics might be more meaningful. Setpwise selection methods were introduced to the most common procedure of significant characteristics selection [10]. However, for screening the design characteristics, stepwise methods do not show the correct p-value (significant value) because there is not a clear correlation among independent variables, they may determine unimportant design variables due to their subjective opinion. In order to eliminate bias from the experts' judgments, several authors proposed the use of methods such as partial least squares (PLS) [13], principle component analysis (PCA) [14], cluster analysis (CA) [15], and genetic algorithm-based partial least-squares approach (GA-based PLS) [12]. The PLS method withdraws the latent variables using a high number of design factors by maximizing their correlation. PCA method is an attractive technique to analyze data and determine significant factors, but selected variables might have obscure correlation. In the cluster analysis, variables which have high pairwise correlations are classified into the same cluster, while variables which have low pairwise correlations are assigned into unrelated clusters. GA-based PLS is regarded as a valid model of the best variable combination when compared to previous methods. This method is useful for the product designers to screen out a number of variables in the design process.

The product appearance is an important criterion that can improve the product design quality and reflect customer's requirements. The different roles of product appearance occupy an important part in consumers' decision making, and can be identified as aesthetic, symbolic, functional, ergonomic informational, attention drawing, and categorization related communication [16]. Preference mapping (PREMAP) [17] Method is applied to elicit the user's preference of product shape, which explores design attributes on product quality and visual aesthetic. This method is useful to determine customer's preference and perception by using subjective rating scales. In addition, Interactive Genetic algorithms (IGA) [18] method is an effective tool for evaluating ideal design factors when users make a decision concerning visual aesthetic preferences in the market place. For example, a cola bottle is used as a cast study for assessing user's preference on shape. IGA generates forms of several alternatives by gathering user's preference data, and then designer can get inspiration for attractive designs by understanding aesthetic preferences of customers. These approaches help designers to generate various ideas with different points of view and search for the best product form by controlling parameter variables such as form and target image values. Yoshimura suggests design strategies to improve the relationship between aesthetic design factors and objective attributes to satisfy customer's expected price and manufacturing cost [19]. With lower cost and practical functions, products may have received consumer's attention in the past, but the addition of aesthetic design form can stir consumer's emotion in the modern society.

Kansei engineering [20] focuses on the image of the new product and tries to speak to consumer's feeling in the product design elements. For example, product form design using ANFIS-KANSEI [21] model is used to distinguish the product's preferred image of consumers. Mp3 players are provided as case study to show various types of form. This approach is a useful tool to analyze human feelings for developing new product designs. Emotional response systems such as senses, fun, cuteness, familiarity, metonymy, and color are very powerful factors to determine the human's perception criteria and behaviors toward a product design [22]. Such experimental research motivates consumer's purchasing decision by satisfying psychological and physical condition of consumers. In order to predict the design combination of consumer form preference, a grey relational analysis (GRA) [23], Fuzzy support vector machine (fuzzy SVM) [24], and fuzzy logic [25] methods are applied to the mobile phones as a case study. These approaches contribute to figure out consumer's perception based on Kansei engineering and determine the best design elements of mobile phones.

Table 1: Market share information over year (Source: Gartner Dataquest)

Market Share (%) / Company	2000	2001	2002	2003	2004	2005	2006	2007	2008
Nokia	30.06	35	35.8	34.8	30.7	32.5	34.8	37.8	39.0
Motorola	14.6	14.8	15.3	14.5	15.4	17.7	21.1	14.3	8.7
Samsung	5.0	7.1	9.8	10.5	12.5	12.7	11.8	13.4	16.3
Siemens	6.5	7.4	8.2	8.4	7.2	-	-	-	-
Sony Ericsson	10	6.7	5.5	5.1	6.2	6.3	7.4	8.8	7.9
LG	-	-	-	5.0	6.3	6.7	6.3	6.8	8.4
Other	33.2	29	25.5	21.7	21.6	24.1	18.6	18.9	19.8
Total	100	100	100	100	100	100	100	100	100

3. CASE STUDY

In this study, the multiple linear regression (MLR) analysis technique is used to select highly correlated variables that influence the market share, and Mallow's Cp method is used to determine the best-fitting model. With Multiple linear regression analyses, we explore how 13 discrete variables and 12 continuous variables change to the market share trend. The Partial Regression Coefficients (PRC) technique is implemented to evaluate the relative importance of design criteria. The experiment consisted of finding out important characteristics of mobile phones that influence the market shares.

3.1 Data set and Coding

We collected market share information for mobile phone manufacturers between 2000 and 2008. The top mobile phone manufacturers are chosen based on market share rates every year. As shown in Table 1, the market shares changed over the years between 2000 and 2008. The top five mobile phone manufactures competed over the past 9 years. A few points need mentioning with respect to the data in Table 1, *Siemens* data set does not include the values for 2005 to 2008. The market share percentage for *Siemen* is combined with the market share percentages of *other*. While *LG* has been one of the top mobile phones companies for the recent years, there is no market share data between 2000 and 2002. In order to limit data bias, we disregard all market share data between 2000 and 2002

In order to figure out important design factors, data for 1028 different released mobile phone characteristics were collected. Design characteristics are classified into 25 individual criteria as shown in the Table 2. Upon examination of the characteristics, one would see that 10 of these are form related, and 15 relate to functions. Overall shape of the phone is categorized into seven types', clamshell, block, slider, swivel, flip, dual face or watch.

Table 2: Design characteristics of mobile phones

Form Variables	a. Form Style- Clamshell, Block, Slider, Swivel, Flip, Dual face, Watch b. Weight (g) c. Volume- Length(mm) Width(mm) Thickness(mm) d. Display Size (Pixels)
Function Variables	f. Network (2G or 3G) g. SAR Value(w/kg) h. Sensor -Touch screen QWERTY key pad Touch sensitive scroll wheel Navigation Trackball i. Contact numbers j. Received call numbers k. Outgoing call numbers l. Shared memory (Mb) m. Photo call n. MP3 player o. Instant Messenger (IM) p. Data Speed (kbps) q. Bluetooth r. Camera Pixels s. Battery standby time(Hour) t. Battery talk time(Hour)

After an initial assignment of product characteristics as either “form” characteristic, or “function”, we have ascertained our assignments by conducting a patent search for all these characteristics. Not surprisingly, for the form characteristics, all the patents found were design patents. Further, most of the patents for the functional characteristics were utility patents. Tables 3 and 4 contain the information collected.

Table 3: Patents for Function Characteristics

Feature		Patent No	Patent Date	Description
Function	Camera	US D500,992 S US 7,228,151 B2	Jan. 18, 2005 Jun. 5, 2007	The function that can capture either photographs or motion video
	Rotatable Camera	US D528,093 S US 0088310 A1	Sep. 12, 2006 Apr. 27, 2006	The function that rotates camera mobile phone without users' movement.
	QWERTY Keypad	US D561,723 S US 7,107,018 B2	Feb. 12, 2008 Sep. 12, 2006	QWERTY Compact for on-hand typing using three fingers that are placed over the keyboard having such small, portable size
	Navigation Trackball	US 0188471 A1	Aug. 16, 2007	The device that points out designated information on a display screen as navigation tool device.
	Touch sensitive scroll wheel	US 0134578 A1	Jun. 23, 2005	The function that uses Synaptic' knack for navigation by making scroll wheel clickable
	Touch screen	US D558,756 S US 0052422 A1	Jan. 1, 2008 Feb. 28, 2008	The function that touch or contact to the display of device by finger or hand
	MP3 Player	US 0027385 A1	Feb. 3, 2005	The function that plays mp3 file, digital audio file compressed using a standard defined by Motion Picture Experts Group (MPEG)
	Instant Messaging	US 7,200,634 B2	Apr. 3, 2007	The function that sends real time messages to another mobile phone user. It is much faster and simpler way to communicate than using e-mail
	Wireless Banking Service	US 7,258,267 B2	Aug. 21, 2007	M-banking Service used for performing balance checks, account transactions, and payment. The function that can use the mobile banking service anywhere if you have your own PIN
	GPS	US 0065326 A1	Mar. 13, 2008	The Global Positioning System (GPS) is a satellite-based navigation system to help accurately determine their locations world- wide.
	Battery Lifetime	US 6,463,305 B1	Oct. 8, 2002	Time that can operate mobile phone without recharging the battery. Battery power is provided in a form which specifies available talk time and available standby times.
	2G Network	US 6,594,242 B1	Jul. 15, 2003	CDMA-based personal communication service that allows for the introduction of digital data services, such as short messaging service (SMS) and e-mail.
	3G Network	US 7,206,604 B2	Apr. 17, 2007	Third generation that represent an international standard for W-CDMA (Wideband Code Division Multiple Access). It results in faster data transmission for advanced multimedia services and large network capacities.
	Multimedia	US 0005767 A1	Jan. 3, 2008	The function that can experience various mobile internet services such as shopping, game, and video with your phone browser.
	Call Log Memory	US 6,920,208 B1	Jul. 19, 2005	The memory capacity that can save received, dialed, and missed call number, and the approximate length of your calls in the network service.
	Personalizatio n	US 7,248,835 B2	Jul. 24, 2007	The function that adjusts various phone settings for different events and environments and customizes the profile you want to change
	Shared Memory	US 6,681,287 B2	Jan. 20, 2004	The amount of memory shared other features such as phone book, text and multimedia messages, images and ringing tones in gallery, calendar, to-do notes, and Java games and applications
	Bluetooth	US 7,242,970 B2	Jul. 10, 2007	A wireless hand free kit that uses low power radio communications over short distances from fixed and mobile
	One Touch Dialing	US 7,190,975 B2	Mar. 13, 2007	The function that assigns a phone number to one of the speed dialing keys from 1 to 500 in the address book.

Feature		Patent No	Patent Date	Description
Function	Camera	US D500,992 S US 7,228,151 B2	Jan. 18, 2005 Jun. 5, 2007	The function that can capture either photographs or motion video
	Rotatable Camera	US D528,093 S US 0088310 A1	Sep. 12, 2006 Apr. 27, 2006	The function that rotates camera mobile phone without users' movement.
	QWERTY Keypad	US D561,723 S US 7,107,018 B2	Feb. 12, 2008 Sep. 12, 2006	QWERTY Compact for on-hand typing using three fingers that are placed over the keyboard having such small, portable size
	Navigation Trackball	US 0188471 A1	Aug. 16, 2007	The device that points out designated information on a display screen as navigation tool device.
	Touch sensitive scroll wheel	US 0134578 A1	Jun. 23, 2005	The function that uses Synaptic' knack for navigation by making scroll wheel clickable
	Touch screen	US D558,756 S US 0052422 A1	Jan. 1, 2008 Feb. 28, 2008	The function that touch or contact to the display of device by finger or hand
	MP3 Player	US 0027385 A1	Feb. 3, 2005	The function that plays mp3 file, digital audio file compressed using a standard defined by Motion Picture Experts Group (MPEG)
	Instant Messaging	US 7,200,634 B2	Apr. 3, 2007	The function that sends real time messages to another mobile phone user. It is much faster and simpler way to communicate than using e-mail
	Wireless Banking Service	US 7,258,267 B2	Aug. 21, 2007	M-banking Service used for performing balance checks, account transactions, and payment. The function that can use the mobile banking service anywhere if you have your own PIN
	GPS	US 0065326 A1	Mar. 13, 2008	The Global Positioning System (GPS) is a satellite-based navigation system to help accurately determine their locations world- wide.
	Battery Lifetime	US 6,463,305 B1	Oct. 8, 2002	Time that can operate mobile phone without recharging the battery. Battery power is provided in a form which specifies available talk time and available standby times.
	2G Network	US 6,594,242 B1	Jul. 15, 2003	CDMA-based personal communication service that allows for the introduction of digital data services, such as short messaging service (SMS) and e-mail.
	3G Network	US 7,206,604 B2	Apr. 17, 2007	Third generation that represent an international standard for W-CDMA (Wideband Code Division Multiple Access). It results in faster data transmission for advanced multimedia services and large network capacities.
	Multimedia	US 0005767 A1	Jan. 3, 2008	The function that can experience various mobile internet services such as shopping, game, and video with your phone browser.
	Call Log Memory	US 6,920,208 B1	Jul. 19, 2005	The memory capacity that can save received, dialed, and missed call number, and the approximate length of your calls in the network service.
	Personalization	US 7,248,835 B2	Jul. 24, 2007	The function that adjusts various phone settings for different events and environments and customizes the profile you want to change
	Shared Memory	US 6,681,287 B2	Jan. 20, 2004	The amount of memory shared other features such as phone book, text and multimedia messages, images and ringing tones in gallery, calendar, to-do notes, and Java games and applications
	Bluetooth	US 7,242,970 B2	Jul. 10, 2007	A wireless hand free kit that uses low power radio communications over short distances from fixed and mobile
	One Touch Dialing	US 7,190,975 B2	Mar. 13, 2007	The function that assigns a phone number to one of the speed dialing keys from 1 to 500 in the address book.

Table 4: Patents for Form Characteristics

Feature		Patent No	Patent Date	Description
Form	Clamshell	US D566,670 S	Apr. 15 2008	When the clamshell is open, the device is ready for use. The interface components are kept inside the clamshell, which offers more surface area than the device is closed.
	Folder	US D571,344 S	Jun. 17, 2008	A folder form has a main body, and is in two or more parts that fold via a hinge
	Slide	US D570,815 S	Jun. 10, 2008	A slide form made of two or more parts that slide against each other
	Swivel	US D541,248 S	Apr. 24, 2007	A swivel form made multiple segments that swivel past each other around a point.
	Block	US D552,058 S	Oct. 2, 2007	A block form is a rigid rectangular cuboids, and it resembles a candy bar or slab in size and shape.
	Watch	US D543,192 S	May 22, 2007	A watch form is constructed in a manner such that a pair of housing facing each other can rotate relative to each other

Table 5: Mobile phone features defined as discrete and continuous variables

Features		Description
Discrete Variables	Networks	Most of cell phones utilize 2G networks, and 3G network also supports 2G network. Number of phones which support a 3G or 2G network for a given manufacturer and year.
	Camera	Number of phones that include a camera for a given manufacturer and year
	MP3Player	Number of phones that include a MP3 player for a given manufacturer and year
	Instant Messaging	Number of phones that include instant messaging capabilities for a given manufacturer and year
	Bluetooth	Number of phones that include Bluetooth capabilities for a given manufacturer and year
Continuous Variables	SAR (w/kg)	Average measurement of radio frequency in order to communicate with the network
	Weight	The average weight of mobile phone
	Volume	The average volume of mobile phone based on length, width, and thickness
	Contact	To measure the average contact numbers that can be stored to the mobile phone
	Received	To measure average received calls that can be stored to the mobile phone
	Outgoing	To measure average outgoing calls that can be stored to the mobile phone
	Shared Memory	Average memory to share features such as multimedia messages, images, text, phone book, ring tone, and games
	Data Speed	The average speed of transferring data supported by mobile phone
	Standby time	Without recharging the battery, average standby time for operating mobile phone.
	Talk time	Without recharging the battery, average talk time to communicate on mobile phone.
	Display Pixels	The average size of the mobile phone screen
	Camera Pixels	The average resolution of the camera

3.2. Data Procedure

After colleting market share data of manufacturers and summarizing design features of mobile phone models, we determined the variable levels to include in the study. Table 5 provides 17 variables along with short descriptions. Mobile phone features can be classified into two groups as per their data type. One group contains the discrete variables for which we recorded the total number in the sample; the other includes the continuous variables for which we determined averages. For variables that are classified as discreet, we calculated the value from the discrete model data. For example, if a mobile phone has the Bluetooth feature, it will be added to the total count of mobile phones with the Bluetooth feature. Hence, 'Bluetooth' means the total number of models released by a given manufacturer and year that include the Bluetooth feature. Variables that represent the average value are calculated from continuous model data. For instance, 'Weight' signifies the average weight value for all mobile phones released by each manufacturer and year.

Visual form variables are classified into 7 categorical types (Table 6). The seven different form styles are defined as discrete variables. Instead of calculating the average value for continuous variables, discrete variables are computed by the number of mobile phone's form style that manufacturers released for given years. Since over 95 % of all mobile phones are blocks, clamshells, or sliders, the three main variables are represented as manufacture's preference form styles.

Table 6: Visual Form style

Form		Description	Count
Discrete Variables	Block	# of block phones that manufacturers released for given years	401
	Clamshell	# of Clamshell phones that manufacturers released for given years	394
	Slider	# of Slider phones that manufacturers released for given years	187
	Flip	# of flip phones that manufacturers released for given years	26
	Swivel	# of swivel phones that manufacturers released for given years	17
	Dual Face	# of dual face phones that manufacturers released for given years	2
	Watch	# of watch phones that manufacturers released for given years	1
Total			1028

4. Results and Discussion

4.1 Variance Inflation Factor (VIF)

Variance Inflation factor is a method to measure the magnitude of multicollinearity. Multicollinearity refers to a situation that three or more variables are highly correlated in a multiple regression model. The variance inflation factor (VIF) is defined as

$$VIF_j = \frac{1}{1-R^2_j} \quad (1)$$

R^2_j is the measure of square coefficient of the multiple correlation. If VIF is bigger than 10, it indicates the existence of serious multicollinearity. As shown in Table 7, we look for the variables with high VIF, and delete them from regression model. After removing the variables with the high VIF values, a new regression model is generated without the previously removed variables. This process continued until all variables in the model had a VIF score of less than 10. As a result, the three variables 'DReceived', 'DVolume', and 'DSlider' were deleted. Removed variables in Table 7 can be defined. For example, 'DReceived' means the change in 'Received' from one year to the next year. Because we are interested more in modifications or improvements that manufacturers affect the market share, we calculate the difference of each of these variables. After all, potential variables remained as shown in Table 8. Variables which are remained by VIF scores generate all possible regression models.

Table 7: Removed variables based on VIF scores

Step	Removed variable	VIF	Model R-square	F-value	ρ - value
1	DReceived	149.63	95.3	3.19	0.184
2	DVolume	65.78	94.5	3.84	0.101
3	DSlider	32.39	94.5	5.07	0.041

4.2 Mallows' C_p

Mallows' C_p is used for identifying the best fitting model among models with all possible subsets of the independent variables. This procedure provides all candidate regression models and determines the best-fitting models in multiple regressions. Table 8 indicates that the top 8 best fitting models is selected in terms of C_p. Based on the maximum R-sq (adjusted) and the minimum C_p, the best subsets model is chosen. It is consisted of 9 independent variables, and the value of the minimum C_p is calculated as 4.9.

$$C_p = \frac{RSS_p}{S^2} - N + 2P \quad (2)$$

Where:

C_p: Subset criterion to be used in selecting a reduced model

N: The number of observations

P: The number of variables in the regression

RSS_p: The residual sum of square error using p variables

S^2: The residual mean of square error

4.3 Design factors in the best fitting model

The best fitting model which is selected in terms of C_p represents the following multiple regression model.

$$Y = A + \beta_1 X_1 + \beta_2 X_2 .... \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 \quad (3)$$

Where,

A: The constant term

X_k: Independent variables for design factors of mobile phone

β_k: Coefficients of independent design factors

Y: Dependent variables for market share of mobile phone

β_k represents the change in Y corresponding to a unit increase in x_k, holding all other variables constant. The coefficients of β_k can be interpreted as shown Table 9. 'DWeight', 'Dshared', and 'DBluetooth' have negative coefficients. Negative coefficient means the decrease of the market share as predictors increase. 'DContacts', 'DDataSpeed', 'Dtalk', and 'DCamera' have all positive coefficients. As average contact numbers, average data transfer speeds, average talk time, or the number of camera phones increase, their market share increases. However, there are some interesting results. As manufacturers increase average share memory and Bluetooth-enabled phones, their market share is decreased. Moreover, both 'DBlock' and 'Dclamshell' have positive coefficients. This may not tell us much information because block and clamshell styles were the predominant forms of mobile phone.

Table 8: The top 8 best-fitting models in terms of C_p

#Variables	R^2	R^2 (adj)	Cp	s	DWeight	DContacts	DOutgoing	DShared	DDataSpeed	DBattery	DTalk	DDisplayPixels	DCameraPixels	DBlock	DClamshell	D3G	DCamera	DMP3	DIM	DBluetooth
9	92.8	87.8	4.9	0.65	x	x		x	x		x			x	x		x			x
8	90.2	84.6	5.7	0.73		x		x	x		x			x	x		x			x
9	91.7	85.9	6.1	0.70	x	x		x	x					x	x		x	x		x
10	93.5	88.2	6.1	0.64	x	x		x	x		x			x	x		x		x	x
10	93.1	87.4	6.5	0.66	x	x		x	x		x			x	x		x	x		x
11	93.9	87.8	7.7	0.65	x	x		x	x		x			x	x		x	x	x	x
11	93.7	87.5	7.8	0.66	x	x		x	x	x	x			x	x		x		x	x
7	85.1	78.1	9.3	0.87		x		x	x					x	x		x			x

Table 9: Weight of design factor for mobile phone

Attribute / Predictor	β_k	Coefficient(b_k)	S_k	S_y	VIF	T	ρ	β- weight	Ranking
Dweight	β_1	-0.059	5.52	0.648	1.21	-2.15	0.05	0.50	9
Dcontacts	β_2	0.004	311.4	0.648	1.67	7.16	0.00	1.89	4
Dshared	β_3	-0.002	418.9	0.648	1.23	-5.35	0.00	1.22	6
DdataSpeed	β_4	0.001	573.0	0.648	1.62	4.12	0.00	1.12	7
DTalk	β_5	1.148	0.39	0.648	1.51	2.65	0.02	0.68	8
DBlock	β_6	0.310	6.15	0.648	1.79	8.53	0.00	2.94	1
Dclamshell	β_7	0.112	9.13	0.648	2.95	4.26	0.00	1.58	5
Dcamera	β_8	0.184	8.94	0.648	3.20	6.66	0.00	2.54	3
Dbluetooth	β_9	-0.144	12.69	0.648	4.16	-6.22	0.00	2.82	2

4.4 Partial Regression Coefficients

In Table 9, all p value are less than 0.05, and all design factors in the best fitting model have a score of less than 5. It shows that design variables of mobile phones are moderately correlated. The best fitting model reduces multicollinearity by removing unimportant independent predictors. Among remaining design factors of the best fitting model, the most important design factors are calculated. As a result, block form style of mobile phone is regarded as the most significant factor of design. Bluetooth enabled mobile phone is determined as the second significant factor of design in function part.

$$\beta_k = \frac{s_k}{s_y} \text{x } b_k \qquad (4)$$

Where,

β_k: The standardized partial regression coefficient or the β-Weight

b_k : Coefficients of the Kth independent variable

s_k: being the standard deviation of the Kth independent variable

s_y: being the standard deviation of the dependent variable

5. Conclusion

In this study, relative importance of nine design factors was determined by the partial regression coefficients method. Based on the ranking of design factors, customers prefer the block and clamshell type, consider camera to be an important factor. Also, the market share of mobile phones can increase as manufacturers increase the average number of contacts, the average data transfer speed, and the average talking time. Based on our results, battery life and available contact storage space are desirable primary functions which can satisfy consumers' requirements. Because consumers are tired of new complex functions, improving the quality of primary functions may lead to market share

changes for mobile phones. As a result, future mobile phone development might focus on highly efficient primary characteristic functions rather than complex new functions. Moreover, sales numbers and prices of released products can be investigated as factors to affect market share, and questionnaire data will be collected for determining a customer's preferred features.

Manufacturers of mobile phones are pursuing a functional design which can be used easily by consumers. Even though manufactures of mobile phones obtain highly advanced technology, they do not always meet consumers' satisfaction and increase market share. Because consumers are not ready to use a number of new functions, easy-to-handle functions are essential. As the function of sensitive full touch phones become similar, User Interface (UI) becomes an important competitive factor. Because the full touch phones do not have significant differences with respect to design form, comfortable and intuitive user interfaces can lead to improved overall design and consumer satisfaction. Recently, popularity of sensitive touch screen phones has led to the development of 3D User Interface. This interface shows how to use mobile phones automatically through more intuitive three dimensional screens than previous two dimensional plane screens. In terms of industry research, the development of sensor technology such as sound, light, temperature, and pressure will lead to innovative products in the near future.

The innovative product design process does not always follow the standard principles. Ultimately despite the ability to rank and classify design priorities based on form and function, occasionally an innovative product design appears which disregards the old design paradigm with functionality and beauty. This revolutionary product can change market shares and reorient consumer preferences. These moments of change are the ones researchers should study and designers should emulate in the creation of new product.

References

[1] Waters, R., 2007, "Design with Heart," Design Management Review, 18(1), 16-22.

[2] Bloch, P.H., 1995, "Seeking the Ideal Form: Product Design and Consumer Response," The Journal of Marketing, 59(3), 16-29.

[3] Yamamoto, M., and Lambert, D., 1994, "The Impact of Product Aesthetics on the Evaluation of Industrial Products," Journal of Product Innovation Management, 11(4), 309-324.

[4] Chae, M., and Kim, J., 2004, "Do size and structure matter to mobile users? An empirical study of the effects of screen size, information structure, and task complexity on user activities with standard web phones," Behavior and Information Technology, 23(3), 165-181.

[5] Osgood, C.E., Suci, C.J., and Tannenbaum, P.H., 1957, "The Measurement of Meaning," University of Illionois Press, Urbana, 76-124.

[6] Hsu, S.H., and Chunang, M.C., 2000, "A semantic differential study of designers' and users' product form perception," International Journal of Industrial Ergonomics, 25, 375-391.

[7] Zhu, Y.L., Luo, S.J., and Xu, X.H., 2006, "Research on designers' product color perception of mobile phone," 7th International Conference on Computer-Aided Industrial Design and Conceptual Design, November 17-19, 1-5.

[8] Chuang, M.C., Chang, C.C., and Hsu, S.H., 2001, "Perceptual factors underlying user preferences toward product form of mobile phones," International Journal of Industrial Ergonomics, 27, 247–258.

[9] Petiot, J.F., and Grognet, S., 2002, "A multidimensional scaling approach for product design and preference modeling," Proceedings of the IEEE International Conference on Systems, Man and Cybernetics, 4, 54-59

[10] Yun, M. H., Han, S. H., Hong, S. W. and Kim. J.S., 2003, "Incorporating user satisfaction into the look-and-feel of mobile phone design," Ergonomics, 46(13), 1423 – 1440.

[11] Han, S.H., Yun, M.H., Kim, K., and Kwahk, J., 2000, "Evaluation of product usability: development and validation of usability dimensions and design elements based on empirical models," International Journal of Industrial Ergonomics, 26, 477–488.

[12] Han, S.H., and Yang, H.C., 2004, "Screening important design variables for building a usability model: genetic algorithm-based partial least-squares approach," International Journal of Industrial Ergonomics, 33, 159–171.

[13]Geraldi, P., and Kowalski, B.R., 1986, “Partial least-squares regression: a tutorial,” Analytica Chimica Acta, 185, 1–17

[14]Jolliffe, I.T., 1986, “Principal Component Analysis,” Springer, New York.

[15]Anderberg, M.R., 1973, “Cluster Analysis for Applications: Probability and Mathematical Statistics,” Academic Press, New York.

[16]Mariëlle, E. H., Creusen, Jan P., and Schoormans, L., 2005, “ The Different Roles of Product Appearance in Consumer Choice,” Journal of Product Innovation Management,22,63-81

[17]Kelly, J., and Papalambros, P.Y. 2007, “Use of Shape Preference Information in Product Design,” In the International Conference on Engineering Design, Paris, France.

[18]Kelly, J., Wakefield, G.H., and Papalambros, P.Y., 2006, “The Development of a Tool for the Preference Assessment of the Visual Aesthetics of an Object Using Interactive Genetic Algorithms,” In the Generative Art Conference, Milan, Italy, December 13-15.

[19]Yoshimura, Masataka., and Yanagi, Hisaichi., 2001, “Strategies for implementing aesthetic factors in product designs,” International Journal of Production Research, 39(5), 1031-1049.

[20] Nagamachi, M., 1995, “Kansei engineering: a new ergonomic consumer-oriented technology for product development,” Journal of Industrial Ergonomics, 15(1), 3-11.

[21]Wang, K.C., Chen, S.M., 2007, “Product form design using ANFIS-Kansei engineering model,” 2007 IEEE International Conference on Systems, Man, and Cybernetics, *SMC* , 2034-2043

[22] Demirbilek, Oya., and Sener, Bahar., 2003, “Product design, semantics and emotional response,” Ergonomics, 46(13-14), 1346-1360.

[23] Lai, Hsin-Hsi., Lin, Yang-Cheng., and Yeh, Chung-Hsing., 2005, “Form design of product image using grey relational analysis and neural network models,” Computers and Operations Research, 32(10), 2005, 2689-2711.

[24] Shieh, Meng-Dar., and Yang, Chih-Chieh,. 2008, “Classification model for product form design using fuzzy support vector machines,” Computers and Industrial Engineering, 55(1), 150-164.

[25] Lin, Yang-Cheng., Lai, Hsin-His., and Yeh, Chung-Hsing., 2007, "Consumer-oriented product form design based on fuzzy logic: A case study of mobile phones," International Journal of Industrial Ergonomics, 37(6), 531-543.

