

# THE APPLICATION OF NUMERICAL DEFINITION-BASED SYSTEMATIC APPROACH IN FORM OF HIGH-HEEL SHOES TO IMAGE PERCEPTION

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## ABSTRACT

High-heel shoes are product of human civilization. With the advancement of consumers' requirements and aesthetic variation, high-heel shoes not only provide function-based fitness but the emotional response in personal image perception, especially in different gender perception. Further, Tom Ford talked "There is no sexy woman without high-heels." Hence, there is a significant relationship between high-heels form and consumers' perception.

The study focus on high-heels form, according to Kansei engineering as a foundation and employ qualitative and quantitative analyses to define the style of the product. Therefore, different sensational image products of the design principal will emerge. Firstly, we propose 30 high-heel shoes samples constructed by 2D computer software; and then 4 representative sensuous words—sweet, elegant, hot and fashionable were identified through approaches of questionnaire analysis, expert interview, and the KJ method. In addition to apply Numerical Definition-based Systematic Approach (NDSA) and element factors to define high heels form. Finally, using quantitative theory type I and multiple linear regression analysis to analyze high heels form between form elements and image words to obtain the principle of design is used.

The results from multiple linear regression analysis indicated that "height" is the most influence on participants' image perception. On the other hand, the relation between each element factors and form image was also determined through analysis of quantitative theory type I. And through the weighing level of different pairs of words, we found out that the major influence factor for form image lies in the thickness of heel, secondly the rear heel, and then the opening of shoes and the last is shoe tongue. This study combined with conclusion for corresponding relations between sensuous perception and high heels form, in order to establish a high-heel design method for designers to refer to.

**keywords:** *NDSA, image perception, Kansei Engineering, high heels, sensuous words*

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## 1. INTRODUCTION

Full consumers' satisfaction depends not only on product durability, safety, efficacy, aesthetics and nice price, consumers also demand an extra quality in terms of symbolic value and the image transmitted through the product appearance. Both are closely related to perception of products, mental images and users' preference.[1] Aspects such as function, performance, efficiency and ergonomics can be conveyed to some extent by the visual form of the product which can create in the observer expectations of what the other senses will perceive.[2][3]

In this context, the importance of stimulating appropriate emotions is increasing constantly because they have been found to enhance the value of physical products.[4][5] Customers' emotional response is derived from their perception of attributes expressed by products, playing a significant role in their visual appearance. As a consequence, in the design of user-oriented products, there is an increasing need for integrating emotional performance as part of product's requirements.

On the other hand, shoes are the product of human civilization. With the advancement of productivity and the development of production facilities, their original function of protection has gradually evolved to that of body garnish. Furthermore, people's need for shoes has shifted from a function-based progressively to a psychological need-based one, given that with the supplement of aesthetics, not only fitness but the formal beauty of shoes is seriously emphasized. Moreover, high-heel shoes not only provide function-based fitness but the emotional response in personal image perception, especially in different gender perception. For instance, "Shoes possess magical properties": they make you beautiful or sexy, elegant or vivid immediately.[6] In addition, high-heel shoes still symbolize something though, the symbolism to be more of a status within fashion and high heels is such a style statement for women which cannot be compared to any of the clothing articles. [7] Further, famous fashion designer--Tom Ford talked "There is no sexy woman without high-heels." [8] Hence, there is a significant relationship between high-heels form and consumers' perception.

This study focus on high-heels form, according to Kansei engineering as a foundation and employ qualitative and quantitative analyses to define the style of the product. According to Numerical Definition-based Systematic Approach (NDSA) [9] which constructs an explicit product-form definition by synthesizing the size, angle, proportion and coordinate descriptions of a product's form. The product definition is then used as the basis for an experimental study designed to investigate the influence of the various detailed features of the product's form on the consumers' perception of the product image. Afterward four representative adjectives describing the product image perceptions induced by the high heels 2D models are identified using the K.J. (Kawakita Jiro) method. [10] The evaluation results are then analyzed statistically in order to determine the extent to which each design variable is responsible for inducing a particular product image.

## 2. MATERIAL AND METHOD































The work was carried out in three phase:

- Identification of high-heel shoes samples.
- Definition of high heels form using numerical approach and element factors
- Selection of meaningful adjectives with which to describe the image projected by high heels' model.

### 2.1. Identification of high heels samples

The first step to define the meaning of “high heels” and obtain lots of high heels picture from internet or magazine etc...to illustrate to 2D sample, therefore, we define the restriction of high heels and propose 30 samples illustrated by Adobe Illustrator as the Table 1 shows

**Table 1:** 30 high heels samples

1	2	3	4	5	6
					
7	8	9	10	11	12
					
13	14	15	16	17	18
					
19	20	21	22	23	24
					
25	26	27	28	29	30
					
<b>Restriction</b>					
<ul style="list-style-type: none"> <li>• Samples should be side view without any angle of depression or elevation</li> <li>• Samples should cover toes and heel</li> <li>• Samples exclude the type of boots or tube-shaped</li> <li>• The appearance of samples is non-colored, and there are two parts of shoes in different transparency black. K-50: shoes body, K-80: shoes sole.</li> <li>• Samples exclude the type of decorated, shoelace, special material on surface.</li> </ul>					

## 2.2. Definition of high heels form

This study is focus on high-heel shoes' form within consumers' perception, therefore, to make the samples standardize, we adjust the 30 high heels samples zoomed by different shoes' height when users arched their foot. As Figure 1 represents.

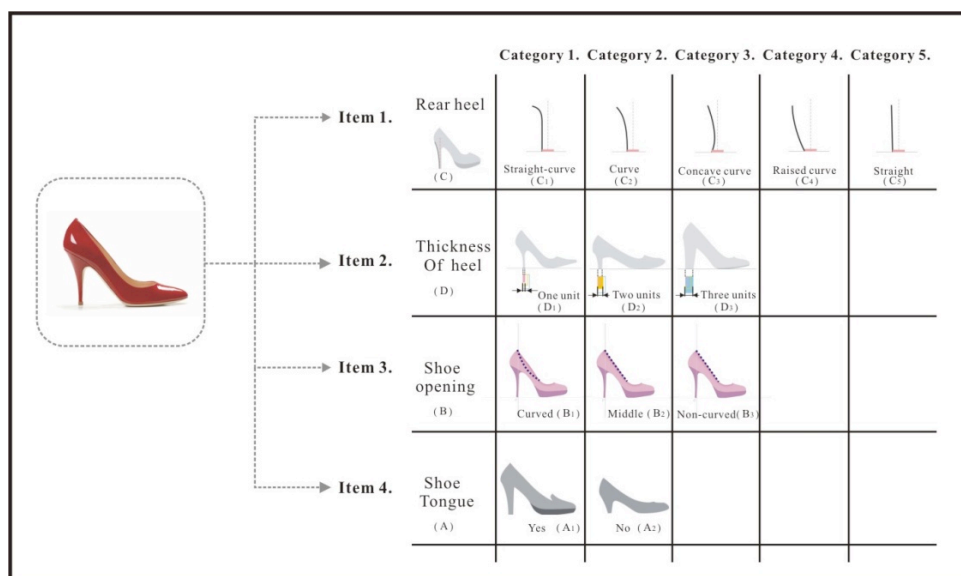


**Figure 1:** zoom in or out with different shoes height correspond to user's foot arch

After this standard procedure, we can adjust accurate samples size; moreover, we define high heels form by two methods, element factors and numerical approach, and divide the high heels form into six parts, rear heel, thickness of heel, front heel to sole (empty triangle), shoe toe, shoe opening and shoe tongue respectively. The below paragraph shall discuss detail of high heels form.

### 2.2.1. Application of element factors

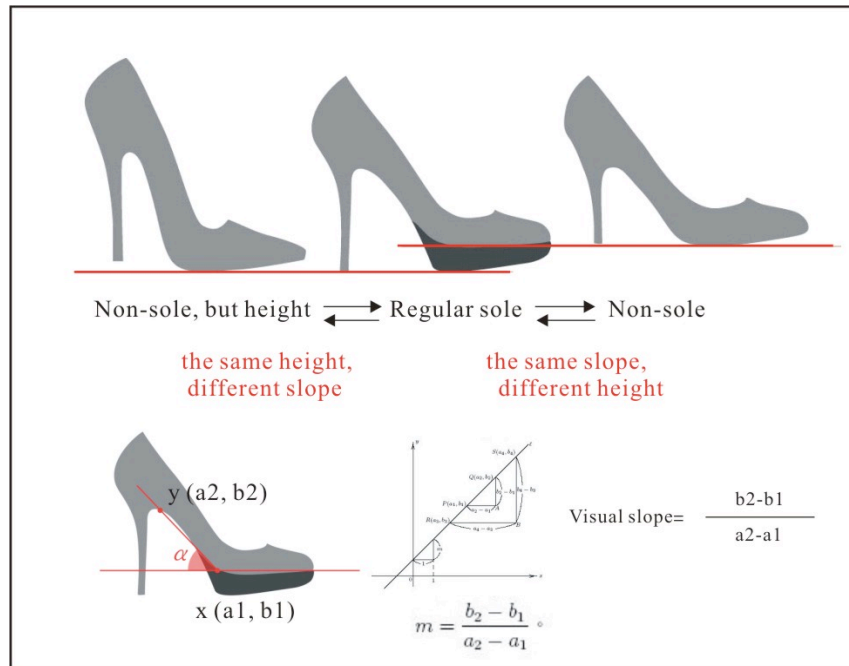
We define the "rear heel", "thickness of heel", "shoe opening" and "shoe tongue" these four items by using element factors in order to employ the concept of "items" and "categories" to develop a qualitative description of the overall product form in terms of its basic design features. [11][12][13]. The Figure 2 illustrates the approach for high heels form by the concept of "items" & "categories".



**Figure 2:** the application of element factors in high heels

### 2.2.2. Application of numerical approach

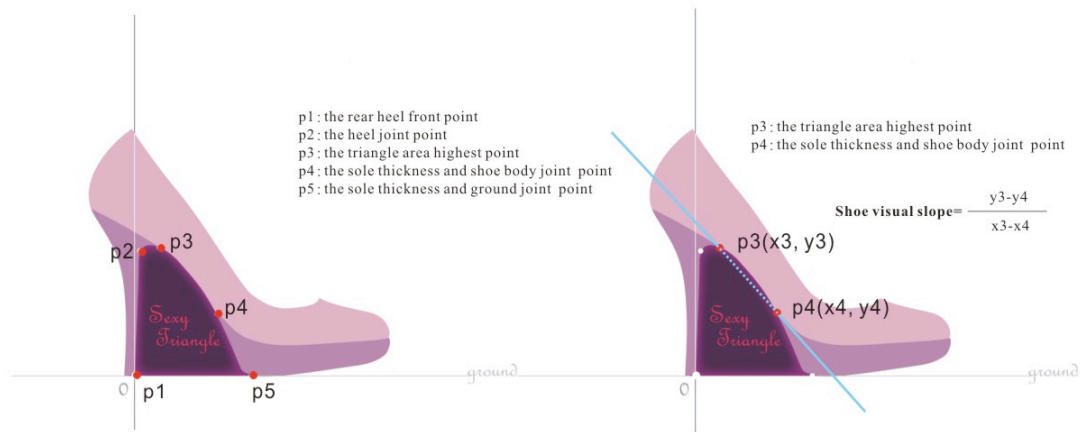
Based on the previous definition in form element factors, we also apply numerical definition to implement the various detailed features such as size, angle, proportion and coordinate descriptions of high heels form. There is a significant difference in consumers' perception between "heights" and "slope of visual" corresponding to "heel height" and "shoe sole" respectively. As the Figure 3 represents



**Figure 3:** the difference between "height" and "visual slope"

The charts above shows shoe soles indeed affect the relation between consumers' perception and visual slope. In equal height, the thicker soles represent the smaller slope, whereas if the visual slope is similar, it could be affected by different thickness of sole rather than original height. Hence, the triangle area is composed of heel's height and horizontal ground linked by shoe sole, and this triangle area combine consumers' visual slope and empty form of whole high heels form. Therefore, we propose this part for numerical approach because we can figure out the accurate slope value and the difference of sole's thickness by coordinates (x, y) in different points. To enable the modeling of fine variation in the triangle area, constructed using a total of five control points (p1~p5). As shown in Figure 4, to standardize the coordinates' value, we set up p1 as (0, 0) for the origin to ensure every control point aligned in positive quadrant. There are specific meaning in different coordinates' x and y value from p1 to p5:

- p1's x and y value: is (0, 0), represent the origin, based value.
- p2's y value: represent the heel's height.
- p3's y value: represent the triangle area highest point, the visual slope's highest point.
- p4's y value: represent the thickness of sole.
- p5's x value: represent the triangle area horizontal distance, the base of triangle.
- The subtraction of division in p3 (x3, y3) and p4 (x4, y4) value: represent the visual slope. As the Figure 4 shown:



**Figure 4:** the numerical definition in triangle area from p1 to p5

Moreover, to discuss the shoe toe's form including arc or raise, we use triangle square and the angle of elevation between shoe toe and ground, the procedure is (1). To extend the tangent of shoes' bottom and toe, crossing third point, and connect to opposite the middle point of line, is indicated L. (2). Then measuring the extended tangent's angle  $\alpha$ , according to formula of triangle square-- $\Delta = \tan \alpha/2 \times L2 \times 1/2$ , we can calculate the square of shoe toe. (3). Finally measuring the elevation angle  $\beta$ , constructed by shoe toe raising and ground, to discuss the shoes toe is raised or not.

### 2.3. Selection of adjective words

Consumers commonly use simple adjectives to express their perceptions of a product's image. [14] These adjectives provide an explicit representation of the consumers' abstract emotional response to a product's form as a result of their personal values, preferences and experiences. Accordingly, in this stage of the NDSA procedure, approximately 60 adjectives (in Chinese) pertaining to high heels form of various types were collected from web sites, magazines, catalogues and so forth. These adjectives were selected and grouped in order by KJ method; hence the classification procedure described below resulted in the formation of four groups with the following titles: "sweet", "elegant", "hot" and "fashionable" as the Table 2 shown:

**Table 2:** 4 different adjectives group in high heels image

Adjectives group	Adjective words
sweet	Innocent type: innocent, pretty, young, cute, childlike, fresh, pure, vivid, witty. Office lady type: beautiful, shiny, ladylike, glamorous, confident.
elegant	Simple-elegancy: elegant, delicate, graceful. Brilliant-elegancy: honorable, mature, classic, amazing, gorgeous, complicated.
sexy	External-sexy: hot, wild, bold, passion. Internal-sexy: provoking, attractive, lust, fantasy, luring, charming.
fashionable	New-style: modern, fashionable, contemporary, future. Old-style: remindful, ancient style, traditional.

Therefore, we chose 4 representative adjectives which are “sweet”, “elegant”, “hot” and “fashionable” respectively. In addition, thirty participants (15 male, 15 female, average age 25 years old) were invited to evaluate the images projected by the 2D high heels form using five Likert scales, i.e. one scale for each of the five perception domains identified in the K.J. classification process. In accordance with the  $7 \pm 2$  limit on an individual’s capacity for processing information [15], each scale comprised a total of nine points.

### 3. ANALYSIS OF RESULTS

This study is focused on two parts, first of all applying quantitative research which discuss partial high heels’ from characteristics factors and using quantitative theory type I to analyze consumers’ perception corresponding to specific form characteristics. Secondly, we proposed multicollinearity test was performed to investigate the strength of the correlations between the individual independent variables and multiple regression analysis with a stepwise selection procedure was then employed to construct the functional models.

#### 3.1. Quantitative theory type I

In order to analyze the high heels form corresponding to users’ perception, we provided quantitative theory type I to analyze correlation, and the Table 3 and Table 4 showed the relation of partial high heels form characteristics (independent) and different adjectives in consumers’ perception (dependent).

**Table 3:** results of quantitative theory type I for high heels form characteristics and image perception-“sweet” and “elegant”

Product image description		sweet				elegant			
Items	Categories	Category score	dif. coefficient	Partial correlation coefficient	importance	Category score	dif. coefficient	Partial correlation coefficient	importance
A. Shoe tongue	A1:yes	-1.091	1.212	0.296	24.3%	0.249	0.277	0.078	5.4%
	A2:no	0.121				-0.028			
B. Shoe opening	B1: curved	0.606	1.174	0.408	23.5%	-0.774	1.28	0.445	25%
	B2: middle	0.094				0.208			
	B3: non-curved	-0.568				0.506			
C. Real heel’ form	C1:straight -curve	1.060	2.102	0.493	*42.1%	-0.123	1.331	0.273	26%
	C2:curve	-0.059				0.166			
	C3:concave curve	-1.042				0.251			
	C4:raised curve	0.388				-0.131			
	C5:straight	-1.303				-1.080			
D. Heel thickness	D1:thin	0.003	0.503	0.128	10.1%	0.880	2.229	0.593	*43.6 %
	D2:middle	-0.142				-0.294			
	D3:thick	0.361				-1.349			
		R=0.660 **R <sup>2</sup> =0.435				R=0.660 **R <sup>2</sup> =0.435			

\* indicate the importance of statistic

\*\* the square of correlative coefficient

**Table 4:** results of quantitative theory type I for high heels form characteristics and image perception-“hot” and “fashionable”

Product image description		hot				fashionable			
Items	Categories	Category score	dif. coefficient	Partial correlation coefficient	importance	Category score	dif. coefficient	Partial correlation coefficient	importance
A. Shoe tongue	A1:yes	-0.497	0.552	0.116	6.3%	-0.374	0.416	0.129	6.9%
	A2:no	0.055				0.042			
B. Shoe opening	B1: curved	-0.962	2.203	0.590	25.2%	-0.660	1.341	0.519	22.3%
	B2: middle	-0.659				-0.197			
	B3: non-curved	1.241				0.681			
C. Real heel' form	C1:straight -curve	-1.265	2.664	0.491	30.5%	-0.729	1.629	0.428	27%
	C2:curve	0.156				0.073			
	C3:concave curve	1.399				0.705			
	C4:raised curve	-0.480				-0.389			
	C5:straight	0.639				0.900			
D. Heel thickness	D1:thin	1.073	3.311	0.596	*37.9%	0.894	2.637	0.632	*43.8%
	D2:middle	-0.130				-0.155			
	D3:thick	-2.238				-1.743			
		R=0.742 **R <sup>2</sup> =0.551				R=0.739 **R <sup>2</sup> =0.547			

\* indicate the importance of statistic

\*\* the square of correlative coefficient

Each category score represents the degree of different categories affect the factors, and the value is higher and positive standing for the increase of consumers' positive influence correspond to form characteristics, vice versa if the value is minus, it is weaker in form variable. Moreover, the absolute value of category score indicates the absolute influence. For example, the image of “hot” in quantitative theory type I showed in Figure 4, the item D represent heel thickness-D1: thin (1.073), D2: middle (-0.130), D3: thick (-2.238), and the order in these three categories corresponding to hot image is D1(thin)>D2(middle)>D3(thick). In addition, D1 (1.073) is positive value, showing that using thinner heel could promote the image of hot.

The importance sequence of different form characteristics toward each image of adjectives is shown below:

- **Sweet:** C-real heel form (42.1%) > A-shoe tongue (24.3%) > B-shoe opening (23.5%) > D-heel thickness (10.1%)
- **Elegant:** D-heel thickness (43.6%) > C-real heel form (26%) > B-shoe opening (25%) > A-shoe tongue (5.4%)
- **Hot:** D-heel thickness (37.9%) > C-real heel form (30.5%) > B-shoe opening (25.2%) > A-shoe tongue (6.3%)
- **Fashionable:** D-heel thickness (43.8%) > C-real heel form (27%) > B-shoe opening (22.3%) > A-shoe tongue (6.9%)



### 3.2. Multiple regression analysis

To discuss the relation of high heels samples numerical statistics with consumers' perception, we apply multiple regression analysis to investigate 30 high heels samples specific coordinates, value of angle and slope, regarding these variables as independent variables. Hence, the dependent variable is consumers' perception (sweet, elegant, hot, and fashionable) In addition; we use backward regression procedure to find which specific variable affect the most and obtain the formula of numerical statistic and evaluative rating form image perception. The Table 5 shows results of multiple regression analysis for relationship between high heels form variables and image perception.

**Table 5:** results of multiple regression analysis for relationship between high heels form variables and image perception

Product image descriptors		sweet			elegant			hot			fashionable		
High-heels form	variable	UC	SRC	sig	UC	SRC	sig	UC	SRC	sig	UC	SRC	sig
Triangle area	P <sub>2</sub>												
	v <sub>3</sub> x												
	v <sub>4</sub> y	-.164	-.888	.000	-.315	-1.672	.046				-.275	-1.577	.023
	P <sub>3</sub>												
	v <sub>5</sub> x												
	v <sub>6</sub> y				.536	2.899	.001	.309	1.228	.000	.434	2.537	.001
P <sub>4</sub>	v <sub>7</sub> x												
	v <sub>8</sub> y				-.191	-.639	.033						
P <sub>5</sub>	v <sub>9</sub> x												
Slope	v <sub>10</sub>				-1.63	-.624	.016	-.990	-.279	.077			
Toe's angle	v <sub>11</sub>	.046	.249	.052									
Ground's angle	v <sub>12</sub>				-.085	-.407	.004	-.046	-.162	.082	-.036	-.188	.064
Triangle square	v <sub>13</sub>				-7.88	-.468	.021	-5.969	-.261	.028	-5.525	-.355	.004
Constant		6.126		.000	4.811		.000	1.94		.000	3.07		.000
R		0.82			0.84			0.90			0.88		
R <sup>2</sup>		0.67			0.7			0.81			0.77		

The criteria showed p-value of less than 0.05 was required for entry of greater than 0.1 for removal so as to retain only those design variables having a significant effect on consumers' perception of the high heels form, especially the design variables from v<sub>3</sub>x to v<sub>9</sub>x present P<sub>2</sub> to P<sub>5</sub> the original coordinate system in X and Y axis respectively. In addition, the multiple correlation coefficient value (R) and the square of correlation coefficient value (R<sup>2</sup>) imply the existence of significant relationship between the thirteen design variables and four image perception domains. The signs and values of the Standardized Regression Coefficients (SRCs) shown in Table 5 indicate the nature and intensity, respectively, of the effect of the design variables on each image perception domain. In general, a positive value of the SRC indicates that a change in the corresponding design variable in the positive direction will reinforce the consumers' perception of the product image, e.g. the image sensation will

become sweeter, more elegant, and so on. Conversely, if the SRC is negative, variation of the design variable in the positive direction weakens the corresponding product image, i.e. the high heels form is perceived as less sweet, less elegant, and so forth.

In clarifying the effect of the design variables on each image perception domain, the following discussions firstly start from sweet: it is affected deeply by design variable-v4y ( $p=.000<0.05$ ), representing the heel's height and the value is negative indicated that lower heel's height is sweeter in image perception. Moreover, the design variable-v11, showing the arc shape in shoe toe, the value of SRC is positive (0.249) indicated that more arc shape in shoe toe is sweeter in consumers' perception. Secondly, elegant: the most remarkable variable is v6y (SRC=2.889,  $p=0.001<0.05$ ) showing positive value means "the visual of shoes' height" is primary factor in elegant image perception. Thirdly, hot: the noticeable variable is also v6y (SRC=1.228,  $p=0.000<0.05$ ) indicating positive value supports that high heels height is most significant variable in hot image perception, whereas, the variable-v10 (SRC=-2.79,  $p=0.077>0.05$ )-slope variable is negative value indicated that slope is not the most important factor in hot image perception rather than height variable. Finally, fashionable: it shows similar statistics to elegant and hot image perception in variable-v6y (SRC=2.573,  $p=0.001<0.05$ ), but it is not contain the variable-v11 (slope), we presume that fashionable image perception is fuzzy in consumers' cognition. Therefore, the height (v6y) is the major variable in these three adjectives (elegant, hot and fashionable)

The data presented within the Unstandardized Coefficients (UC) column of Table 5 can be used to construct functional models relating the design variables of the high heels form to an evaluative rating in each of the four product image perception domains. The functional models for each product image perception domain can be formulated as follows:





- "Sweet" image= $6.126-0.164(v4y) + 0.046(v11)$
- "Elegant" image= $4.811-0.315(v4y)+0.536(v6y)-0.191(v8y)$   
 $-1.634(v10)-0.085(v12) -7.822(v13)$
- "Hot" image= $1.94+0.309(v6y)-0.99(v10)-0.046(v12)-5.969(v13)$
- "Fashionable" image= $3.072-0.275(v4y)+0.434(v6y)-0.036(v8y)-5.525(v13)$

#### 4. DISCUSSION

This paper has presented a numerical definition- based systematic approach (NDSA) to support the product design task. NDSA provides designers with the ability to create an explicit numerical definition of a product and to predict the consumers' likely psychological response to the product form. Further, the proposed approach has been verified using a high heels form for illustration purposes. Based on the image evaluation results obtained for 30 high heels form samples, multiple regression analysis was used to construct functional models relating the design variables of the high heels form with the product image projected in four image perception domains. The multiple regression analysis results show the most significant factor is design variable-v6y, representing the height of high heels in visual sense. It is different from slope is primary factor affected to consumers' perception we hypothesized previously. The reason probably caused by consumers' visual illusion in high heels' triangle area, and it is easy to focus on the highest point on illustration. Therefore, the height of high heels is the most noticeable variable in consumers' image perception rather than slope.

Further, according to quantitative theory type I and multiple regression analysis results, we propose the four highest point's samples by multiple regression formula in different image perception and modify these representative samples by quantitative theory type I within appreciate high heels form characteristics in different image perception. The Table 6 shows the final representative samples in four images (sweet, elegant, hot and fashionable)

**Table 6:** final representative samples in different image perception

Image perception		sweet	elegant	hot	fashionable
sample					
Multiple regression		6.5928	7.449	7.485	7.323
Quantitative theory type I	Shoe tongue	no	yes	no	no
	Shoe opening	curved	non-curved	non-curved	non-curved
	Real heel form	straight-curved	concave curved	concave curved	straight
	Heel thickness	thick	thin	thin	thin

Although this study has introduced an approach for identifying product forms which satisfy the consumers' product image expectations, the factors causing a consumer to like or dislike a particular high heels form have not been addressed. However, if the specific features of the high heels form design which invoke strong favorable (or unfavorable) reactions in the consumer can be reliably identified. Finally, the high heels form indeed affected by human different posture such as standing or overlapping in consumers' perception. Therefore, this study could be the fundamental research for fashion designer with specific guidelines in the form of pre-programmed design variable constraints and the research shall improve deeply in human posture within high heels form corresponding to different image perception in the future.

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