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Creating a Bicycle Design Approach Model Based on Fashion Styles

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Abstract: *The authors created a Bicycle Design Approach Model Based on Fashion Styles as a means of supporting idea generation for product development that takes into account customer sensibilities, and the effectiveness of this model was then verified. Specifically, an eye-tracking camera was used to analyze line of sight and discover the areas of a bicycle's exterior design that caught customers' attention. Next, preference studies were conducted and the results were analyzed using statistical science to identify subjective words that match four fashion styles. Rough Set Analysis and Quantification Theory Type I were used to analyze the findings and determine the extent of influence of each design element with respect to the subjective words, thus making it possible to create bicycle designs that match the preferences of each fashion group. The effectiveness of the proposed model in supporting idea generation during actual bicycle design and development was then verified.*
Keywords: *bicycle exterior design, Bicycle Design Approach Model, Fashion Styles*

I. Introduction

One of the most pressing concerns facing Japanese industry in the 21st century is the diversification of customer preferences and values, which raises the question of how to create products that the market find attractive. One of the elements that affects customer's drive to purchase is exterior design, and the case of bicycles is a classic example.

In this study, the authors develop a Bicycle Design Approach Model Based on Fashion Styles and verify its effectiveness. The model is designed as a means of triggering ideas for product development that take into account customer sensibilities. Specifically, they employ an eye-tracking camera to analyze line of sight and determine the importance of fashion sense in developing bicycle designs as well as the areas of a bicycle's exterior where customers place their attention. Next, they conduct a preference study and analyze the results using statistical science methods (principal component analysis and cluster analysis) to identify subjective words that match four fashion styles.

A Rough Set Analysis and Quantification Theory Type I are then used to analyze the above findings to identify the degree of influence that different design elements have on customers' subjective impressions, making it possible to create bicycle designs that match the preferences of each fashion group. The approach model developed by the authors is then used as a way to trigger ideas during actual bicycle design and its effectiveness is verified.

II. Background

A higher percentage of people use bicycles in Japan than in almost anywhere else in the world. Unlike Western Europe, however, where bicycle use is pervasive but people see them as vehicles on par with cars or buses, the Japanese typically see bicycles as a way to travel only short distances; in other words, riding them is simply another form of pedestrian activity. Rather than a means of getting to work or school, cyclists use bicycles as a form of recreational activity.

This has pushed the diversification of what customers value in recent years and changed the way people think about bicycles. Functionality has become increasingly important in bicycle manufacturing and sales, but the exterior elements of a bicycle (in other words, its design), are playing an increasingly pivotal role in purchasing decisions in recent years as well. In light of these changes, developing bicycles with designs and concepts that appeal to customer sensibilities are steadily gaining importance in bicycle development.

III. Prior Research

Consumer values (Morita, 2007. "Visualizing gaps in business processes in product planning and design departments aimed at identifying consumer values: Constructing measures of customer satisfaction ability that enhance subjective quality in the manufacturing industry"). This study statistically identified consumer values critical for product planning and design by constructing measures to evaluate the level of customer satisfaction, and then verified the effectiveness of those indicators.

Asami et al (2008) studied bicycle design in their "A-CEAM approach model for exterior vehicle design". In this paper, a new design process to support the generation of product planning ideas was defined with the purpose of suggesting bicycle designs and body colors that would appeal to women.

This study identifies designs preferred by females using market surveys and multivariate analysis, and then uses statistical descriptions of designs and 3D-CAD tools to visualize them. The effectiveness of these detailed findings are then verified. Another study on bicycle design was done by Koizumi et al (2012), entitled "A Bicycle Design Model Based on Young Women's Fashion Combined with CAD and Statistics". Their work statistically defined bicycle designs in terms of women's fashion through market surveys, multivariate analysis, AHP, and other means. The authors then created bicycle designs using 3D-CAD tools and verified the effectiveness of their approach model.

In looking at this prior research, the authors saw the importance of conducting a study on bicycle designs that aligned with different women's fashion styles—something that had not been done before.

IV. Design Of This Study

4.1 Research design

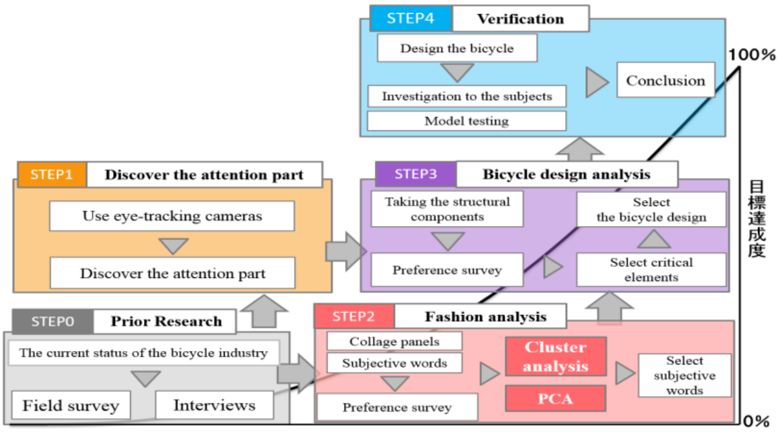

Fig 1. Research design

Figure 1 shows the research design devised to achieve the aim of this study; namely, to create a Bicycle Design Approach Model Based on Fashion Styles. In step 0, the authors survey the current status of the bicycle industry, observe bicycle activity on city streets, and conduct interviews with bicycle manufacturers. In step 1, they use eye-tracking cameras to discover what areas subjects tend to focus on. In step 2, they create collage panels, select subjective words, and conduct preference surveys in order to analyze fashion. In step 3, the structural components that make up a bicycle are identified and preference survey results are used to select those that are most critical. The elements selected are then used to analyze bicycle design. Finally, in step 4, bicycle designs generated using the approach model that the authors develop are verified.

4.2 Identifying areas of visual focus

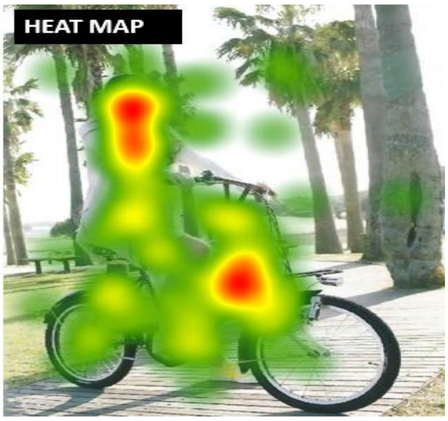

Fig 2. Heat Map

Creating bicycle designs requires that we know whether customers are actually focusing on a particular area of the product. In this study, the authors employed eye-tracking cameras to statistically determine these visual areas of focus. The results were used to generate a heat map, which is shown in Figure 2. The heat map indicates that subjects focused primarily on style (46.4%), followed by the frame (21.2%), the front tire (8.9%), the rear tire (8.5%), then handlebars (7.7%), the seat (4.0%), and other areas (3.3%). The findings made it clear that style should be taken into account, as it drew the most attention from viewers. They also indicated that the frame and front and rear tires should be key areas of design focus as well.

4.3 Fashion analysis

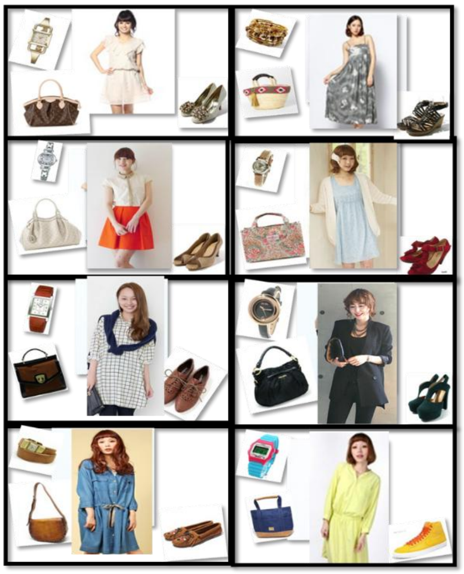

Fig 3. Collage panels for each fashion style

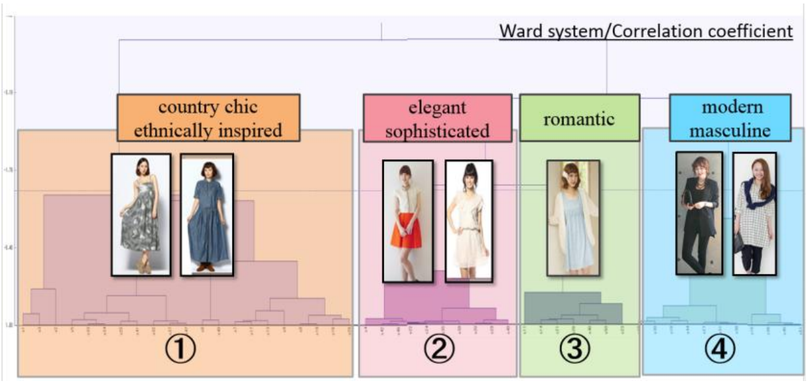

Fig 4. Results of cluster analysis

The authors conducted a fashion analysis in order to consider different fashion styles. They started by creating collage panels featuring women's fashion in eight distinct style categories—elegant, ethnically inspired, sophisticated, romantic, masculine, modern, country chic, and athletic—and the panels were used to survey preferences among women in their 20s. The actual collage panels used for the preference survey in the study are shown in Figure 3 below.

The survey asked participants to rate on a seven-point scale how closely the eight fashion collages matched their personal sense of style. It then asked them to rate the collages in terms of seventeen subjective characteristics thought to be attractive in bicycles (e.g. playful, untiring, cute, refined, etc.) and analyzed the collective data. The 51 subjects who took the preference survey were then sorted into eight style types using a cluster analysis. The results are shown in Figure 4. This information allowed the authors to create four distinct fashion groups, which were then subject to a principal component analysis in order to identify the subjective qualities (words) each group was looking for in a bicycle. These results are shown in Figure 5.

Based on these findings, the authors identified five subjective words that defined what those in the modern/masculine group were looking for: a bicycle that was stylish, classic, sporty, chic, and cool. They repeated this process, sorting the subjective words into the rest of the fashion groups. Next, in order to judge the degree of influence that the subjective words classified through cluster analysis and principal component analysis had on each fashion group, the authors analyzed the data using partial correlation coefficients. The results were 0.05 for "chic", 0.18 for "cool", 0.504 for "stylish", 0.52 for "sporty", and –0.127 for "classic".

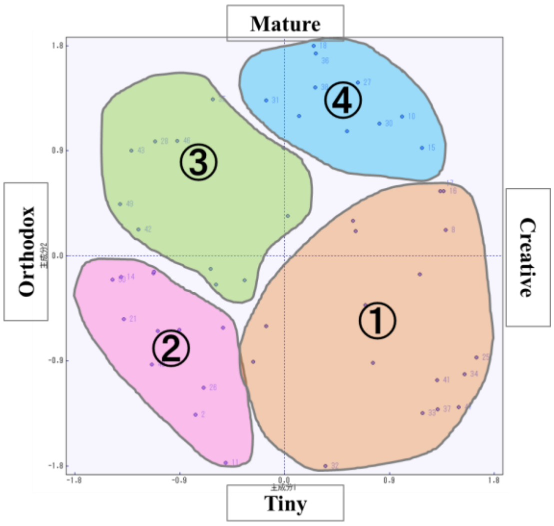

Fig 5. Results of principal component analysis (Modern/ Masculine)

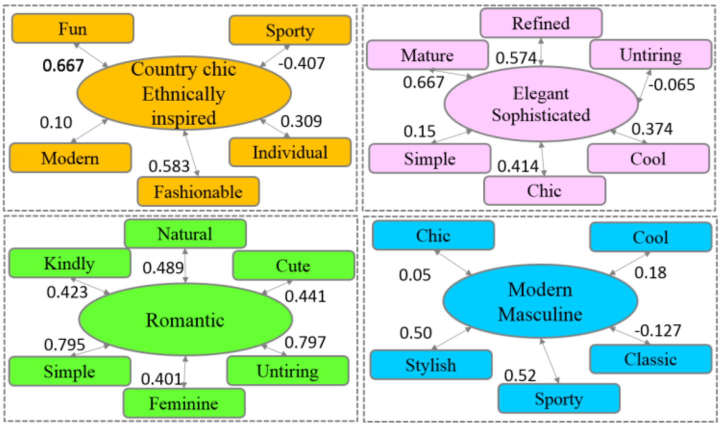

Fig 6. Influence of subjective words on each group

4.4 Bicycle design analysis

In the prior study "Using statistical science and CAD to create a bicycle design approach model based on fashion: Targeting women in their 20s", it was determined that the bicycle designs that women preferred were not simply about style; the way the individual parts of the bike coordinated with the design was also found to be important.

For the current study, the authors identified the structural components that make up a bicycle in order to see how the coordination among them affected women's preferences. The elements with the most impact were then combined in order to create a bicycle design. The components were identified through preference surveys given to women in their 20s, and this required that the authors create a model of a bicycle. They surveyed those currently on the market, created an attribute chart (Table 1), and then extracted images of the each structural part.

The nine components were these: (A) frame shape (mixed, staggered, diamond, looped, crossed); (B) frame color quality (vivid, light, pale, deep, dark, gray, neutral); (C) frame color (red, orange, yellow, yellowish green, green, bluish green, blue, bluish purple, purple, reddish purple, white, black); (D) handlebar color (brown, white, black); (E) handlebar shape (drop, level, angled up); (F) tire color (brown, white, black); (G) the basket (none, traditional weave, aluminum);(H) whether it had fenders; and (I) whether it had a chain cover.

The structural components in the attribute c can be combined into a total of 136,080 combinations, making it impossible to find images of every one. The authors selected 50 for their preference survey, and the number of times each component was featured in the images is shown in Table 1. Structural components in the images were identified based on this information, and then 51 women in their 20s took the survey that included the images generated. Specifically, the survey asked the subjects to rate each of the 50 bicycle pictures on a seven-point scale ranging from “I don’t like it at all” to “I really like it”. Data from the survey was then used to carry out a rough set analysis.

Conducting the rough set analysis first required that the authors convert the survey results to binary data. They did this by treating evaluations 1–4 (“don’t like it at all”, “don’t like it”, “dislike it a bit”, and “neutral”) as “dislike” answers, and evaluations 5–7 (“like it a bit”, “like it” and “really like it”) as “like” answers. The converted data was then analyzed for each group along with Table 1. When the authors looked at the decision class for the elegant/sophisticated fashion group, they found that the combination of a2 (standard frame shape) and g2 (traditional weave basket) had the highest CI value at 0.203. This means that it is likely that a bicycle with a standard shape frame and a basket will trigger the preferences of women in the elegant/sophisticated fashion group. The next most influential combination for this group is likely to be a2 (standard frame shape) and d1 (brown seat and handlebars), followed by b5 (dark colored frame) and e2 (level handlebars).

Table 1. Results of Quantification Theory Type I analysis

ATTRIBUTE	ATTRIBUTE VALUE	MARK	COUNT
A: frame shape	1. mixed	a1	11
	2. staggered	a2	10
	3. diamond	a3	10
	4. looped	a4	13
	5. crossed	a5	6
B: frame color quality	1. vivid	b1	6
	2. light	b2	11
	3. pale	b3	4
	4. deep	b4	6
	5. dark	b5	8
	6. gray	b6	7
	7. neutral	b7	8
C: frame color	1. red	c1	7
	2. orange	c2	5
	3. yellow	c3	5
	4. yellowish green	c4	4
	5. green	c5	5
	6. bluish green	c6	3
	7. blue	c7	4
	8. bluish purple	c8	3
	9. purple	c9	3
	10. reddish purple	c10	4
	11. white	c11	8
	12. black	c12	4
D: handlebar color	1. brown	d1	25
	2. white	d2	11
	3. black	d3	14
E: handlebar shape	1. drop	e1	15
	2. level	e2	24
	3. angled up	e3	11
F: tire color	1. brown	f1	10
	2. white	f2	8
	3. black	f3	32
G: basket	1. none	g1	25
	2. traditional weave	g2	14
	3. aluminum	g3	11
H: fenders	1.none	h1	24
	2.one	h2	26
I: chain cover	1.none	i1	35
	2.one	i1	15

When the decision class was changed to 0 (dislike), b4 (deep-colored frame) had the highest CI value at 0.167. This tells us that creating bicycle frames in deep hues has the structural component with the least effect on the preferences of women in the elegant/sophisticated fashion group. The findings from this part of the study are shown for each fashion group. The combination most preferred among women in the romantic style group was b3 (light grayish color) and d1 (brown seat and handlebars), followed by d1 (brown seat and handlebars) and f1 (brown tires), and then a2 (standard frame shape) and d1 (brown seat and handlebars). The best combinations for women in the modern/masculine fashion group were a5 (cross-shaped frame) and b7 (neutral color), followed by a5 (cross-shaped frame) and c11 (white frame), and then c11 (white frame) and g3 (aluminum basket). Women in the country chic/ethnically inspired group responded best to the a3 (diamond-shaped frame) and c10 (reddish-purple frame) combination, followed by c10 (reddish-purple frame) and d1 (brown seat and handlebars), and then c1 (red frame).

The authors next used Quantification Theory Type I to discover the relative importance of the other structural components. They designated the assessment values that each subject assigned the bicycle photos as the objective variable, and the structural components (frame design, handlebar design, and so on), as the explanatory variables. They then analyzed this data for each fashion style group. The results for frame shape and the elegant/sophisticated group are shown in Table 2. Looking at the partial correlation coefficients, we see that the standard frame shape component has the highest value. This means that creating a bicycle design that includes a standard frame shape is likely to appeal to the preferences of women in the elegant/sophisticated style group.

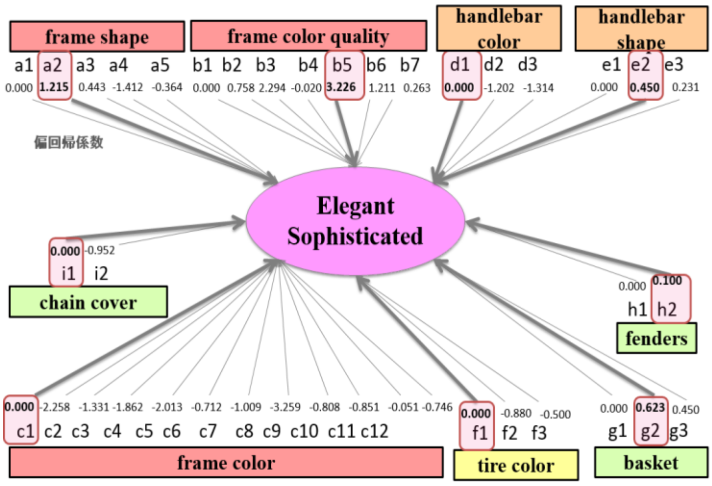

Fig 7. Impact of each structural component according to Quantification Theory Type I analysis (Elegant/sophisticated fashion group)

Quantification Theory Type I was used to analyze the other structural components (quality of frame color, handlebar/seat color, handlebar shape, frame color, tire color, basket, chain cover, and fenders) in the same way, and the results are shown in Figure 7. It indicates that the highest score (ideal characteristic) for each component are as follows: quality of frame color 3.226 (b5/dark), frame color 0.0 (c1/red), handlebar/seat color 0.0 (fi/brown), handlebar shape 0.45 (e2/level), tire color 0.0 (f1/brown), basket 0.623 (g2/with basket), with fender, no chain cover. This same analysis was applied to the other three style groups in order to come up with the bicycle design that would best match their preferences.

Table 2. Structural component attribute chart

Subjective variables name	**Residual sum of squares**	**Multiple correlation coefficient**	**Contribution rate (R^2)**	**R^*^2**
Evaluation of elegant and sophisticated	862.303	0.778	0.606	0.582
	R^{**}^2	Residual flexibility	Residual a standard deviation	
	0.559	518	1.29	
Explanatory variables	Residual sum of squares	Variation	Variance rate	Partial correlation coefficient
Constant term	1028.931	166.628	100.0959	3.835
Frame shape	1027.294	164.991	24.7782	
mixed				0

staggered	1.215
diamond	0.443
Looped	-1.412
crossed	-0.364

V. Verification

To verify the results of the study, a bicycle design was created for each fashion style group based on the findings obtained in section 4.4. These designs are shown in Figure 8. A survey was conducted comparing these new designs to those of existing bicycles to verify whether the ones predicted by the model were a better match for women's preferences. Specifically, the survey asked participants to rate how much they liked each design on a seven-point scale as well as the degree to which they embodied the subjective qualities (words) selected in section 4.3.

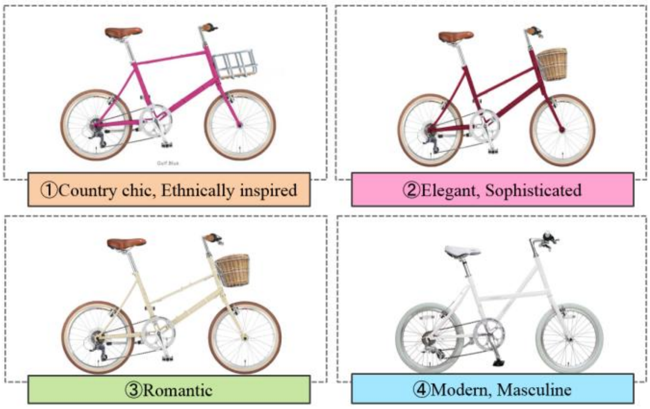

Fig 8. Designs generated by the model.

Table 3. Preference survey results (Elegant/sophisticated fashion group)

	Like		existing designs		custom design	
Subject	existing designs	custom design	mature	refined	mature	refined
Subject 4	5	6	2	2	7	7
Subject 2	4	4	4	4	6	4
Subject 20	2	6	1	1	7	6
Subject 22	3	6	1	1	5	7
Subject 24	4	4	4	4	5	6
Subject 29	2	4	2	2	7	5
Subject 35	1	7	1	1	7	7
Subject 39	5	5	3	3	5	5
Subject 42	5	4	4	4	4	4
Subject 43	2	7	3	3	7	7
Subject 49	2	7	2	1	6	6
Subject 15	2	5	2	2	5	5
Average	3.08	5.42	2.42	2.33	5.92	5.75

Table 3 shows the results of the survey for the elegant/sophisticated style group. Looking at the numbers, we can see that women in this group not only preferred the bicycle designed for them, but also rated it highly in their key subjective qualities ("mature" and "refined"). The validity of the study results was thus verified. Women in this group also rated their bicycle design higher than existing designs. Other groups yielded the same results, rating their custom design higher than that of existing products. As part of a qualitative investigation, the authors also conducted interviews at bicycle companies to confirm the validity of their model.

Interviews took place at two locations: the Bicycle Culture Center and Konno Corporation. Interview participants noted that the study offered a quantitative analysis of design development—which in the past had relied on the talent or unique skills of individual designers—and allowed them to carry out the process without past preconceptions. Japanese bicycle manufacturers currently take a conservative stance towards design development, creating models with the aim of appealing to the masses. In the interviews, however, these manufacturers suggested that the approach model designed in this study might make it possible for them to enter into collaborative tie-ups with fashion magazines or apparel manufacturers—opportunities that could not only enhance bicycle manufacturers' design capabilities, but also stimulate the domestic bicycle market as well.

These findings demonstrate that the authors successfully created a Bicycle Design Approach Model

Based on Fashion Styles as a result of this study.

VI. Conclusion

Although many studies have already been done on vehicle design, very few have addressed bicycle design. Bicycles have several components that automobiles lack, and the preferred fashion style of the person riding them has an impact on the bicycle design they select. However, prior research in Japan has been focused on bicycle components and there have been no studies on overall bicycle design.

Neither have there been studies that seek to define fashion statistically. This study addresses that gap by addressing the styles that are reflected in customer preferences with the aim of statistically understanding the effect that changes in bicycle design have on customer sensibilities. To achieve this aim, the authors employed tools such as statistical science and eye-tracking cameras in order to generate an approach model for bicycle design.

Based on the results of this study, it is hoped that future research will (1) verify the results obtained here with actual bicycles, (2) attempt to apply the authors' approach model to other fields, and (3) engage in joint research with companies to verify these outcomes through real-world case studies.

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