

## Research on Automobile Exterior Color and Interior Color Matching

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### ABSTRACT

The objective of this research was to optimize the matching of automobile exterior colors and interior colors as a method of creative support for product planning. First, preference surveys were conducted to determine which exterior colors and interior colors suit the preferences of women in their twenties, who were the target of the research. Second, color combinations were created based on the data obtained from the preference surveys. Third, for the purpose of validation, the effectiveness of the method was confirmed by conducting surveys to determine whether the color combinations created were suitable for women in their twenties.

**Keywords** – automobile, exterior colors, interior colors, color matching, preferences of women

### I. INTRODUCTION

One of the important challenges faced by Japanese industry in the 21st century is how to generate appealing products. For industries in the 20th century, how to achieve consistency in their products was an important issue. Nowadays, however, customer preferences are diversifying and it is necessary to create products to suit individuals. Merely providing products at low prices is not sufficient as a product development principle. When planning and developing new products for the automobile industry, it is vital to properly understand and incorporate customers' preferences and sense of values.

When a consumer buys a car, the most important element is the design. This is because the current market is overflowing with products offering functional performance that is sufficient to satisfy most consumers to a certain extent and, therefore, psychological elements have become more important when choosing a car. Design is a representative example of such psychological elements. Furthermore, considering the fact that a car is also a means of self-expression, psychological elements are becoming increasingly important.

### II. BACKGROUND

A February 2010 survey conducted in Tokyo that asked car buyers to name up to three decisive factors in their purchase decision revealed that 25.6% considered design/color to be critical—making it the sixth most influential feature. Although a car's exterior design and body color play a critical role in sending a message to customers, they are still not as important as price or brand name. Many of today's

vehicles do not express or effectively promote a clear concept or message with their design and color.

The authors therefore decided to look at the question of identifying users' rapidly changing needs and accurately addressing them by having auto manufacturers' product planning and design departments incorporate them in well-timed design development strategies and then effectively promoting and advertising the results. Of the countless studies done on car manufacturing, most focus on analyzing customer information, collaboration among automaker departments, design and development, or other individual components of the auto-making process. Scientifically analyzing customer information to identify preferences or taking a scientific approach to generating exterior designs and body colors have also been extensively studied, but there has been no methodological inquiry on how to best promote these features in the commercial market) [1][9].

### III. PREVIOUS STUDY

Much research has been conducted on automobile manufacturing, but this research mainly concentrates on process level matters such as analysis of customer information, interdepartmental cooperation, and design and development. Although there is much research that scientifically analyzes customer information to determine customer preferences or takes a scientific approach to creating exterior designs, no research has been conducted that focuses on matching exterior colors and interior colors [2][3].

Thus, this research seeks to optimize the matching of automobile exterior colors and interior

colors, focusing on women in their twenties as the targets of the research.

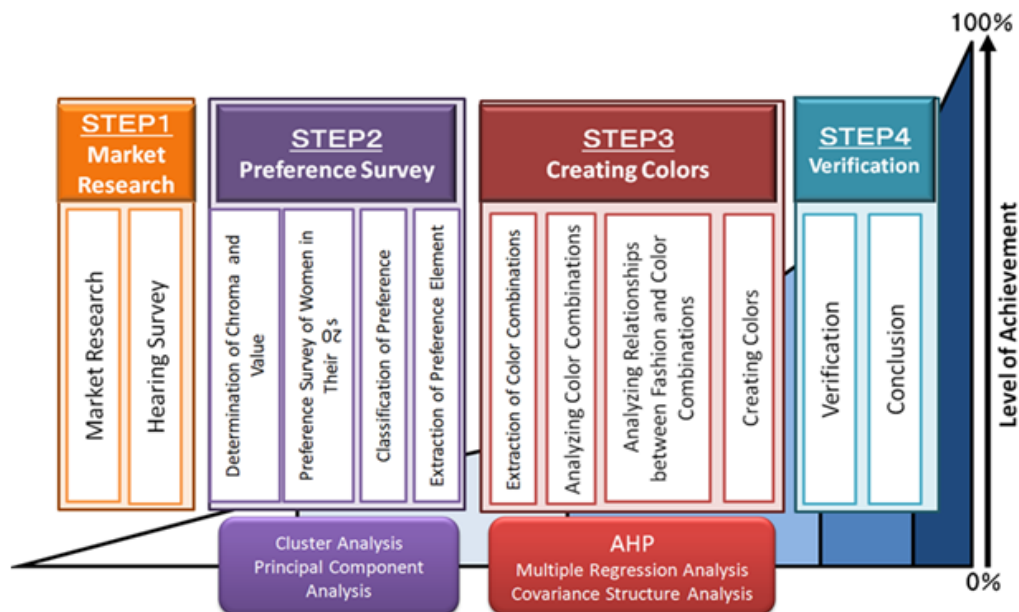


Fig. 1 Research program

## IV. PRELIMINARY RESEARCH

### 4.1 Automobile Exterior colors

Since the beginning of the 21st century, automobiles have evolved significantly in many ways, and automobile exterior colors have also diversified. The automobile industry has actively incorporated colors that women tend to prefer. With user-friendly functionality as well as fashionable colors and designs, the image of automobiles is likely to develop significantly in the future. Colors are also entering the next stage of their evolution.

Automobile exterior colors are influenced by a range of factors such as the current needs and sense of values of customers and the colors of other industries' products, trend information, styles and designs, colored materials, paints and painting techniques. It is necessary to have a sufficient understanding of these factors when undertaking color. This is because more people in their twenties tend to purchase a car for personal use than any other age group, making them the ideal targets in terms of understanding the needs of customers.

Furthermore, women also tend to be more interested in design than men. "Passo" made by Toyota Motor Corporation has been chosen as the vehicle for this research as it was created from the perspective of women customers, and the developers took into account feedback from women right from the development stage. The plan for this research is as shown below as shown in Fig. 1 [5][6].

### 4.2 Automobile Interior colors

When designing automobiles, the interior design has become just as important as the exterior design.

Unlike the exterior, the image sketches for the interior design portray the interior as viewed from the inside. For the interior design, designers do not produce large numbers of image sketches like they do for the exterior. This is because a design will not be adopted if, for example, it impedes the operation of functions or the visibility of the meters. Although individuals' color-related interests and preferences vary significantly, there are clear trends from the consumer perspective when viewed statistically. Color trends change through a 10 to 12 year cycle. These color trends also vary slightly depending on the region such as Japan, the US and Europe.

In addition to trends, consumers' color preferences also depend on cultural factors and the significance of a color may vary slightly in each market. Color designers need a good sense of color, but individual designers also have their own preferences and biases. Designers tend to believe that other users will like the same colors as they do. It is necessary to consider consumers overall when developing colors and materials. Therefore, designers must select the most appealing colors based on an understanding of the market environment and trends, gained through a statistical interpretation of consumers' preferred colors[7][8].

### 4.3 The Target Vehicle "Passo"

There are nine exterior colors available for the Passo, enabling customers to choose colors according to their preferences as shown in Fig.2. However, only one interior color is available.



Size	Total Length 3,640mm/ Width 1,665mm/Overall height 1,535mm
Riding Capacity	5 people
Total Emission	1NR-FE 1.329L/1KR-FE 0.996L
Price	1,000,000 yen ~ 1,470,000yen

Fig. 2 Summary of “Passo”

## V. MARKET RESEARCH

Questionnaire surveys were conducted to clarify what kind of cars women in their twenties prefer, and what they require from an automobile. The question items are as shown below [4].

Question items for determining the automobile-related preferences of women in their twenties:

- Automobile-related interests/awareness
- Preferred automobile exterior colors and interior colors
- Priorities when choosing a car

Question items for determining the lifestyle-related preferences of women in their twenties:

- Regularly read fashion magazines
- Usual fashion/style

### 5.1 Categorization by Preferences

Based on the results of the questionnaire surveys, cluster analysis was used to separate the car-related requirements into five groups (Group 1: Design color group, Group 2: Visual importance group, Group 3: Price importance group, Group 4: Function importance group and Group 5: Ride importance group). Next, Principal component analysis was then used to derive the factor loadings and create a positioning map as shown in Table.1 and Fig.3.

Table. 1 The factor loadings

Variable	主成分1	主成分2	主成分3	主成分4	主成分5
1 燃費	0.141	-0.361	0.831	0.040	-0.101
2 外装デザイン	0.690	0.580	0.082	0.002	0.139
4 内装デザイン	0.751	0.082	0.086	-0.415	-0.303
5 外装カラー	0.770	0.536	0.079	0.009	0.019
7 動力性能	0.781	0.165	0.030	-0.311	-0.175
8 居住性	0.509	-0.466	-0.018	0.438	-0.349
9 乗り心地	0.656	-0.514	-0.275	-0.092	0.341
10 ハンドル操作	0.667	-0.374	-0.424	-0.014	0.341
11 ブランド名	0.591	-0.413	-0.067	0.276	-0.211
12 価格	0.338	0.469	0.118	0.716	0.149
	0.184	-0.240	0.806	-0.097	0.375

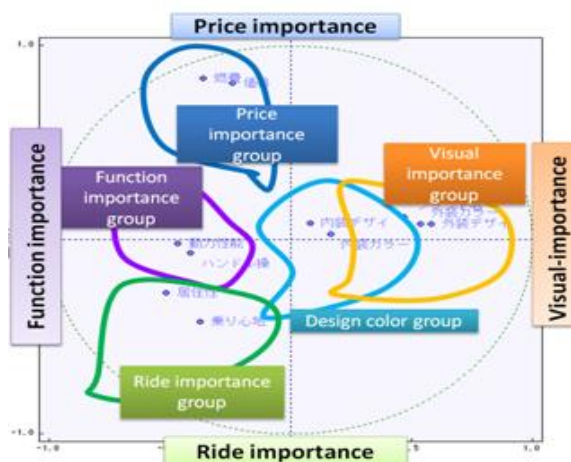


Fig. 3 Positioning map

Because the research involved varying the exterior colors, seat colors, and front panel colors, the researchers decided to target group 1 which prioritized the interior design and colors as well as the exterior design and colors. The results of the analysis for group 1 are as shown below.

### <Group1:Design color group>

The second principal component is positioned strongly towards the positive direction, indicating that appearance is an important requirement for an automobile. The third principal component is distributed around the center, indicating a tendency to pay little attention to ride comfort and price. It is also clear that the interior design and color are important as well as the exterior design and color.

Define abbreviations and acronyms the first time they are used in the text, even after they have been defined in the abstract. Abbreviations such as IEEE, SI, MKS, CGS, sc, dc, and rms do not have to be defined. Do not use abbreviations in the title or heads unless they are unavoidable.

## VI. CREATING COLORS

### 6.1 Producing Colors

Market research indicates that bright and pale colors (bright colors that are positioned comparatively close to the top of the color solid in the diagram) are

popular as automobile exterior colors for women in their twenties, who are the target for this research. Observation in urban areas also found that many women in their twenties tend to drive bright and pale colored vehicles. Thus, 10 light toned colors (five basic color hues and five intermediate color hues) were selected to use when varying the exterior colors, seat colors, and front panel colors.

In terms of “PCCS” numbers, the colors had uniform saturation (6S), and luminosity as indicated (Red: 7, yellow red: 7.75, yellow: 8.5, yellow green: 8, green: 7.5, blue green: 6.75, blue: 6, purple blue: 6, violet: 6, red purple: 6.5). (Due to the nature of color hues, brighter colors tend to look yellower while darker colors tend to look more purple blue. Thus, the luminosity of a particular tone will differ depending on the hue.) Based on the selected colors, the exterior colors, seat colors, and front panel colors were varied using GIMP image editing software.

The hue was changed while keeping the luminosity and saturation constant. A total of 10 colors were created, with five basic colors (red, yellow, green, blue, purple) and five complementary colors (Yellow red, yellow green, blue green, purple blue, red purple) as shown in Table. 2. These ten colors were used for the exterior colors, seat colors, and front panel colors respectively to produce a lineup of (10×10×10=) 1000 color combinations. These color combinations are analyzed in the next section.

### 6.2 Color Analysis

Analytic Hierarchy Process (AHP) was used to identify three important colors each for the exterior colors, seat colors, and front panel colors respectively. The exterior colors, seat colors, and front panel colors thus identified as shown in Table 3. Weighting (importance) was calculated for each of the 10 resulting exterior colors.

As a result, yellow, red purple, and blue green were identified as the important exterior colors. The same analysis was then conducted for the seat colors and the front panel colors. Red, yellow red, and purple blue were identified as the important seat colors while yellow red, green, and purple were identified as the important front panel colors.

Table. 2 Evaluation data of color parts

Sample	Picture1	Yellow exterior color	Yellow red exterior color	Yellow green exterior color	...
1	5	5	4	5	...
2	4	6	3	4	...
3	3	4	5	2	...
4	2	6	4	5	...
5	5	7	4	3	...
6	4	5	2	3	...
7	6	5	1	2	...
:	:	:	:	:	...

Table. 3 Result of AHP (Exterior color)

Alternative	Weight
Yellow	0.13
Yellow red	0.09
Yellow green	0.08
Purple	0.10
Blue	0.10
Purple blue	0.10
Blue green	0.11
Red	0.10
Red purple	0.12
Green	0.10

### 6.3 Analyzing Color Combination

The results of the color analysis identified three colors each for the exterior colors, seat colors, and front panel colors. These colors were combined to produce a total of 27 combinations, which were then evaluated as shown in Table. 4.

Table. 4 Combination

Exterior color Yellow (Y)	Exterior color Blue green (BG)	Exterior color Red purple (RP)
Y/Yellow red/ Green	BG/ Yellow red/ Green	RP/ Yellow red/ Green
Y/Yellow red/ Yellow red	BG/ Yellow red/ Yellow red	RP/ Yellow red/ Yellow red
Y/Yellow red/ Purple	BG/ Yellow red/ Purple	RP/ Yellow red/ Purple
Y/Purple blue/ Green	BG/ Purple blue/ Green	RP/ Purple blue/ Green
Y/Purple blue/ Yellow red	BG/ Purple blue/ Yellow red	RP/ Purple blue/ Yellow red
Y/Purple blue/ Purple	BG/ Purple blue/ Purple	RP/ Purple blue/ Purple
Y/Red/ Green	BG/ Red/ Green	RP/ Red/ Green
Y/Red/ Yellow red	BG/ Red/ Yellow red	RP/ Red/ Yellow red
Y/Red/ Purple	BG/ Red/ Purple	RP/ Red/ Purple

Averages were calculated for each of the evaluations. The average for the exterior color (red purple), seat color (yellow red), front panel color (purple) (hereafter, “Red purple+ yellow red + purple”) was the highest at 4.705. The second highest average was 4.647 for the combination of blue green+ purple blue + green. These combinations look very different when seen in photographs. However, when represented on a color pallet, they appear as shown in Fig. 4. The three colors (exterior color, seat color, and front panel color) are plotted as points on the color pallet, and the points are joined with lines to create a triangle.



Seen in the diagram, the balance (triangle) of the exterior color, seat color, and front panel color has a similar shape. Looking at the triangle separately, the difference in hue between the exterior color and the seat color is 5, while the difference in hue between the exterior color and the front panel color is 2 to 3 and the difference in hue between the front panel color and the seat color is 7 to 8. Thus, they are clearly related.

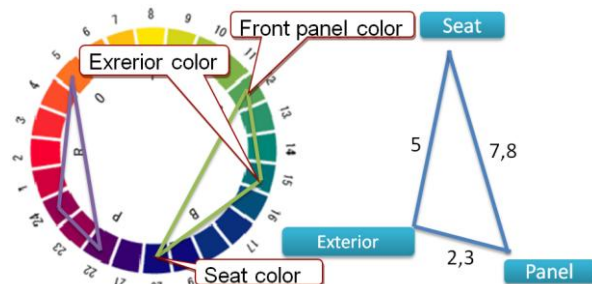


Fig. 4 Color expressed in the color palette and the triangle that is extracted

Four other triangles were extracted from the color pallet (①Exterior: red purple, Seat: yellow red, Panel: purple, ②Exterior: blue green, Seat: purple blue, Panel: green, ③Exterior: yellow green, Seat: blue green, Panel: yellow, ④Exterior: yellow red, Seat: yellow green, Panel: red). Triangles ① and ② are the original triangles, while triangles ③ and ④ are newly-found triangles. Of the 24 colors on the color pallet, this research uses five basic colors and five intermediate colors, making a total of 10 colors. These 10 colors are represented on the color pallet by the numbers 2, 5, 8, 10, 12, 15, 18, 20, 22 and 24.

#### 6.4 Identifying Similar Color Combinations Using Multiple Regression Analysis

Multiple regression analysis was used to analyze the 27 color combinations identified through color analysis. For the analysis of the color combinations, the combination of colors with the highest average “Red purple+ yellow red+ purple” was used as the objective variables while the other combinations were used as explanatory variables. When the variables were freely varied using the stepwise method it was found that, with respect to the objective variables “Red purple, yellow red and purple”, the partial regression coefficient for the combination of “Blue green + red + yellow red” was comparatively high at 0.617. Similarly, the partial regression coefficient for the combination of “Red purple+ red + purple” was also comparatively high at 0.522.

The combination of “Blue green + red + yellow red” is represented on a color pallet as shown in Table 4. The difference in hue between the exterior color and the seat color is 11, while the difference in hue between the exterior color and the front panel color is 10 and the difference in hue between the front panel color and the seat color is 3.

#### 6.5 Analyzing Relationships between Fashion and Color Combinations

In order to investigate the relationships between the nine color combinations as shown in Table 5 and the eight types of fashion defined as shown in Fig. 5, multiple regression analysis was conducted using the 27 color combinations identified through the color analysis.




Fig. 6 gives an example of a collage representing the eight types of fashion. It is clear from the diagram that “feminine” styles directly contrast with “masculine” styles, and “country” styles directly contrast with “city” styles. The fashion collage was constructed from the results of questionnaires targeting women in their twenties. The surveys investigated the kind of magazines the respondents read and the kind of brands they like, and collages were created for each.

Multiple regression analysis was repeated nine times using each of the color combinations as the objective variables and eight types of fashion collage as the explanatory variables. With respect to the Blue-green, Blue-violet, and Green objective variables, the partial regression coefficient for “romantic” fashion was comparatively high at 0.723 while the other explanatory variables showed minus values.

With respect to the “Blue green+ red+ yellow red” objective variables, the partial regression coefficient was 0.710 and “active” and “country” showed plus values. Thus, when the variables were added, each of partial regression coefficient values became lower. However, if only the country explanatory variable was used, the partial regression coefficient was high at 0.718. This indicates that there is a relationship between “country” and the combination of “Blue green + purple blue + green”

Results were also calculated for the other color combinations and summarized in a path diagram as shown in Fig. 7. This figure shows that there is a relationship between “Blue green + red + yellow red” and two types of fashion (Ethnic, Country).

Table. 5 Color combination of nine were extracted from the analysis

Exterior	Seat	Front panel	Triangle
Red purple	Yellow red	Purple	
Blue green	Purple blue	Green	
Yellow Green	Blue Green	Yellow	
Yellow red	Yellow green	Red	
Blue green	Red	Yellow red	
Blue	Yellow red	Yellow	
Red purple	Red	Purple	
Purple blue	Purple	Blue	
Yellow green	Green	Yellow	

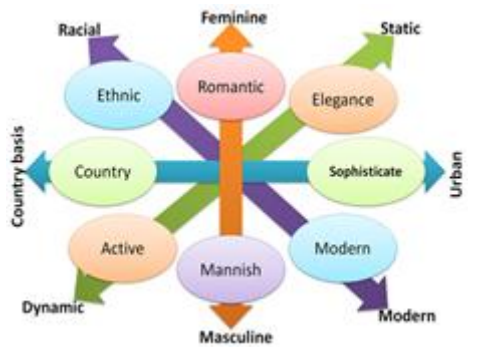


Fig. 5 Relationship diagram of eight fashion



Fig. 6 Fashion collage

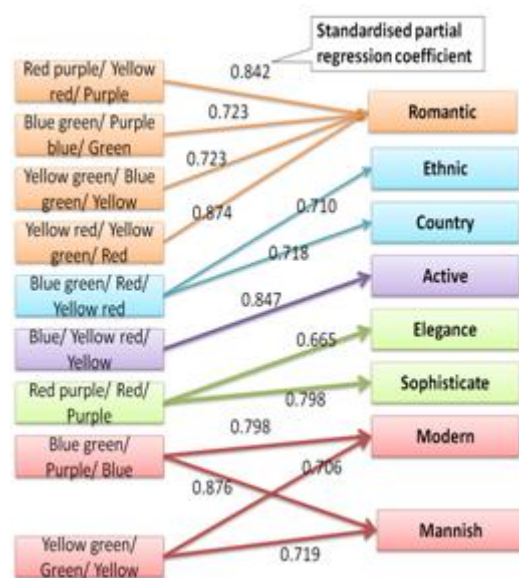


Fig. 7 Pass diagram

Similarly, there is a relationship between “Red purple + red + purple” and “elegant” and “sophisticated”, as well as between “Blue green +purple + blue” and “Yellow green + green + yellow” and “modern” and “manly”. However, the relationship between the two is unclear. Thus, covariance structure analysis was conducted in order to clarify this relationship. The regression coefficient for “elegant” and “sophisticated” was 0.76, which clarified the relationship. Similarly, the regression coefficients for “manly” and “modern” and “country” and “ethnic” were high at 0.88 and 0.83 respectively as shown in Fig. 8 and Fig. 9.

In the same way as (1), covariance structure analysis was next conducted with the objective variables and explanatory variables reversed. The analysis revealed that the regression coefficient for

“sophisticated” and “elegant” was 0.81, indicating that there is a relationship. Similarly, the regression coefficients for “manly” and “modern” and “country” and “ethnic” were high at 0.84 and 0.82 respectively. The other regression coefficients have minus values, or low values.

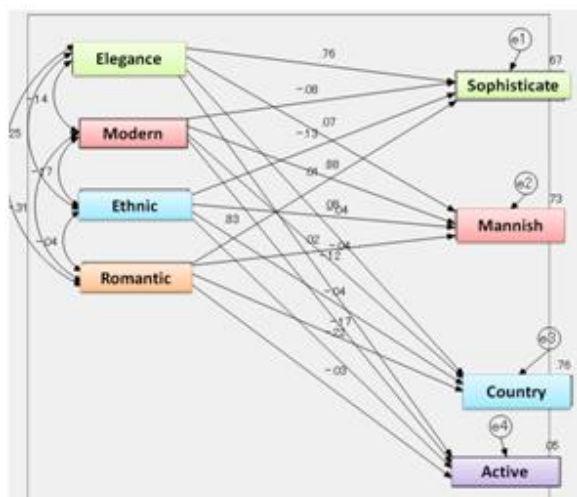


Fig. 8 Covariance structure analysis of the relationship of the fashion (1)

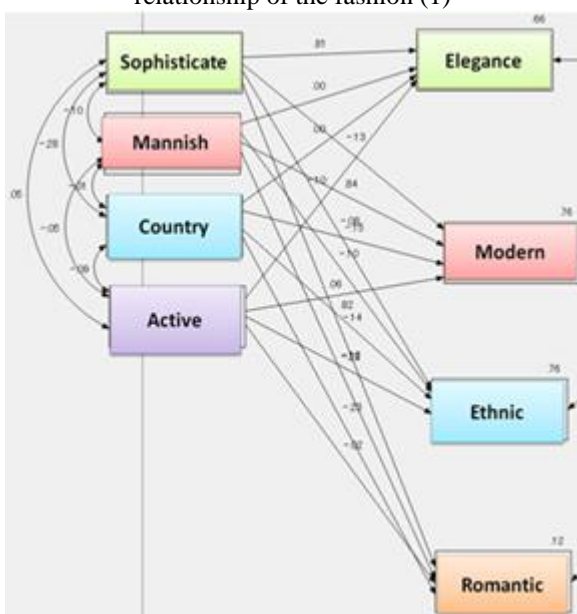


Fig. 9 Covariance structure analysis of the relationship of the fashion (2)

This indicates that there is a weak relationship for fashion styles other than “sophisticated” and “elegant”, “manly” and “modern”, and “country” and “ethnic”. When the fashion collages were reviewed based on these results, it was found that there were definite similarities between each of these pairs. These fashion styles are also positioned similarly (Fig. 6). In the “sophisticated and elegant” collage, there is an overall white theme. In the “manly and modern” collage, similar kinds of beige or blacks are used for a relaxing impression. In the “ethnic and country”

collage, even similar words are used. Based on the above results, fashion collages were reconstructed for the pairs “sophisticated and



Fig. 10 New fashion collage

“elegant”, “manly and modern”, and “ethnic and country” as shown in Fig. 10.

The “sophisticated and elegant” collage gives a mature impression overall. The “ethnic and country” collage incorporates both “ethnic” style and “country” style elements. The “manly and modern” collage has a beige and black theme, giving a relaxing impression. Conducting analysis in this way has enabled previously unnoticed relationships to be discovered between fashion styles.

### 6.6 Discussion of Color and Fashion

When reviewing the color combinations and fashion styles for which relationships were discovered during analysis, it becomes evident that they are connected to a certain degree.

<Romantic> (Fig. 11)

Overall, this is an intermediate color combination with only slight differences between the hues, giving rise to indistinct color combinations. Women who prefer romantic fashion also tend to be interested in slight color differences. Indistinct color combinations are often used, and it is clear that this triangle also applies to fashion.

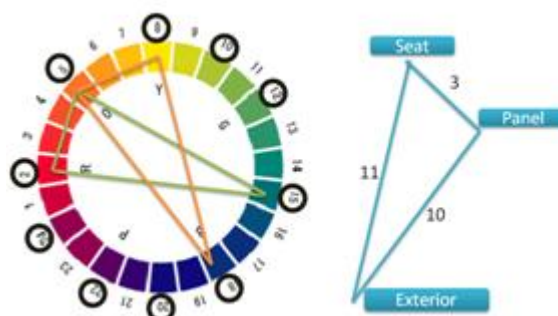


Fig. 11 A triangle of Romantic



<Ethnic×Country> (Fig. 12)

Both the seat colors and the front panel colors are complementary colors of the exterior colors, making this a contrasting color combination. As an energetic and stimulating color combination, the stimulating colors relate to the “country and ethnic” fashion styles while the energetic colors relate to “active”.

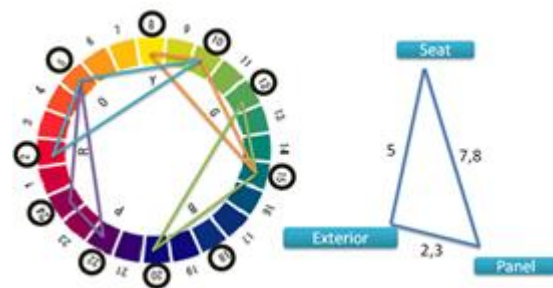


Fig. 12 Triangles of Ethnic×Country and Active

<Modern×Mannish, Elegance×Sophisticate> (Fig. 13)

Overall there are only slight differences between the hues, making this a triangle of analogous colors. The overall unity of the hues gives a relaxing impression. The related fashion styles also have a mature image and a relaxing impression. The color combinations therefore have a similar relationship to the styles.

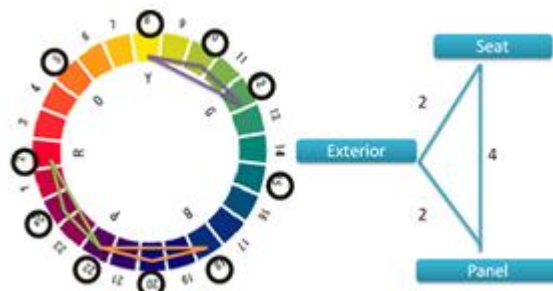


Fig. 13 Triangles of Modern×Mannish and Sophisticate

## VII. VERIFICATION

In order to validate the research, 17 women in their twenties were asked to clarify their own fashion style and then freely change the exterior colors, seat colors, and front panel colors in images using GIMP image editing software.

The results showed that the “romantic”, “ethnic + country”, and “elegant + sophisticated” color combinations matched the color combinations sought by the women in their twenties who indicated those fashion preferences. As the luminosity and saturation were fixed (bright and pale colors) for this research, no correlations were found in the color combinations sought by women in their twenties in terms of luminosity and saturation. However, similar results were obtained concerning differences in hue (triangles).

For evaluation and validation purposes, Makita Craft Inc. was consulted on the research as a whole and the following opinions were given. Due to the costs involved in automobile manufacturing it seems that there is a tendency to try to apply the largest common denominator and use the most easily acceptable colors.

However, companies are now undertaking initiatives such as incorporating single accent colors in seat fabrics. At the current stage, it will be difficult to apply this research in practice because the seat color of the Passo is limited to one color. However, the company has said that if the research is developed further it should be possible to formulate a model that can be used for practical applications.

## VIII. CONCLUSION

This research focused on automobile exterior colors and interior colors to clarify previously indistinct color combinations, and the relationships between these color combinations and fashion styles. One

future aim is to develop an approach model and apply it to other subjects. Although this research targeted women in their twenties, it will be preferable to extend the scope in the future to include other age groups and other countries.

Due to feedback from interviews, this research covered only 10 types of bright and pale colors applied to the exterior colors, seat colors, and front panel colors. However, as innumerable colors exist, it will therefore be necessary to conduct further research to include more colors. Color is described in terms of luminosity, saturation, and hue. However, for example, factors such as shine and grain should also be taken into consideration for exterior colors.

## IX. ACKNOWLEDGEMENTS

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