https://doi.org/10.31436/iiumej.v26i1.3239

APPLICATION OF KANSEI ENGINEERING IN VARIOUS TRAIN COMPARTMENT DESIGNS TO DETERMINE THE USER'S AFFECTIVE RESPONSE

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(Received: 27 March 2024; Accepted: 10 September 2024; Published online: 10 January 2025)

ABSTRACT: Visual appearance (shapes, colors, materials, and surfaces) applied to product design can provide users with emotional and positive affective responses. The desire of such users will provide essential guidelines for companies to develop products, in this case, trains, in the form of private spaces called compartments. Trains are in great demand for long trips, so there is a need for market segmentation. However, current research only focuses on designs that examine functionality needs. Lack of study of design based on visual appearance, research on user preferences, and more scientific evaluation of design is needed. Therefore, this study aims to translate the user's affective response into the interior design specifications of train compartments with the *Kansei* Engineering method. This research consists of 5 steps: (1) Determining product semantics (*Kansei* Words assignment); (2) Define product properties (items and categories), as many as eight design samples; (3) Distributing questionnaires to 150 respondents (75 men and 75 women); (4) Data analysis with multivariate statistics, KMO, Barlett's Test, Principal Component Analysis, and clustering of respondents; (5) Evaluate the results of the most optimal design specifications. The results of this study obtained design recommendations: straight shape, studio green color, pine wood HPL material texture, and doff surface. In addition, several user clusters were formed based on gender, age, and monthly income to segment train compartments when commercialized. This research is expected to be helpful for the wider community and the development of the interior design of train compartments.

ABSTRAK: Penampilan visual (bentuk, warna, bahan dan permukaan) yang digunakan pada reka bentuk produk dapat memberikan tindak balas emosi dan tindak balas afektif positif daripada pengguna. Keinginan pengguna akan memberikan garis panduan penting bagi syarikat untuk membangunkan produk, dalam kes ini kereta api dalam bentuk ruang peribadi yang dipanggil petak ruang kereta api. Kereta api mendapat permintaan yang tinggi bagi perjalanan jauh, jadi terdapat keperluan untuk pembahagian pasaran. Walau bagaimanapun, penyelidikan semasa hanya memberi tumpuan kepada reka bentuk yang mengkaji keperluan fungsi sahaja. Terdapat kekurangan kajian mengenai reka bentuk berdasarkan penampilan visual, penyelidikan mengenai keutamaan pengguna, dan penilaian reka bentuk yang lebih saintifik diperlukan. Oleh itu, kajian ini bertujuan untuk menterjemahkan tindak balas afektif pengguna ke dalam spesifikasi reka bentuk dalaman petak ruang kereta api menggunakan kaedah Kansei Engineering. Penyelidikan ini terdiri daripada 5 langkah: (1) Menentukan semantik produk (penentuan patah kata Kansei); (2) Tentukan sifat produk (item dan kategori), sebanyak lapan sampel reka bentuk; (3) Mengagihkan soal selidik kepada 150 responden (75 lelaki dan 75 perempuan); (4) Analisis data dengan statistik multivarian, KMO, Ujian Bartlett, analisis komponen utama, dan kelompok responden; (5) Penilaian keputusan spesifikasi reka bentuk paling optimum. Hasil kajian mencadangkan reka bentuk: bentuk lurus, warna hijau studio, tekstur bahan HPL kayu pain, dan permukaan doff. Di samping itu, beberapa kluster pengguna dibentuk berdasarkan jantina, umur dan pendapatan bulanan bagi memudahkan pembahagian petak ruang kereta api apabila dikomersialkan. Kajian ini dijangka berguna kepada masyarakat yang lebih luas dan pembangunan reka bentuk dalaman petak ruang kereta api pada masa hadapan.

KEYWORDS: *affective, interior design, Kansei engineering, railway, visual appearance*

1. INTRODUCTION

The visual appearance of a product can satisfy consumers in addition to ease of use. Trains must also consider visual impressions as one of the transportation products used for the public. One of the railway facilities currently being developed in Indonesia is a compartment that offers long trips with comfortable seating and more private beds with partitioned space [1]. Many developed countries already have similar trains that attract foreign tourists, such as the Shiki Shima Train Suite in Japan, the Caledonian Sleeper in England, and the Grand Express in Russia. Each train in the country applies a different visual appearance to its interior design and becomes a characteristic. This condition necessitates the existence of a compartment design that can create an emotional attachment with its users to attract tourists to travel by train in Indonesia. To create a memorable and pleasant experience for train passengers, the designer must consider the correlation with the users' emotions [2]. A person's emotional state results from an affective response when looking at a product. In this case, visual appearance becomes very important because it is the first stimulus captured by the five senses and attracts human attention [3]. Furthermore, the stimulus is processed in the brain and interpreted into perceptions assessing product design's advantages and disadvantages [4]. The visual display comprises shape, color, material, and surface [5].

This research applies *Kansei* Engineering as a method of emotion-based design for the interior design of railway compartments in Indonesia. *Kansei* Engineering is a powerful method for converting users' feelings and emotions into design specifications [6]. Kansei Engineering can also be used as a tool to develop the design of a product that generates innovative solutions [7]. This method is widely used behind the success of several well-known transportation product brands worldwide, such as Mazda, Hyundai, and Toyota. Other research on transportation is reported on the design of economic and business train seats in Indonesia [3] and the design of the product image of railway seats [8]. In the car design industry or interior design project, the *Kansei* Engineering method was used to evaluate respondents' preferences for car design [9]. At the same time, preliminary research on the design of luxury class train compartments resulted in selected design specifications by respondents [1].

To evaluate the design of train compartments with Kansei engineering, a semantic differential (SD) scale is needed to translate stimuli received by the five human senses [10]. The semantic differential scale consists of several Kansei words, which are adjectives that describe the product to be graded on a scale of 1-5. Furthermore, the results of respondents' assessments will be analyzed with multivariate statistics. Principal Component Analysis (PCA) determines the principal components and summarizes the variables into fewer [11]. At the same time, cluster analysis was used to classify the number of groups of respondents [12] in this study based on gender, age, and monthly income. User clustering proved helpful in identifying specific group responses to designs [13].

Considering the findings, this study proposes a specification of the interior design of the railway compartment based on visual appearance (color, shape, material, surface). It also considers three groups of respondents based on selected design and affective responses that best suit user preferences. This study's practical application is evident in its potential to serve as a reference for railway compartment design in Indonesia and around the world, making it a valuable resource for designers and professionals in the field.

2. METHODOLOGY

2.1. *Kansei* Engineering

Kansei Engineering includes the field of ergonomics (human factors), which focuses on human affective responses. Nagamachi, a professor from Japan who first developed this method, defines *Kansei* Engineering as a technology capable of translating user emotions into design specifications [11]. Currently, *Kansei* Engineering is applied to various disciplines (natural sciences, social sciences, and humanities) that integrate affective elements into the development stage of product design. In *Kansei* Engineering, users usually use adjectives that describe a product called *Kansei* Words. Here are the five main steps in *Kansei* Engineering:

2.1.1. Determine Product Semantics

The first step is to choose a product domain by determining the object and subject of the research. Then, *Kansei* Words in adjectives and grammatical forms that describe the product are collected and obtained from various sources, such as journals, books, and magazines. These *Kansei* Words are crucial as they represent users' emotional and affective responses towards the product. Usually, the collection of *Kansei* Words is 50-600, so sorting is necessary [14]. The reduction process is carried out by grouping similar *Kansei* Words and selecting them until they obtain the most representative *Kansei* Words.

2.1.2. Determine Product Properties

In the *Kansei* Engineering procedure, properties are divided into items and categories to be applied to design samples. An item is a particular characteristic used in the design, while the category is the division of groups within each item [1].

2.1.3. Data Collection

This step prepares a questionnaire by combining product samples with Kansei Words. This study used the optimal 5-point semantic differential scale to assign values to each sample. The scale developed by Osgood can translate the stimulus received by the five human senses into numbers [10]. The data obtained from the questionnaire will be analyzed and used to build a relationship model.

2.1.4. Data Analysis

After the data is collected, validity and reliability tests are conducted to ensure the research data is valid and reliable. Then, Kaiser-Meyer-Olkin (KMO) and Barletts's Test of Sphericity tested the feasibility of the data. Principal Component Analysis (PCA) summarizes variable dimensions so readers can understand the data structure [11]. In addition, it is also to find out the score and position of the product from the visualization of product aspect mapping. At the same time, cluster analysis aims to group respondents into clusters based on specific characteristics [15].

2.1.5. Evaluation of the Results of the Design Specification

Decision-making for design specification recommendations is done by drawing conclusions based on the results of data analysis. Research results must be evaluated so that the product can provide an effective mechanism with the overall design expected by the user. As seen in Figure 1, the research framework adopts the procedures from *Kansei* Engineering described earlier.

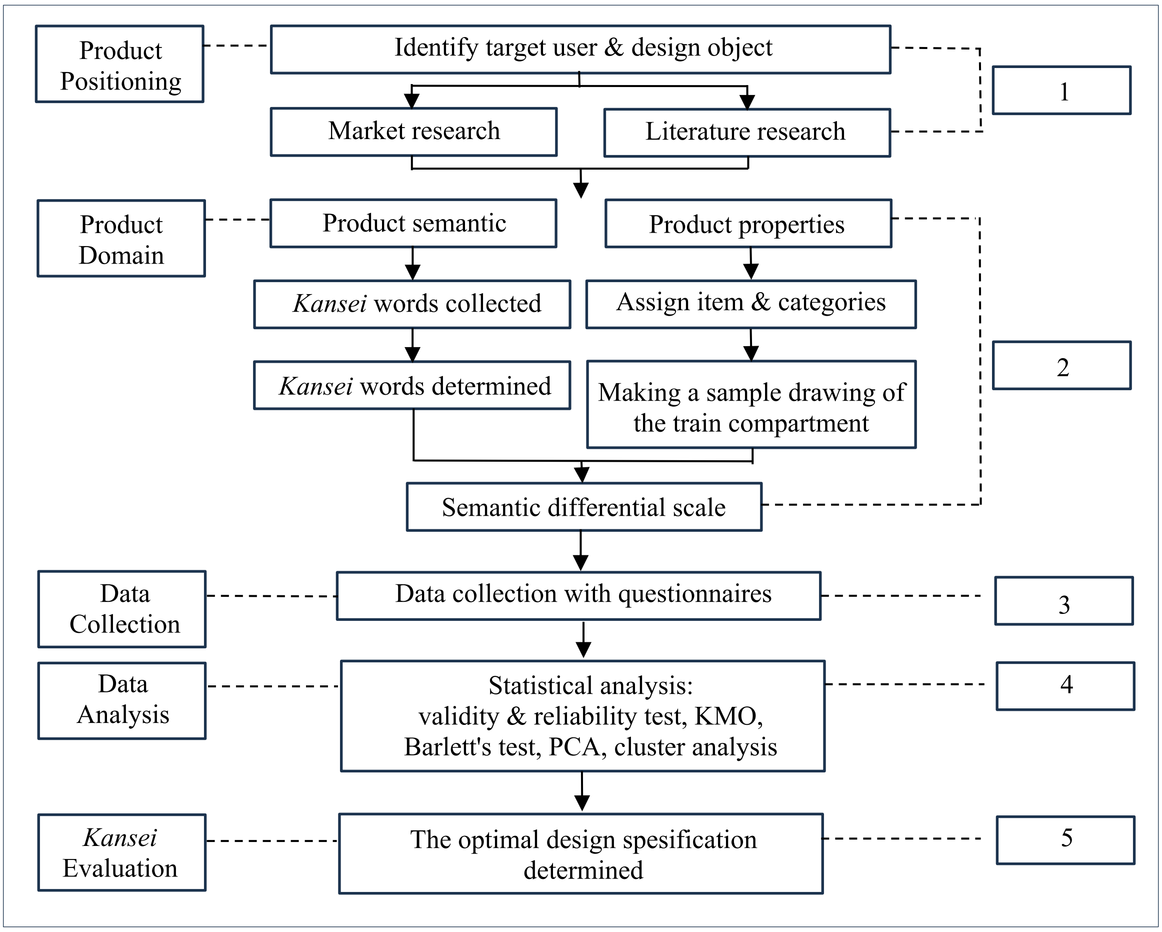

Figure 1. Flow diagram of the *Kansei* Engineering procedure.

2.2. Semantic Differential Method

A person's feelings and impressions of the product are complex structures that require measuring instruments. The semantic differential scale is one of the psychological measurement scales developed by Charles E. Osgood, an instrument to measure human affective responses to product development [7]. The SD scale consists of Kansei Words paired with their antonyms to be assigned point values in the number range 1-5. The 5-point scale is the easiest for respondents to use and understand [11].

2.3. Procedures

Most of Kansei's evaluations are user surveys that use semantic differential scales. This study distributed questionnaires to 150 respondents (75 men and 75 women) Indonesian people who had experience traveling by train. The questionnaire-filling stage begins with an explanation of the research and how to fill out the questionnaire. The respondent fills in their identity based on age, gender, and monthly income. After that, eight samples of train compartment designs appear on an SD scale. Respondents can also view the design display in 360o with AR (Augmented Reality) technology to see samples of train compartment designs. Respondents give scores by filling in the SD scale in the range of 1-5 according to their affective response when looking at the given designs.

3. RESULT AND DISCUSSION

3.1. Collection and Determination of Kansei Words

One hundred twenty words describing the train compartment were collected from journals, books, magazines, and others. Then, a process of selecting Kansei Words was carried out with a focus group discussion (FGD) with the design team to summarize them into 40 Kansei Words. The 40 words were then verified with questionnaires to obtain objective results from respondents. The ranking of the Kansei Words reduction stage was carried out by a questionnaire with the results of 6 words with the top rank, namely 'comfortable,' 'luxurious,' 'unique,' 'enjoyable,' 'simple,' and 'modern,' for further use on an SD scale. Table 1 below is a questionnaire form with an SD scale with six selected Kansei Words.

Table 1. Questionnaire form for semantic differential analysis

Opposite Words	Scale					*Kansei* Words
	1	2	3	4	5	
Uncomfortable						Comfortable
Spartan						Luxurious
Ordinary						Unique
Boring						Enjoyable
Complex						Simple
Traditional						Modern

3.2. Determination of Specifications and Design Samples

The task in this step is to determine the design domain and specifications that can represent the target group and market needs. Then, prepare a comprehensive set of eight train compartment designs for the questionnaire. Design specifications are applied based on four visual display items (shape, color palette, surface, and material texture), and each is further divided into 2-3 categories. The shape items consist of curved and straight lines, the color palette consists of studio green, emerald green, and sage green, the surface appearance consists of glossy and doff, and the texture material of HPL (High-Pressure Laminate) consists of teak wood, mahogany wood, and pine wood. The design refers to the results of previous research [1] and the development of the compartment mock-up made by a railway company in Indonesia (PT. INKA). Table 2 shows eight interior designs of railway compartments as samples applied to the questionnaire.

Table 2. The samples of railway compartment interior design and specifications

Code	Design Sample	Specifications
S1		• Shape: curved • Color: studio green • Surface: doff • Texture: teak wood

S2		• Shape: curved • Color: emerald green • Surface: glossy • Texture: mahogany wood
S3		• Shape: curved • Color: sage green • Surface: doff • Texture: pine wood
S4		• Shape: curved • Color: studio green • Surface: glossy • Texture: mahogany wood
S5		• Shape: stright line • Color: emerald green • Surface: doff • Texture: teak wood
S6		• Shape: stright line • Color: sage green • Surface: glossy • Texture: mahogany wood

https://doi.org/10.31436/iiumej.v26i1.3239

S7		• Shape: stright line • Color: studio green • Surface: doff • Texture: pine wood
S8		• Shape: stright line • Color: emerald green • Surface: glossy • Texture: mahogany wood

Source: Design development from Indonesian Railway Company (PT. INKA)

3.3. Questionnaire Result

The respondents' identity or characteristics based on the questionnaire results include gender, age, and monthly income. The ratio of males and females is equal, with 50% each, totaling as many as 75 people. The age data of respondents can be seen in Figure 2, with the majority aged in the range of 20-30 years, as much as 70%, the age range of 30-40 years, as much as 16%, the age over 40 years as much as 11%, and the age range of 17-20 years as much as 3%. Then, based on monthly income in Figure 3, respondents were highest in the range of 1-5 million rupiah (IDR), as much as 53%, in the range of 5-10 million rupiah (IDR), as much as 22%, below 1 million rupiah (IDR), as much as 16%, and above 10 million rupiah (IDR) as much as 9%.

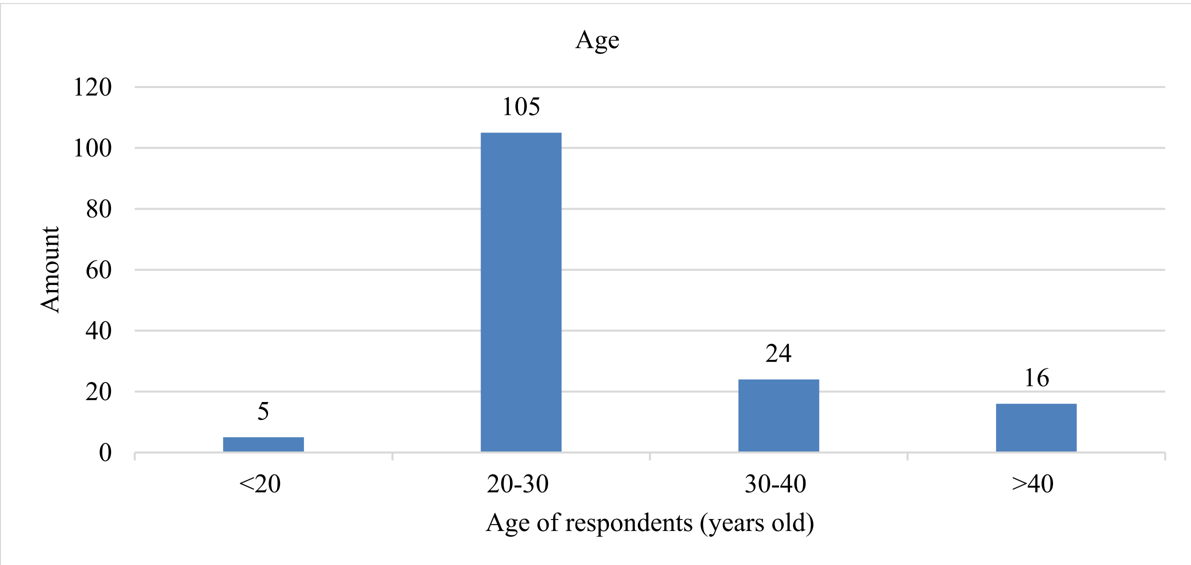

Figure 2. Respondent profile based on age.

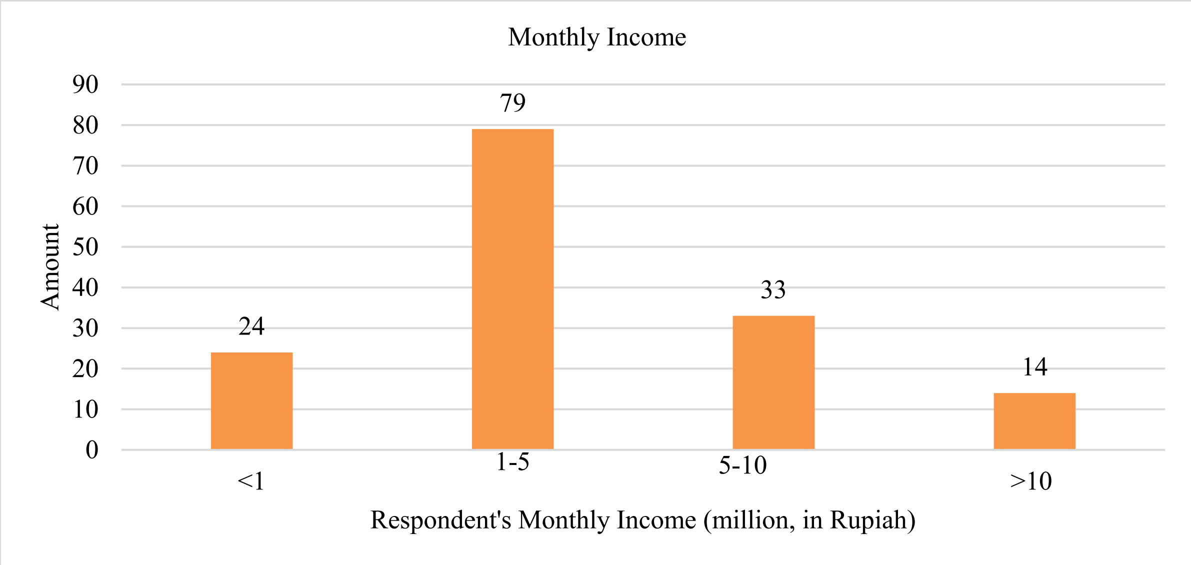

Figure 3. Respondent profile based on monthly income.

The clustering of respondents can be divided into geographic segmentation (city, province, country), demographic segmentation (age, gender, occupation), and psychographic segmentation (lifestyle). However, what is used in this study is only demographic segmentation [16]. Figures 2 and 3 show the cluster grouping for respondents determined based on demographic segmentation, namely gender, age, and monthly income of each respondent.

3.4. Data Analysis

3.4.1. Validity and Reliability Test

Testing the validity and reliability of the data is done with the help of SPSS 17.0 software. The value of the R table for 150 respondents with a significance level of 5% was 0.159, and for a significance level of 1%, it was 0.208. From the validity test results, all correlation values are more significant than the value of the R table, or it can also be called R calculate > R table so that the data is declared valid. Another requirement to report whether or not data other than correlation is to look at the significance value (Sig.). If the significance value < 0.05, then the data is declared valid. After being tested for validity, the next step is to test reliability. The reliability test results show that Cronbach's alpha value is 0.959 > 0.6, so the data is declared reliable.

3.4.2. KMO and Barlett's Test

KMO (Kaiser-Meyer-Olkin) and Barlett's Test of Sphericity to determine the feasibility of data before factor analysis or PCA (Principal Component Analysis). KMO aims to determine whether the variable is adequate and has a KMO value criterion of > 0.5. Then, the analysis can continue. While Barlett's Test seeks to assess the level of a significant relationship between variables with sig value criteria of < 0.05, it can be indicated that the variables are sufficiently correlated. The test results show that the KMO value for each design (S1-S8) is > 0.5, thus qualifying that the sample is adequate. The results also showed that all sig values were 0.000 < 0.05, and Barlett's Test produced a sufficient correlation between variables.

3.4.3. Principal Component Analysis (PCA)

Principal Component Analysis (PCA) was carried out in this study to reduce the initial variables that amounted to fewer without eliminating the information in the initial data. The new variable of reduction results is called the main component or factor. A variable can explain a factor with an extraction value of > 0.50. The analysis showed that all variables (comfortable, luxurious, unique, enjoyable, simple, modern) were valued at > 0.50.

The eigenvalue is the magnitude of the total variance that can be explained by the factor formed and is greater than 1. Table 3 illustrates that the eigenvalue of factor 1 is 4.611 > 1, thus explaining 76.852% of the variation. Meanwhile, the eigenvalue of factor 2 is 1.011, so it can explain 16.844% of the variation. Factor 1 and factor 2 can account for 93.696% of the variation. The values of factor 1 and factor 2 already represent data analysis or user preferences.

Table 3. PCA value for all respondents (total variance explained)

Component	**1**	**2**	**3**	**4**	**5**	**6**
Eigenvalue	4.611	1.011	0.265	0.087	0.024	0.001
Variability (%)	76.852	16.844	4.422	1.458	0.403	0.020
Cumulative (%)			98.119	99.577	99.980	100.000

From Table 4 of the Component Matrix, two factors influence user preferences for train compartment design based on Kansei Words: factor 1, consisting of ‘comfortable,’ ‘luxurious,’ ‘unique,’ ‘enjoyable,’ and ‘modern,’ and factor 2, consisting of ‘simple’ Kansei Words.

Table 4. Component matrix

Component	**Comfortable**	**Luxurious**	**Unique**	**Enjoyable**	**Simple**	**Modern**
1	.866	.959	.967	.949	-.580	.877
2	.392	-.159	-.210	.305	.804	.220

Biplot is the delivery of data information presented in a two-dimensional graph. Biplot analysis is descriptive and visually presents a cluster of objects and variables. This graph shows the proximity between objects with similar observed characteristics and correlated variables [17]. The biplot graph in Figure 4 presents information on the proximity between objects or variables with similar characteristics. The interpretation of biplot graphs based on the same quadrant, as below:

a. Quadrant I, S3, and S7 are the favorite designs because they are on the positive axis.
b. Quadrant II, namely S1, S2, and S4, has similar characteristics in design specifications and is closely related to the Kansei Words, which are ‘comfortable,’ ‘modern,’ ‘unique,’ ‘luxurious,’ and ‘enjoyable.’
c. Quadrant III, namely S5, S6, and S8, has similar characteristics in the design specifications.
d. Quadrant IV is simple Kansei Words, but the distance is close to quadrant III, allowing a relationship to occur.

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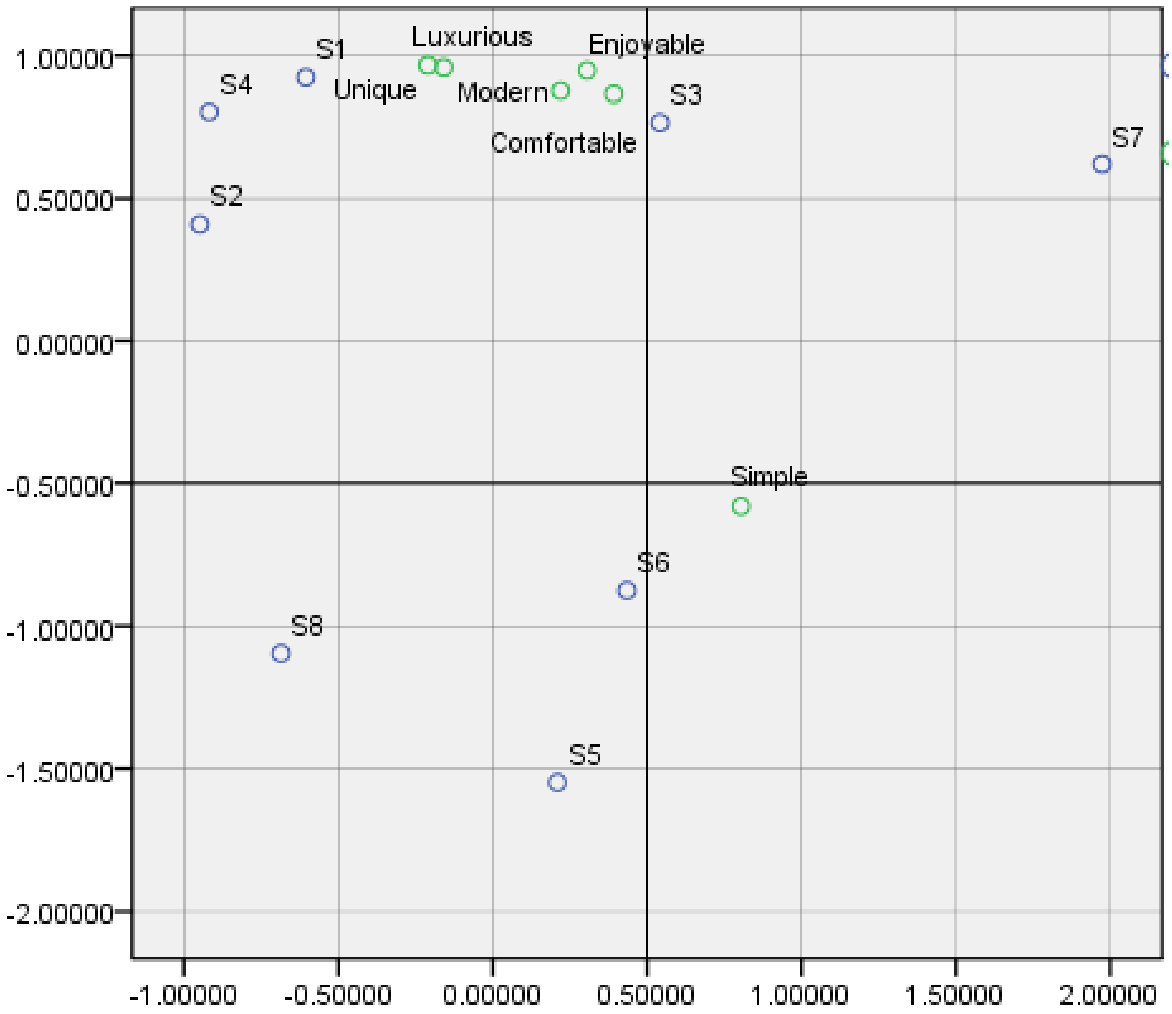

Figure 4. Biplot graph of a train compartment design samples.

3.4.4. Clustering of Respondents

The output results in Table 5 refer to the z-score standardization provided that the data is above the total average if positive (+). Three clusters were formed: Cluster 1, consisting of 86 respondents who chose the S1 design the most; Cluster 2, composed of 8 respondents who chose the S7 design the most; and Cluster 3, consisting of 56 respondents who chose the S3 design the most. A total of 150 respondents were declared valid.

Table 5. Final cluster centers

Design Samples	Cluster		
	1	2	3
S1	3.62	2.12	4.15
S2	3.40	1.96	4.21
S3	3.55	2.21	4.30
S4	3.55	2.07	4.14
S5	2.91	2.06	4.09
S6	3.10	2.42	4.21
S7	3.48	2.69	4.41
S8	2.99	2.38	4.09

Cluster results based on the respondent's gender can be defined as follows:

a. *Cluster 1*: Consisting of 86 respondents, more female respondents amounted to 53% or 46, while males amounted to 47% or 40.
b. *Cluster 2*: Consists of 8 respondents; more male respondents are 75% or 6, while females are 25% or 2.
c. *Cluster 3*: There are 56 respondents, of which more respondents are male, 55% or 31, while females are 45% or 25.

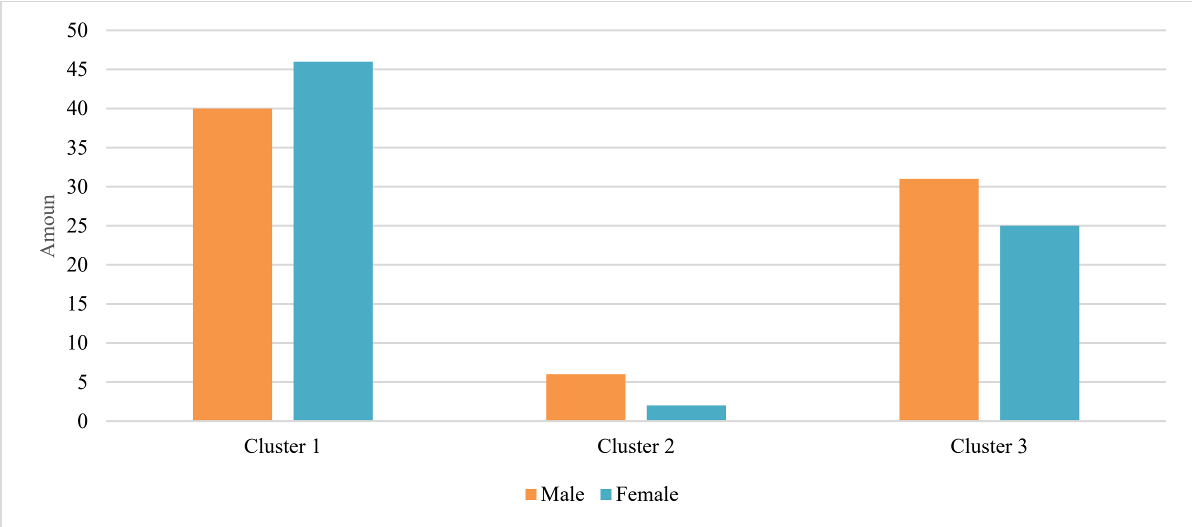

Figure 5. Clusters by the gender of respondents.

The results of cluster analysis based on respondents' age can be defined as follows:

a. *Cluster 1*: Consists of the most, namely, sixty-four people aged 20-30, twelve people aged 30-40, eight people over 40 years old, and two people less than 20 years old.

b. *Cluster 2*: Consists of the most, namely, seven people aged 30-40 and one person aged 20-30.

c. *Cluster 3*: Consists of the most, namely, forty people aged 20-30, eight people over 40, five people aged 30-40, and three people less than 20 years old.

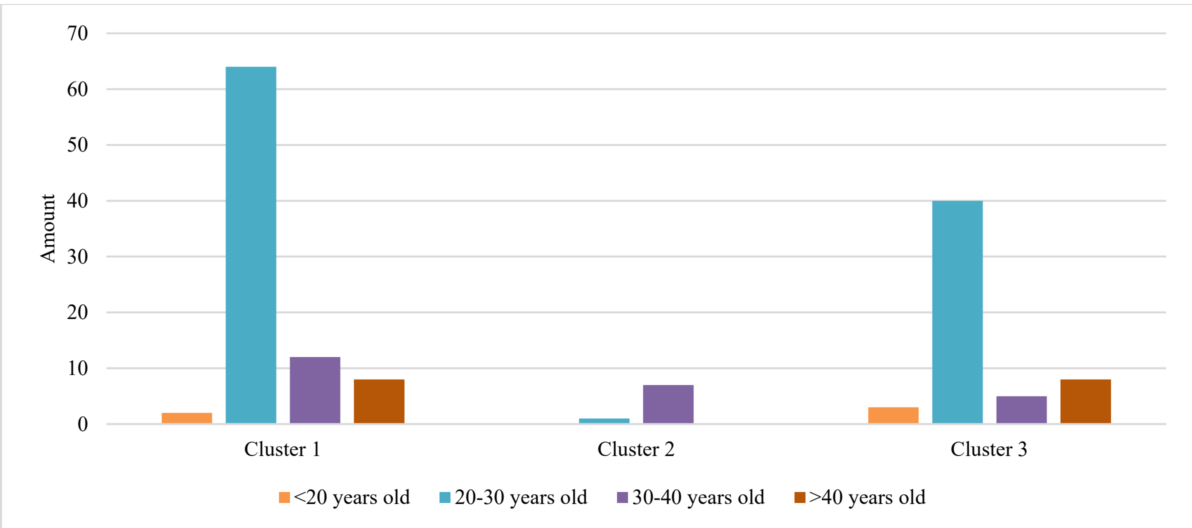

Figure 6. Clusters by the age of respondents.

The results of the cluster analysis in terms of respondents' monthly income can be defined as follows:

a. *Cluster 1*: Dominated by the respondents with incomes of 1-5 million (in Rupiah), as many as 45 people, less than 1 million (in Rupiah), as many as 16 people, 5-10 million (in Rupiah) as many as 15 people, and more than 10 million (in Rupiah) as many as 10 people.
b. *Cluster 2*: Dominated by the respondents with an income of 5-10 million (in Rupiah), as many as 5 people, and more than 10 million (in Rupiah) as many as 3 people.
c. *Cluster 3*: Dominated by respondent groups with incomes of 1-5 million (in Rupiah), as many as 34 people, 5-10 million (in Rupiah), as many as 13 people, less than 1 million (in Rupiah) as many as eight people, and more than 10 million (in Rupiah) as many as one person.

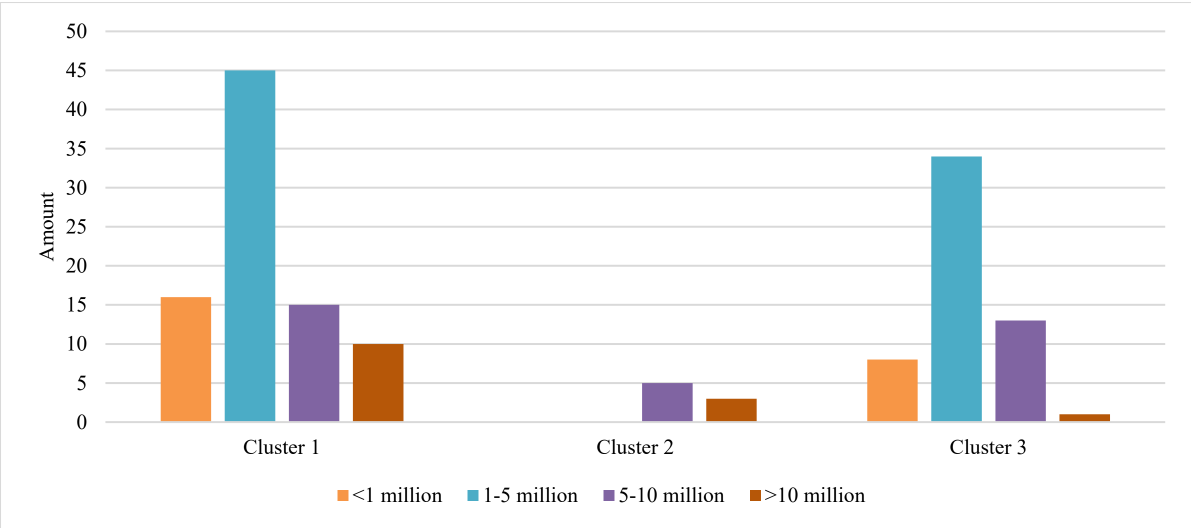

Figure 7. Clusters by the monthly income of respondents (in Rupiah).

3.5. Discussion

Discussion of the biplot graph of PCA output results places S3 and S7 in the first quadrant with positive axis values. The biplot graph displays the distribution points of the respondents' most and least selected items [18]. S3 and S7 emerged as the favored designs chosen by many respondents chose. The doff surface and texture of pine wood material are utilized in both favored designs due to pine wood's neutral and light color appearance [19], so it is in great demand by most respondents of various ages.

Based on the cluster analysis result based on design samples, respondents in cluster 1 opted for S1 with specifications: curved shape, studio green color palette, doff surface, and teak wood material texture. Females dominate this cluster with a productive adult age of 20-30 years and a monthly middle-class income ranging from 1-5 million (in Rupiah). Productive adults prefer dynamic design forms with curves that look dynamic, resembling human figures that were required to be efficient and adapt quickly following the times.

Many respondents in cluster 2 chose S7 with specifications: straight shape, studio green color palette, doff surface, and pine wood material texture. The characteristics of respondents in this cluster is characterized by males in their middle age of 30-40 years and the upper median income of 5-10 million (in Rupiah) per month. Middle-aged adults typically prefer simple shapes with straight lines and minimal ornamentation. The combination of studio green and light pine wood creates a serene and tranquil impression.

Many respondents in cluster 3 chose S3 with specifications: curved shape, sage green color palette, doff surface, and pine wood material texture. Cluster 3 respondents have characteristics dominated by males aged 20-30 years with a middle-class income ranging from 1-5 million (in Rupiah) per month. Bright green hues are often favored as design schemes with high-brightness colors provide better satisfaction [20]. The choice of design, according to the character of the respondents in this cluster, is quite dynamic with a combination of sage green, which is quite bright with pine wood.

4. CONCLUSION

This study concludes that six Kansei Words—'comfortable,' 'luxurious,' 'unique,' 'enjoyable,' 'simple,' and 'modern'—describe user preferences based on statistical analyses. Principal Component Analysis (PCA) identified two main components, Factor 1 and Factor 2, explaining 93.696% of the variation in user preferences. Factor 1, termed Variable A, includes 'comfortable,' 'luxurious,' 'unique,' 'enjoyable,' and 'modern,' while Factor 2, termed Variable B, consists of 'simple.' Biplot graphics revealed that respondents favored design S3, characterized by a curved shape, sage green color palette, doff surface, and pine wood texture, while S7, featuring a straight shape, studio green color palette, doff surface, and pine wood texture, also ranked highly. Clustering analysis further segmented respondents into three clusters: Cluster 1 (86 respondents, favoring S1), Cluster 2 (8 respondents, favoring S7), and Cluster 3 (56 respondents, favoring S3), categorized by gender, age, and monthly income. These findings highlight the role of specific clusters in shaping user preferences based on visual design features. The author is optimistic that this study's results will serve as a valuable resource for future research and applications in train compartment design, offering insights that could drive innovative solutions and enhance user experiences.

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