

**ORIGINAL RESEARCH ARTICLE****Do we think alike? Exploring user perceptions of road aesthetic dimensions in Nairobi**

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**Abstract**

Road aesthetics is critical to improving safety, traffic flow, and user experience. This study hypothesises that these aesthetic qualities exist as latent factors in urban roads, influencing how people perceive them. The study aims to examine how different road users perceive these qualities. The study used a mixed-methods approach to collect data from 354 road users and identified coherence, naturalness, and imageability as the inherent aesthetic qualities in the roads. Different road user categories demonstrated distinct perceptions of the aesthetic dimensions. Regarding coherence, there was evidence of a difference in the perceptions by the types of road users;  $H(2) = 55.684, p < .001$ , among the categories of age groups;  $H(4) = 15.624, p = .004$ , and in the frequency of road use;  $H(2) = 9.006, p = .011$ . With regards to road naturalness, statistically significant differences were found between pedestrians and motorcyclists  $U(N_{pedestrians} = 170, N_{motorcyclists} = 87) = 3928.00, z = -6.170, p < .001$ , as well as between pedestrians and drivers  $U(N_{pedestrians} = 170, N_{drivers} = 97) = 5963.00, z = -3.772, p < .001$ . There was also evidence of a difference in male and female users,  $H(1) = 12.844, p < .001$ . Additionally, the one-way ANOVA showed a statistical difference among age groups,  $F(4,349) = 3.40, p = .010$ . Finally, the test results for road imageability indicated a difference in the types of road users,  $H(2) = 31.513, p < .001$ . It also revealed a statistical difference among groups based on the frequency of use  $F(2,305) = 3.93, p = .021$ . These findings suggest differences in cognitive loads among different categories of road users and highlight the need to review how road users prioritise self-explaining road principles. The study proposes consideration of diverse user cognitive abilities as a major contributor to the human factors in the initial stages of road planning. This consideration will lead to more inclusive and effective road design strategies, ultimately resulting in safer urban roads.

**Keywords:** Road Coherence, Road Likability, Self-Explaining Roads, User Perceptions

**1.0 Introduction**

Understanding road user perceptions is important in designing transportation systems that are safe, efficient and user-friendly (Cheng & Chen, 2015; Israt & Hassan, 2022; Munala & Maina, 2012; Tinella et al., 2023). Aesthetic dimensions play a critical role in shaping the user's perception, experiences and subsequent behaviour (Thompson, 2018), implying that these

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dimensions, if they exist in the road environments, affect road users and cause them to behave in a certain way. While research exists on how objective measures such as road geometry ensure the safety and functionality of the road (Gichaga, 2017; Ziakopoulos & Yannis, 2020), equally important subjective experiences and user perceptions (Lättman et al., 2016; Pyrialakou et al., 2020) are not fully captured. As such, there is a growing recognition of the need to explore road aesthetic dimensions from the perspective of the road users themselves (Carmona, 2021; Tang & Long, 2019). A number of factors, such as road design, the environment, road furniture and user characteristics, influence the perception of the road's aesthetic dimensions (Ma et al., 2021; Polat & Akay, 2015). Cultural, social and psychological factors also influence perceptions (Cordellieri et al., 2016; Kavoi et al., 2019) therefore, understanding these factors is essential for identifying opportunities for enhancing road infrastructure and improving user safety and experiences.

The importance of user-centred design principles in optimising user experiences and safety has been highlighted (Woodcock, 2016); therefore, by incorporating the correct feedback from relevant, diverse user groups and considering their unique needs and preferences, transportation planners can create road environments that are intuitive, easy to navigate, and conducive to safe and efficient travel. However, despite the growing emphasis on user-centred approaches, there remains a gap in the literature regarding road user perceptions of the road aesthetic dimensions. Studies (Cervero, 2013; Charlton et al., 2010; Fuller R. & Santos J.A., 2010; Gitelman et al., 2016; Wegman et al., 2008) primarily focus on objective measures of road design and functionality, with limited attention paid to subjective user experiences. This study seeks to address this gap by exploring road user perceptions of the aesthetic dimensions that exist in the Nairobi urban roads.

## 2.0 Methodology

This study employed a mixed method approach to explore the diverse perceptions held by users toward urban road environments as well as determine the existing latent underlying dimensions in these roads. It involved an analysis of urban road environments in Nairobi by carrying out a survey where road users were asked to rate the likability of urban road environments. As environmental aesthetics has previously been structured within perception, cognition, and response, the photographs of road scenes were used as visual stimuli. The analysis of road scene likability provided a basis for evaluating and describing road aesthetics.

## 2.1 Study area

The area of this study is Nairobi, located in the south-central part of Kenya, at approximately 1°17' S and 36° 49' E, with an average altitude of 1795m above mean sea level. Nairobi was established in June 1899 as a transportation and administrative centre, and according to an analytical report on urbanisation in Kenya (Kenya National Bureau of Statistics, 2022), it has the largest population among Kenya's urban centres. The recorded high population provides a larger pool from which to draw diverse road user opinions in this study. This study identified the Kenya National Highway Authority (KeNHA) roads in Nairobi County using the road classification criteria provided in the Kenya Roads Act of 2007. These roads had a variety of characteristics

that provided visual stimuli that enabled the identification of the road's aesthetic dimensions. Moreover, Blumentrath et al. (2015) and Múčka (2017) suggest that the higher class of roads is preferred for an in-depth evaluation of road aesthetics. The specific roads indicated in Figure 1 from which the visual stimuli were generated included the Southern bypass, Kiambu Road, Kangundo Road, Magadi Road, the Dagoretti-Karen Road and the Nairobi-Thika superhighway, which is part of the Trans-African Highway, Cape to Cairo Road, also called the Pan-African Road.

## 2.2 Respondents

The respondents for this study were road users. Three hundred and eighty-four road users were approached. However, a review of the questionnaires revealed a response rate of 67.97% for the on-site questionnaires and 73.81% for the web-based surveys. According to Bryman (2012), these response rates were considered acceptable and very good for both the field and web-based surveys, respectively. As a result, the final sample of road users was 354 respondents, with 74% of the respondents completing the questionnaires on-site and 26% completing the web-based questionnaire. It is these data that have been used and reported in this study.

The general characteristics of the respondents reflected that the 354 participants comprised 48% pedestrians, 24.6% motorcyclists, and 27.4% drivers. The composition of the respondents was 66.1% males and 33.9% females. Their age distribution was as follows: 2.8% were under the age of 20, 58.2% between 20-34 years, 31.1% between 35-49, 7.6% between 50–65 years old, and only 0.3% were above 65 years old. As for the frequency of road use, 12.1% indicated using the road once a week, 33.3% used the road at most three days a week, and 42.4% used the road every day. The data suggested that males used urban roads more often than females, with 77.3% of daily road users being male compared to 22.7% of females who used the roads daily. 50% of the female road users reported using the urban roads an average of three days a week.

## 2.3 Identification and creation of the visual stimuli inventory

Visibility, also known as 'visual scale,' deals with perceptual units' experiences. There have been indications that an appropriate visual scale varies between users, particularly in road environments (González-Gómez & Castro, 2019; Sanoff, 2016; Vardaki & Kanellaidis, 2019). The difference is due to different sightlines and varying speeds of movement among road users. For this study, gathering video recordings and photographs from the perspectives of various road users provided consistency. Furthermore, frequently used areas may have a significant impact on how users perceive their visual quality. Therefore, management should focus on frequently used areas because they are more likely to elicit public concern.

Cengiz (2014), Ode and Miller (2011) and Cimini and Massacci (2003) suggest that the determination of the location of photographs used as visual stimuli is an essential factor influencing the results of a study; therefore, they should be selected meticulously and mapped. Furthermore, in the sampling stage of any visual assessment method, it is critical to identify and sample from the used and seen landscape rather than the topological or ecological landscape. Ittelson et al. (1974) highlighted factors to determine the choice of scenes from which further

data can be collected as the purpose of the scenes, the use levels relating to the intensity and location of use, and the temporal dimension due to its dynamic nature. This study chose the scenes based on these factors while emphasising characteristics related to highway design.

First, videos of urban road environments were acquired using an AZDOME GS63H 4K Dash Cam installed on an appointed vehicle travelling along the selected roads between 10.00 am and 12.00 noon. The collected urban road environment videos were combined and edited into an 8374-second-long video using OpenShot™, an open-source video editor. Then, using a systematic sampling procedure where frames of the video recording were frozen at an interval ( $i = 109$  seconds) determined by the number of samples necessary for the survey, which had been set at 77, as equation (1) shows, urban road scenes were selected, and the geo-locations of these road sections were mapped (Figure 1). The road scene sample size was determined using the rule of thumb in exploratory factor analysis where Kyriazos (2018) suggests that the N:p ratio is used where the participants (N) to variables (p) is set to 5:1. Therefore, the number of urban road scenes (p) required was based on the 384 participants. This procedure was undertaken to reduce bias in scene selection.

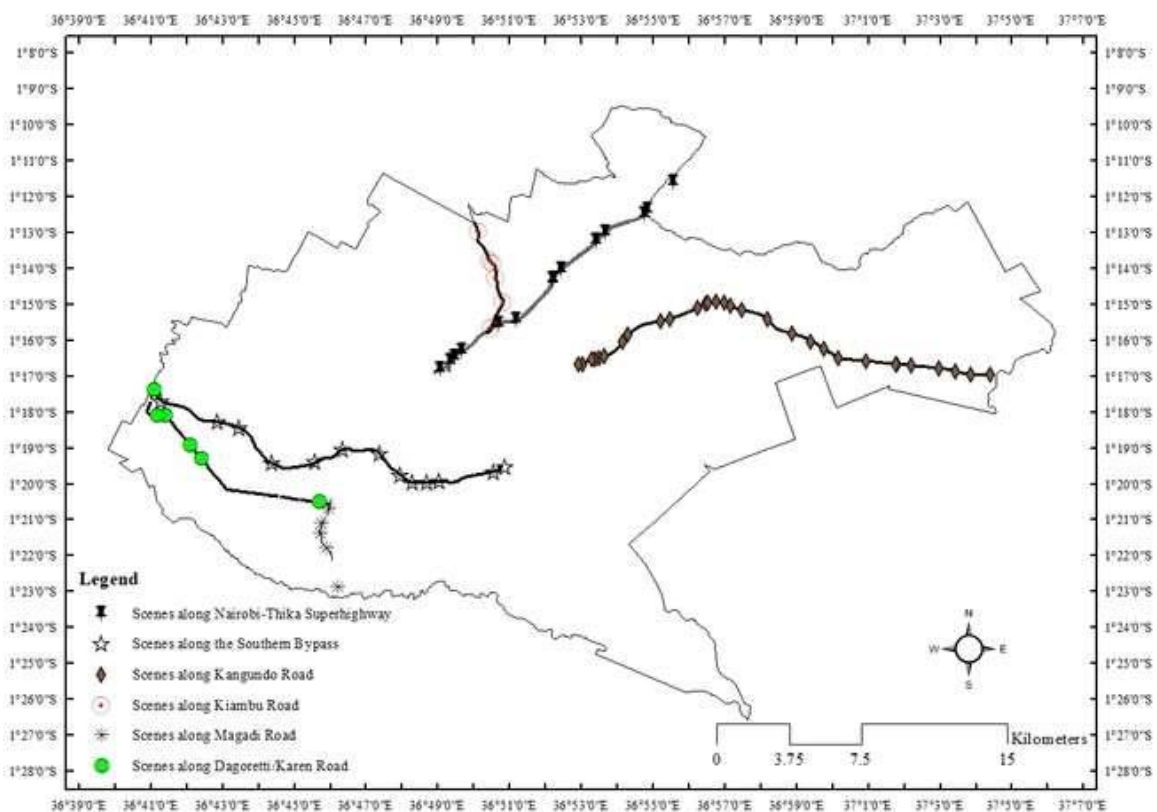


Figure 1: Location of Sampled Scenes

$$i = \frac{\text{Length of the video recording (8374 seconds)}}{\text{the road scene sample size (77 scenes)}} = 108.75 \text{ Seconds} \quad (1)$$



Second, photographs of the identified locations were taken. Du et al. (2016) suggest consistency and similarity in the conditions under which the photographs are taken, i.e., camera settings, constant eye level/height and time. However, the photographs for this study were taken between 10.00 am and 12.00 noon and on different days of the week to sample different environmental and traffic conditions. Differences were observed in the traffic characteristics on different days of the week. The photographs taken along Magadi, Kangundo and Kiambu roads were obtained during the weekdays, while photographs from the Nairobi-Thika superhighway, Southern bypass and the Dagoretti-Karen roads were obtained on the weekends. Based on the varying sightlines, a Canon EOS 4000D DSLR camera was used to take photographs at a standard eye height of 1.4 metres from pedestrian walkways, roadsides, and moving vehicles at the established geo-locations. Banks et al. (2014) suggest that the camera is set at a 50mm focal length, as this is the accepted lens length that produces natural-looking photographs similar to the human eye's perception. These photographs provided a finite population to select the final urban road scenes used as visual stimuli. The scenes were reviewed, and those with similarities occasioned by location proximity and traffic snarl-ups were eliminated. The final road scene sample size was 75.

#### **2.4 Field Data Collection**

The sample of 75 road scenes was used to develop a questionnaire that was administered to road users where the users were asked to rate the likability of each scene using a seven-point Likert scale. Pimentel (2019) suggests that the seven-point scale has the least bias when the data is assumed to be on an interval scale, and Beuckelaer et al. (2013) argued that this scale was the best compromise for precision and readability, reducing data collection errors. Furthermore, experiments that have tested the accuracy of number assignment to various aspects of a stimulus propose the use of the seven-point scale, citing its reliability, validity, sensitivity, ease of use, preference by users, structural recovery, and information processing (Lewis & Erdinç, 2017; Miller, 1956; Taherdoost, 2019).

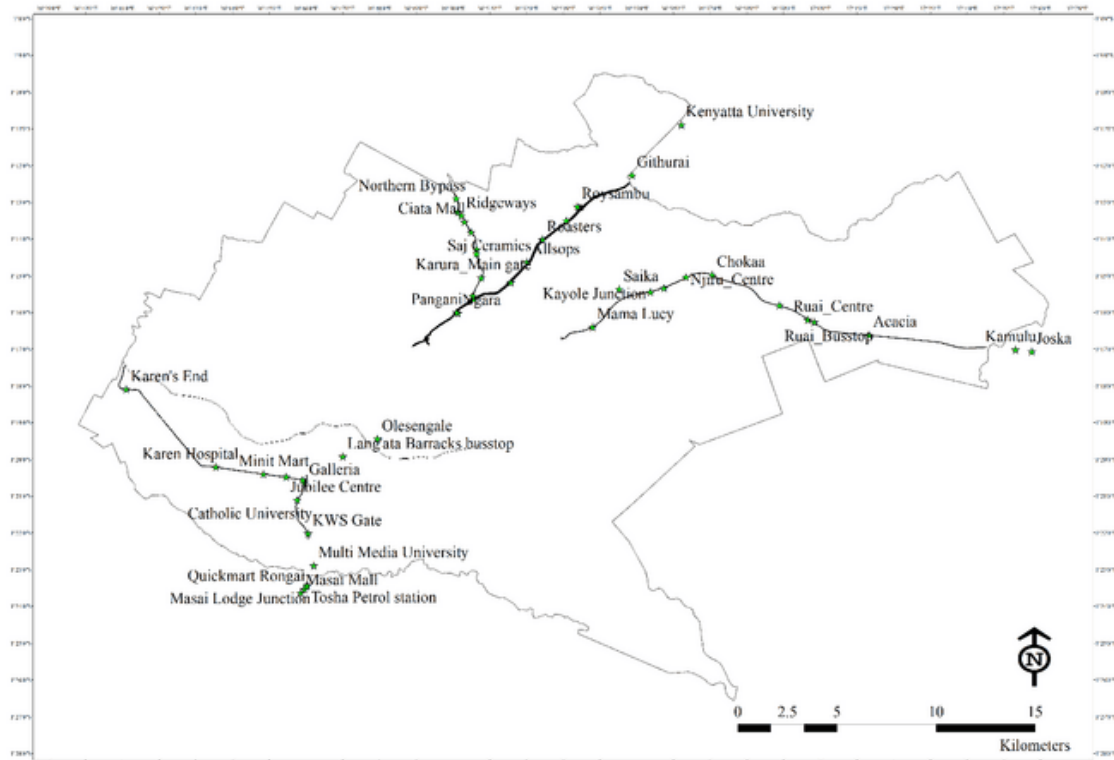


Figure 2: Locations for Respondent Identification

The survey was conducted using both a hard copy and a web-based version of the questionnaire at 46 predetermined survey locations (Figure 2) along the urban roads in Nairobi that had been identified using maximum variation sampling. The web-based questionnaire provided an opportunity for a broad demographic and allowed for ease of participation by road users. In addition, it enabled filling questionnaires at the convenience of interested participants who did not have time to complete the on-site survey.

## 2.5 Statistical analysis

Factor analysis was used to explore the underlying structure of road likability among road users in Nairobi on the basis that the latent constructs underlying scene likability were the aesthetic dimensions of roads. According to Fabrigar et al. (1999), principal axis factoring (PAF) as an extraction method focuses on the common variance among items, delineating the latent factors that underlie the data. Hence, exploratory factor analysis (EFA) was performed using principal axis factoring (PAF) and the varimax rotation with Kaiser Normalization to explore the underlying structure of urban road scene likability and confirm the existence of these constructs in Nairobi roads. It was also used to identify urban road scenes that loaded significantly onto particular factors and removed those that did not load onto any extracted factors. Further, whilst running the exploratory factor analysis in IBM SPSS v24, listwise deletion of cases with missing data, as proposed by Schumacker (2015) was used to account for the missing data, as only <5% of the data was missing.

As to the estimation of the number of factors, a successful factor analysis balances parsimony and comprehensiveness, requiring a balance of these two extremes in the choice of model that estimates enough factors that account for the important covariation among measured variables (Watkins, 2018). Several criteria have been used to estimate factors; however, each provides different conclusions regarding the number of factors. The limitation leads to overestimating or underestimating factors. For instance, the Kaiser-Guttman criterion states that factors with eigenvalues  $>1$  are retained. However, it is not an optimal strategy for identifying the factor structure of the data as it is known to overestimate the number of latent factors (Hayton et al., 2004; Watkins, 2018). The second criterion, a graphical method referred to as the Scree test by Cattell (1966), is critiqued for relying on the researcher's subjectiveness (Gorsuch, 1988) and similar to the Kaiser-Guttman criterion, it also leads to over-extraction of factors (Watkins, 2018). Finally, Parallel Analysis (PA) has been identified as one of the most accurate empirical estimates of the number of factors to retain (Henson & Roberts, 2006; Velicer et al., 2000). Therefore, since no specific techniques have been determined to be the most accurate in all instances, multiple methods are suggested to select the most appropriate factor solution (Gorsuch, 1988; Lloret et al., 2017). This study used all three criteria, namely, the Kaiser-Guttman criterion, the Scree test, and the Monte Carlo parallel analysis, to determine the final factors to retain.

Furthermore, to compare the groups of road users, statistical analysis and comparisons were done using both parametric and non-parametric methods. The Kruskal-Wallis ANOVA and Mann-Whitney-U were employed where parametric assumptions were not met. However, the results of the parametric and non-parametric results were compared, and no major differences were identified in the results.

### 3.0 Results

#### 3.1 Underlying factors linked to aesthetics in Nairobi's urban roads

The first step of the factor analysis was performing a principal components analysis (PCA) using the promax rotation method was chosen together with Kaiser normalisation on the likability ratings of the 75 road scenes collected from the sample of 354 road users to reduce the dimensionality of the road scenes. The promax rotation method was chosen as it provided oblique solutions that considered the relative degree of similarities in the photographs of the road scenes used as visual stimuli. The communality ( $h_2$ ) of the scale, which indicated the proportion of variance in each scene, was assessed to ensure acceptable levels of explanation in the final urban road scenes selected. All communalities were above 0.50, which is the acceptable value (Fabrigar et al., 1999; Hogarty et al., 2005; Matsunaga, 2010).

Weighing the overall significance of the correlation matrix was done using Bartlett's Test of Sphericity (Bartlett, 1950), providing a measure of the statistical probability that the correlation matrix had significant correlations among some of its components. The result indicated that the matrix was not an identity matrix as it was significant ( $p < .05$ ), hence its suitability. Further, the Kaiser-Meyer-Olkin measure of sampling adequacy (MSA), which indicates the appropriateness



of the data for factor analysis, was established as 0.884, an adequate value for analysing the output.

The strength and clarity of the item loadings were assessed to provide a basis for retaining scenes. According to Matsunaga (2010), obliquely rotated solutions provide three matrices that may be examined: the pattern, structure and unrotated component matrices. Henson and Roberts (2006) suggest that it is essential for both the pattern and structure matrices to be examined in deriving appropriate interpretations. Price (2017) and Fabrigar and Wegener (2012) suggest that one should first examine the pattern coefficients and retain items with a primary loading that has an accepted value, which has been identified by Matsunaga (2010) as  $> 0.6$ . This value is also the acceptable threshold in conservative a priori-determined cutoff values for similar studies (Balram & Dragičević, 2005; Fabrigar & Wegener, 2012). However, it is recommended that the final items should be reviewed and examined to make theoretical sense and provide a conceptual explanation.

The study examined the resultant pattern matrix and, using 0.6 as the loading factor, retained 43 scenes, which were used to conduct the second step of the factor analysis. As the data dimensionality had already been reduced, the varimax rotation method and principal axis factoring (PAF) were applied to extract the correlation patterns among the scenes. It aided in investigating the scenes' structure and determining related ones. Using the Kaiser-Guttman criterion, the factor solution derived from the exploratory factor analysis produced ten factors with a computed eigenvalue of  $> 1.0$ . The ten factors accounted for 53.314% of the total variance. In contrast, the resultant scree plot indicated that the elbow point after the seventh factor. Therefore, to accurately determine the number of factors to retain, the eigenvalues computed by running the factor analysis in IBM® SPSS® Statistics v24 were compared to the random eigenvalues generated in the Monte Carlo PCA for Parallel Analysis. Factors whose initial eigenvalues from the original data were greater than those of the random eigenvalue from the Monte Carlo parallel analysis were retained (Figure 3). This criterion retained six of the ten originally generated factors. However, an examination of the rotated factor matrix revealed that not all scenes loaded clearly and significantly on the extracted factors. MacCallum et al. (1999) suggest that a factor is retained if the items squarely tap on the construct and with at least three items per latent factor and propose that the pattern matrix is examined, and scenes that do not load clearly and significantly on the extracted factors are eliminated. Hence, eleven scenes were eliminated. Item communalities were also examined, and two scenes with extracted communalities below 0.40 were eliminated.



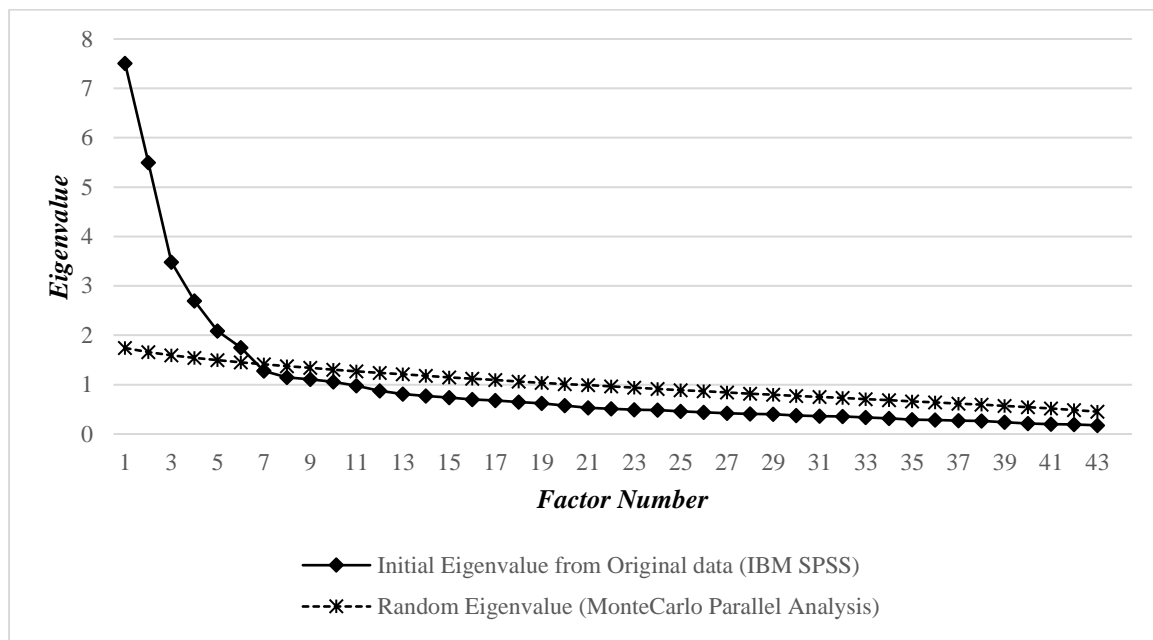


Figure 3: Factors Retention using Initial Eigenvalues and Random eigenvalue from the Monte Carlo Parallel Analysis

The retained thirty scenes were used to run the final step of the factor analysis that determined which selected scenes loaded onto the factors and trimmed those that were not theoretically significant. The resultant rotated factor matrix showed that only three factors had items with factor loadings > 0.50 and were saliently loaded by at least three scenes.

The constructs’ reliability was assessed using Cronbach’s alpha and composite reliability (Table 1). Reliability analysis was run on the resultant three factors by evaluating them against the sample of 354 respondents using the master validity tool, AMOS plugin (Gaskin & Lim, 2016). According to Han et al. (2019) and Matsunaga (2010), a factor should demonstrate internal consistency reliability greater than or equal to ( $\geq$ ) 0.70. The Cronbach’s alpha for each factor was above the required limit. Furthermore, the composite reliability (CR) and maximal reliability (MaxR(H) values for the three factors were greater than (>) 0.70, an acceptable threshold according to Sharif & Nia (2018). Hence, the construct reliability was established for each identified factor.

Table 1: Reliability and Validity Measures for Scenes in Resultant Factors

Latent Construct	Cronbach’s Alpha ( $\alpha$ )	Composite Reliability (CR)	Average Variance Extracted (AVE)	Maximal Reliability (MaxR(H))
Factor 1	0.870	0.872	0.461*	0.879
Factor 2	0.868	0.870	0.428*	0.876
Factor 3	0.789	0.789	0.484*	0.792

Note. \*Factors whose AVE <.50

For convergent validity, to estimate the extent to which scenes loading onto each factor measure the factor, the average variance extracted (AVE) values were assessed. The composite reliability (CR) values for all three factors were greater than the average variance extracted (AVE) values (Table 1). However, the AVE values for all three factors were below the 0.50 accepted threshold. Therefore, the standardised regression estimates (Table 2) were assessed. The regression estimates for scenes 27, 2 and 45 were below the accepted threshold of 0.60. To improve the average variance extracted (AVE) values, these scenes were eliminated, and the model was run until only scenes that contributed the most to each factor were retained.

*Table 2: Regression Estimates for Scenes Contributing to the Factors*

Item	Factor	Regression Estimate
Sc11	Factor1	.768
Sc29	Factor1	.752
Sc12	Factor1	.728
Sc37	Factor1	.681
Sc47	Factor1	.665
Sc7	Factor1	.644
Sc36	Factor1	.602
Sc27*	Factor1	.568
Sc6	Factor2	.770
Sc48	Factor2	.696
Sc49	Factor2	.675
Sc31	Factor2	.656
Sc55	Factor2	.651
Sc32	Factor2	.620
Sc35	Factor2	.616
Sc2*	Factor2	.592
Sc45*	Factor2	.587
Sc65	Factor3	.729
Sc44	Factor3	.719
Sc69	Factor3	.666
Sc9	Factor3	.665

*Note.* \*Scenes whose regression estimates <.60

Scenes 7, 36, 31, 55, 32, 35 and 9 were eliminated, and the validity of the remaining scenes was confirmed. As a result, the average variance extracted (AVE) values for all the factors improved to above the 0.50 accepted threshold (Table 3), concluding that convergent validity had been met. Furthermore, the remaining scenes loading on each factor converged and shared a high proportion of the variance in common, suggesting that the scenes under each factor measured the same aesthetic dimension. Finally, discriminant validity, useful in distinguishing the different factors, was assessed using the Fornell-Larcker criterion. The maximum shared variance (MSV) values for each factor were less than the average variance extracted (AVE) values (Table 3), and each factor's average variance extracted (AVE) square roots had the highest value in both the rows and columns. This observation confirmed the extent to which each factor was truly distinct from other factors. Therefore, this study concluded that each of the three factors was unique and represented a latent construct that other factors did not.

*Table 3: Construct Validity Measures*

Latent Construct	Composite Reliability (CR)	Average Variance Extracted (AVE)	Maximum Shared Variance (MSV)	Maximal Reliability (MaxR(H))	Factor 1	Factor 2	Factor 3
Factor 1	0.842	0.518	0.160	0.853	0.720		0.400***
Factor 2	0.750	0.501	0.006	0.754	-0.001***	0.708	0.077
Factor 3	0.752	0.502	0.160	0.752			0.709

Note. \*\*\* p< 0.001 (significance of correlations)

### 3.2 Interpretation of the aesthetic dimensions

Three main criteria were applied in interpreting and labelling the factors. First, the contents of scenes representing the three factors were qualitatively assessed by reviewing the scenes against the road morphology, which includes the number of carriageways and lanes in each direction of travel, the horizontal alignment, roadside characteristics and observable physical characteristics. Secondly, interpretation was conducted by examining both the factor score coefficient matrix (Table 4) and the structure matrix (Table 5) to determine the relationship between scenes and factors and by reviewing the descriptions of aesthetic dimensions established from existing empirical data. Finally, the dimensions best describing the nature of the scenes representing each factor based on a comparative evaluation of sets of scenes were identified.

*Table 4: Factor Score Coefficient Matrix for the Three-Factor Solution*

	Factor		
	1	2	3
Sc 11	.275	-.042	-.005
Sc 29	.272	-.053	.107
Sc 47	.182	.044	-.068
Sc 37	.175	.033	-.017
Sc 12	.154	.019	-.023
Sc 48	.123	.430	.041
Sc 49	-.159	.421	.077
Sc 6	.041	.223	-.060
Sc 65	-.146	-.070	.614
Sc 44	.008	.023	.203
Sc 69	.015	.001	.182

Extraction Method: Principal Axis Factoring.

Rotation Method: Varimax with Kaiser Normalization.

*Table 5: Structure Matrix for the Resultant Three Factors*

	Factor		
	1	2	3
Scene 29	.784	-.096	.389
Scene 11	.780	-.115	.257
Scene 47	.684	.118	.131
Scene 37	.677	.042	.153
Scene 12	.670	.073	.198
Scene 48	.282	.776	.183
Scene 49	-.305	.764	.062
Scene 6	.037	.666	-.155
Scene 65	.072	-.047	.834
Scene 44	.318	.095	.664
Scene 69	.347	.016	.650

Rotation Method: Varimax with Kaiser Normalization

The factor score coefficient matrix (Table 4) indicated that scenes 11 and 29 contributed the highest toward factor one, while scenes 49 and 65 negatively correlated to this factor. However, the structure matrix (Table 5) indicated that only scene 49 negatively correlated to this factor. This observation led to a comparative evaluation of these scenes (Figure 4). Scenes 11 and 29 displayed a lack of harmony in space use, disorder and undefined space for pedestrian use. In contrast, scene 49 has unity in the placement of elements, identifiable patterns, texture and colour. Furthermore, there is clear harmony and balance between the hard and soft landscape with good integration of buildings into the landscape and minimum disturbance to the observed landscape. Hence, the first factor was interpreted as coherence, as this dimension is related to the ease of comprehension due to unity in a scene.



Scene 29 (Predominantly built-up roadsides with highrise buildings, Building material lying on the roadside, Unprogrammed parking, unpaved and dusty surface, Concrete electricity poles, Electricity lines, Moving vehicles, Pedestrians on the roadsides, Marked lanes, Undefined road shoulders, Abandoned truck bed on the roadside, Concrete open drainage channel)



Scene 11 (Predominantly built-up roadsides with highrise buildings, Building material lying on the roadside, Unprogrammed parking, Steep slope grassed surface, Concrete electricity poles, Electricity lines, Buildings under construction, Street lighting, Moving vehicles, Pedestrians on the roadsides, Marked lanes, Undefined road shoulders)



Scene 49 (Predominantly vegetated roadside with few buildings, Street lighting, Road median, Road curb separating opposing traffic, Vegetation, Signage, Low-rise buildings, Moving vehicles, Electricity lines, Unpaved Road shoulder)

Figure 4: A Comparison of the Contrasting Scenes in Factor One

With regards to the second factor, both the factor score coefficient matrix (Table 4) and the structure matrix (Table 5) showed that scenes 11, 29 and 65 had a negative correlation to the factor, while scenes 48 and 49 contributed the highest score to this factor. A comparative evaluation of the scenes gathered for this second factor revealed that the scenes contributing the highest scores had a predominantly natural appearance with greenery and integration of the road with the natural topography of the existing landscape, depicted by the curved horizontal alignments. The scenes had a high verdancy, and the road fit into the preconceived natural landscape. In contrast, the scenes with negative coefficient scores lacked greenery and had distinctly built-up and dusty roadsides; therefore, the second factor was interpreted as naturalness.



*Scene 48 (Grassed medians and a balance between vegetated and built-up roadsides)*



*Scene 49 (Predominantly vegetated roadside with few buildings and unpaved road shoulder)*



*Scene 6 (Vegetated roadside and no road shoulders)*

*Figure 5: Scenes Contributing Highest Score to Factor Two*

Scene 65 contributed the highest score toward the third factor, with scenes 6, 11, 12, 37 and 47 having a negative correlation (Table 4). A further assessment of the structure matrix (Table 5) showed that only scene 6 had a distinct negative correlation to this factor. The scenes were assessed, and their locations were reviewed. It was revealed that scene 65, which was near the Mowlem Feroze open-air market; scene 44, located at the Super Steel Enterprises; and scene 69, located near the Ruai Central Stage and adjacent to the Ward manager's Offices were sections along the urban roads with major social activity with which the road users were familiar. Furthermore, these scenes had distinct elements with unique characters, such as identifiable structures (Figure 8). In contrast, scene 6 did not have any distinguishable elements and was not located near a known major social activity; hence, the third factor was interpreted as imageability.



*Scene 65*



*Scene 44*



*Scene 69*

*Figure 6: Scenes Contributing Highest Score to Factor Three*

### 3.3 Road user perception toward the identified aesthetic dimensions

The means and medians of existing aesthetic dimensions in Nairobi's urban roads were compared to determine how different groups of road users perceived them. The three dimensions examined were coherence, naturalness, and imageability. Road users were classified according to (i) type of road user, which included pedestrians, motorcyclists, and drivers, (ii) age, (iii) gender, and (iv) frequency of road use. The study hypothesised that there is a statistically significant difference in road user attitudes toward urban road physical characteristics in Nairobi, which prompted the tests.

First, before the groups were compared, IBM SPSS® Statistics v24 was used to transform the user ratings into new variables by computing the means of scenes that contributed to each factor. Then, the assumptions of variance were carried out for these variables. No significant outliers existed, and the box and whisker plots indicated that the perceived coherence of urban roads in Nairobi was higher than naturalness and imageability since it had a higher median and the least spread (Figure 7). The Shapiro-Wilk test of normality revealed that the data was not normally distributed, but as the sample size was greater than (>) 50, a visual inspection of the histograms and Q-Q plots (Figure 8) was undertaken, and it was determined that the data were normally distributed.

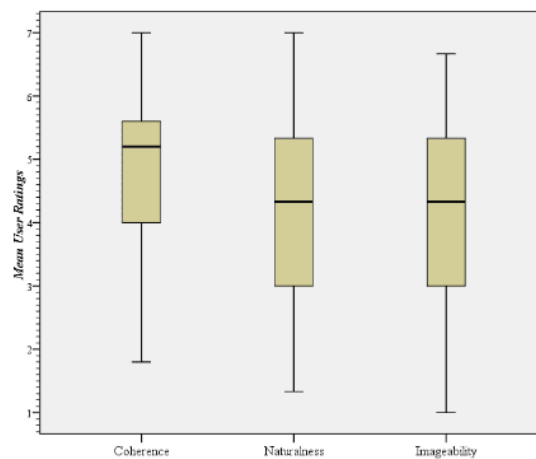


Figure 7: Boxplot of Coherence, Naturalness and Imageability

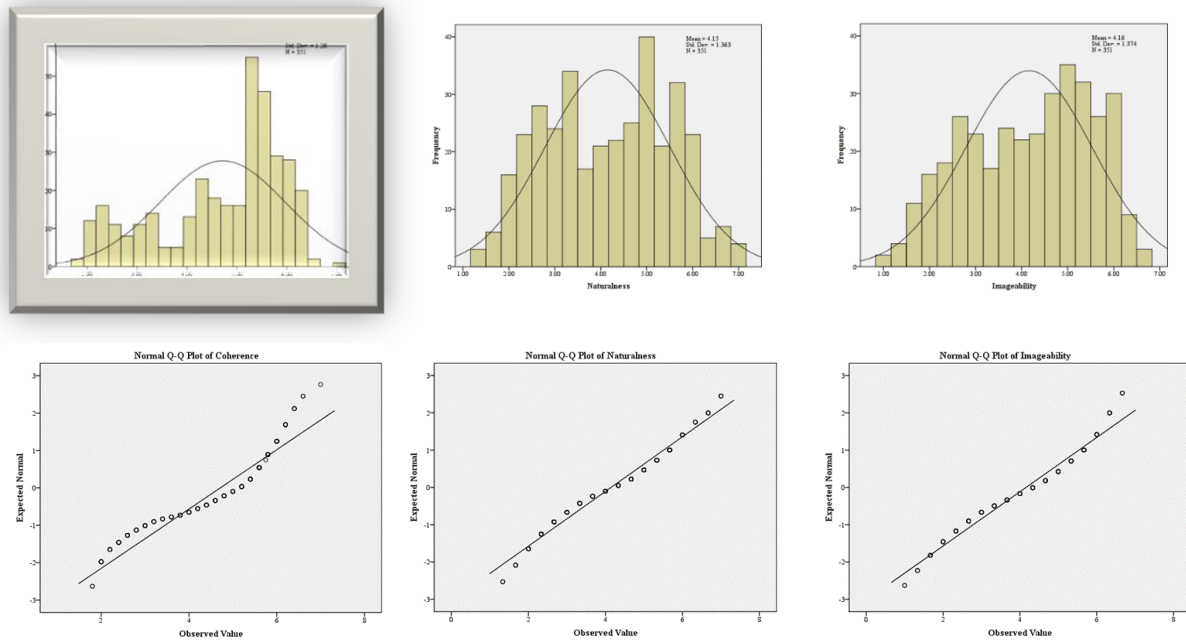


Figure 8: Histograms and Q-Q plots for Normality Checks

A check for homogeneity of variances was carried out using Levene’s test to determine the appropriate statistical test to compare differences in groups of road users. The tests (Table 6) revealed that the assumptions of homogeneity of variances for certain groupings of road users had not been met. For instance, regarding coherence, none of the categories of road user groups had an assumed equal variance, hence rejecting the null hypothesis that there was no difference in the variances of the groups. The assumption of homogeneity of variance concerning naturalness was met by the category labelled age of road user. Finally, for imageability, the assumption of equal variance was met by the categories of road users labelled gender and frequency of road use. Therefore, based on the output of the tests of homogeneity of variance, the choice of parametric or non-parametric test to explain the differences in groups was made (Table 7).

Table 6: Test of Homogeneity of Variances for Different Categories of Road Users

		Levene Statistic	df1	df2	Sig.
Type of Road User	Perceived Coherence	71.483	2	351	.000
	Perceived Naturalness	19.295	2	351	.000
	Perceived Imageability	9.100	2	348	.000
Age of Road User	Perceived Coherence	4.717	3	349	.003
	Perceived Naturalness	1.239	3	349	.295
	Perceived Imageability	3.771	3	346	.011
Gender of Road User	Perceived Coherence	13.053	1	352	.000
	Perceived Naturalness	7.822	1	352	.005
	Perceived Imageability	.170	1	349	.680
Frequency of Road Use	Perceived Coherence	10.958	2	308	.000
	Perceived Naturalness	4.181	2	308	.016
	Perceived Imageability	1.637	2	305	.196

*Table 7: Tests Used to Compare Differences in Categories of Road Users*

	<i>Perceived Coherence</i>	<i>Perceived Naturalness</i>	<i>Perceived Imageability</i>
<i>Type of road user</i>	Non-parametric tests	Non-parametric tests	Non-parametric tests
<i>Age of road user</i>	Non-parametric tests	Parametric tests	Non-parametric tests
<i>Gender of road user</i>	Non-parametric tests	Non-parametric tests	Parametric tests
<i>Frequency of road use</i>	Non-parametric tests	Non-parametric tests	Parametric tests

Note. Non-parametric tests \_the Kruskal-Wallis & Mann-Whitney-U  
Parametric test\_ One-way ANOVA

### 3.3.1 Perceived coherence

The Kruskal-Wallis test with a significance level of 0.05 was used to determine whether there was a difference in median scores on the evaluation of coherence among various categories of road users. The results showed that the type of road user, age of road users and the frequency of road use significantly affected how road coherence was perceived, while there was no significant difference in how different genders perceived road coherence. For the type of road user, three different groups (pedestrians, motorcyclists and drivers) were compared. The null hypothesis was that the median scores were equal across all three road user groups, while the alternative hypothesis was that at least one group had a different median score. The test results,  $H(2) = 55.684, p < .001$ , led to a rejection of the null hypothesis and the conclusion that there was evidence of a difference in median scores among the three types of road users. A pairwise comparison of the type of road users indicated that pedestrians perceived road coherence differently from drivers and motorcyclists. A post-hoc analysis using Mann-Whitney tests showed a statistically significant difference between pedestrians and motorcyclists  $U(N_{pedestrians} = 170, N_{motorcyclists} = 87) = 4305.50, z = -5.488, p < .001$ , as well as a difference between pedestrians and drivers  $U(N_{pedestrians} = 170, N_{drivers} = 97) = 4347.50, z = -6.437, p < .001$ .

For the age of road users, five different groups were compared. The null hypothesis was that the distribution of coherence was the same across the age categories. However, the Kruskal-Wallis test showed that age significantly affects the perception of road coherence,  $H(4) = 15.624, p = .004$ , and led to a rejection of the null hypothesis and conclusion that there was evidence of a difference in median scores among the five categories of age groups of road users. A pairwise comparison of the age groups indicated a significant difference in how road users aged 20-34 and those aged 35-49 perceived road coherence. A post-hoc analysis using Mann-Whitney tests confirmed the statistical difference,  $U(N_{20-34} = 206, N_{35-49} = 110) = 8888.50, z = -3.163, p = .002$ .

Three groups were compared in the frequency of road use (once-a-week, thrice-weekly, and every day road users). The null hypothesis was that the perception of coherence is the same across categories of frequency of road use. However, the Kruskal-Wallis test showed that the frequency with which one used the urban road affected their perception of road coherence,  $H(2) = 9.006, p = .011$ , led to a rejection of the null hypothesis and conclusion that there was evidence of a difference in median scores among the three categories of road users. A pairwise comparison of the age groups indicated a difference in how thrice-weekly and everyday road



users perceived road coherence. A post-hoc analysis using Mann-Whitney tests confirmed the statistical difference,  $U(N_{3 \text{ days a week}} = 118, N_{\text{everyday}} = 150) = 7255.50, z = -2.540, p = .011$ .

### 3.3.2 Perceived naturalness

The Kruskal-Wallis test was used to evaluate the difference in the type of road user, gender of road user and the frequency of road use categories, while one-way ANOVA tested the differences in the age categories of road users. The tests showed a statistically significant difference in the perception of naturalness by type of road users, age and gender of road users. However, no significance was observed in the frequency of road use categories. Three groups (pedestrians, motorcyclists and drivers) were compared for perceived naturalness. The null hypothesis was that the median scores were equal across all three road user groups, while the alternative hypothesis was that at least one group had a different median score. The test results,  $H(2) = 39.037, p < .001$ , led to a rejection of the null hypothesis and the conclusion that there was evidence of a difference in median scores among the three types of road users. A pairwise comparison of the type of road users indicated that pedestrians perceived naturalness differently from drivers and motorcyclists. A post-hoc analysis using Mann-Whitney tests showed a statistically significant difference between pedestrians and motorcyclists  $U(N_{\text{pedestrians}} = 170, N_{\text{motorcyclists}} = 87) = 3928.00, z = -6.170, p < .001$ , as well as between pedestrians and drivers  $U(N_{\text{pedestrians}} = 170, N_{\text{drivers}} = 97) = 5963.00, z = -3.772, p < .001$ .

It was hypothesised that means were equal across categories of groups to determine whether there were significant differences in the evaluation of naturalness across different categories of ages of road users. The data were analysed using one-way ANOVA. The results revealed a statistical difference among categories of age groups of road users,  $F(4,349) = 3.40, p = .010$ . To identify the groups within which the differences lay, independent samples t-tests were conducted by comparing the means of the 20-34 age group ( $M = 4.35, SD = 1.34, n = 206$ ) and 35-49 age group ( $M = 3.85, SD = 1.41, n = 110$ ). The t-value was 3.10 ( $df = 314, p = .002$ ), indicating a difference between means. The effect size was moderate, with Cohen's  $d = .35$ . As the assumption of equal variances had been met with Levene's test results showing non-significance ( $F = .585, p = .445$ ), it was concluded that there is a difference in perception of naturalness between the two age groups.

The two genders of road users (male and female) were compared for naturalness. The null hypothesis was that the median scores were equal across the two genders. The test results,  $H(1) = 12.844, p < .001$ , led to a rejection of the null hypothesis and the conclusion that there was evidence of a difference in median scores between the two genders. This result suggests a difference in the perception of naturalness by female and male road users.

### 3.3.3 Perceived imageability

The non-parametric Kruskal-Wallis test was used to compare the groups in type of road user and age of road user categories and test the differences in the evaluation of imageability by these categories of road users. In contrast, one-way ANOVA was used to test the differences in the gender and frequency of road use categories. The tests revealed a statistically significant

difference between some categories of type of road users and how frequently the users were on the road, while no significant difference was observed in categories of age and gender. These results suggest that the perception of road imageability is not affected by the gender and age of road users.

Three groups (pedestrians, motorcyclists and drivers) were compared for road imageability. The null hypothesis was that the median scores were equal across all three road user groups, while the alternative hypothesis was that at least one group had a different median score. The test results,  $H(2) = 31.513, p < .001$ , led to a rejection of the null hypothesis and the conclusion that there was evidence of a difference in median scores among the three types of road users. A pairwise comparison of the type of road users indicated that motorcyclists perceived road imageability differently from drivers and pedestrians. A post-hoc analysis using Mann-Whitney tests showed a statistically significant difference between pedestrians and motorcyclists  $U(N_{pedestrians} = 169, N_{motorcyclists} = 87) = 4506.50, z = -5.086, p < .001$ , as well as a difference between motorcyclists and drivers  $U(N_{motorcyclists} = 87, N_{drivers} = 95) = 2541.00, z = -4.499, p < .001$ .

The study hypothesised that means were equal across categories of groups to determine whether there were significant differences in the evaluation of road imageability across different categories of frequency of road use. The data were analysed using one-way ANOVA. The results revealed a statistical difference among groups,  $F(2,305) = 3.93, p = .021$ . Post-hoc tests using Tukey's HSD indicated that the mean score for once-a-week road users ( $M = 3.79, SD = 1.26$ ) significantly differed from everyday road users ( $M = 4.44, SD = 1.39$ ). These results suggest that the frequency of road use affects the perception of a road's imageability.

#### 4.0 Discussion

Research on human factors, user experiences and road aesthetics are important aspects of road planning and design, aiming to create self-explaining, forgiving, visually appealing transportation corridors that contribute to the overall quality of the road environment. While significant advancements have been made in understanding these issues, existing research calls for further research into the subjective perception of road environments, highlighting the need for more research on how different individuals perceive and evaluate road aesthetics (Blumentrath & Tveit, 2014; Fathi & Masnavi, 2014), further exploration of the cultural and contextual factors on road aesthetics (Fathi & Masnavi, 2014; Passonneau, 1996; Zijlema et al., 2020) and need to identify potential areas for improvement and optimisation of self-explaining and forgiving road designs based on user preferences and needs (Gitelman et al., 2016). They argue that studying subjective preferences can help identify elements of road design that contribute to positive perceptions and improve user behaviour, helping inform road design decisions to create self-explaining, culturally responsive and context-sensitive roads.

The study hypothesised that there exists within Nairobi urban roads underlying latent structures linked to road aesthetics. It further hypothesised that different categories of road users perceived these dimensions of road aesthetics differently. As a result, two major questions were answered by this study. First, as to the existence of indicators of aesthetics, the study identified

dimensions useful in assessing the aesthetics of urban road environments and demonstrated how different road users in Nairobi perceived these dimensions. This study demonstrated that there are three aesthetic dimensions inherent in the urban roads of Nairobi and that different categories of road users differ in their perception of these aesthetic dimensions. The exploratory factor analysis revealed three underlying dimensions of aesthetics in the Nairobi urban roads. These factors were interpreted as coherence, imageability and naturalness. The study further hypothesised that different categories of road users perceived the road's dimensional structures differently. The null hypothesis was that there is no difference in mean ratings among categories of road users  $\beta_1 = 0$ . The related null hypotheses were rejected as statistically significant differences in mean ratings for likability among certain categories of road users toward specific aesthetic dimensions were observed.

The data suggested that the perception of the three aesthetic dimensions differed depending on the category of road users evaluating the road scenes (Figure 9). It was observed that gender, age, the type of user and frequency of road use were major determinants of how road coherence, naturalness and imageability were perceived. The perception of road coherence was affected by age, type of road user and the frequency of road use, and how road imageability was perceived was affected by the type of road user and the frequency of road use. Finally, age, gender and type of road user affected the perception of road naturalness.

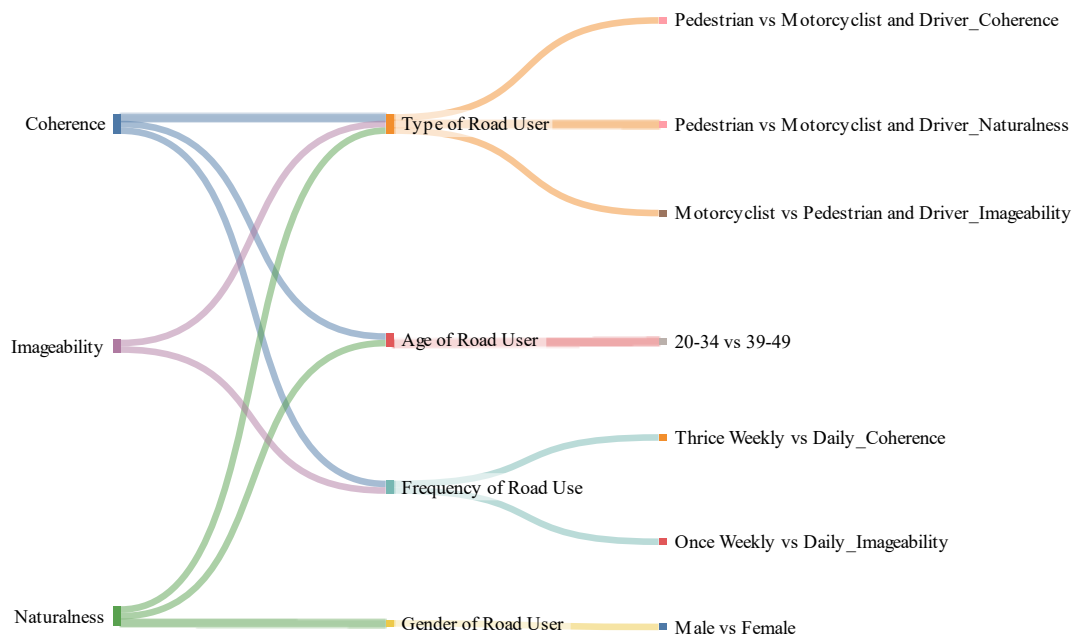


Figure 9: Categories of Road User Perceptual Differences

Note. Diagram generated using [sankeymatic.com/build/](https://sankeymatic.com/build/)

The findings revealed the need to identify and separate aspects of road planning that planners should address while engaging stakeholders during the planning and design process.

Theoretically, this study confirms the need to create inherently understandable road systems by looking at the findings through a theoretical lens of the Self Explaining Road (Theeuwes & Godthelp, 1995). The Self-explaining roads concept is a theoretical framework within transportation and urban planning that emphasises road infrastructure design and arrangement to intuitively guide and communicate with drivers, pedestrians, and other road users. The theoretical implication of the study findings suggests that while the SER concept, which aims to enhance road safety and efficiency through intuitive road design, is generally acceptable, it may not adequately address the diverse cognitive demands experienced by different categories of road users, such as pedestrians, cyclists, and drivers. Hence, further development may be necessary to account for differences in cognitive load among categories of road users, suggesting the need to review how different road users prioritise self-explaining road principles. Addressing these differences in cognitive loading among road users through the refinement of the SER concept could lead to more inclusive and effective road design strategies and emphasise the importance of considering human factors and cognitive psychology principles in transportation planning and infrastructure development, ultimately contributing to safer and more accessible urban environments for all road users.

## 5.0 Conclusion

With regard to the study demonstrating that different categories of road users differ in their perception of the road's aesthetic dimensions, this study points out the need to explore the multifaceted nature of road planning issues through the lens of gender, age and user-type perception of aesthetics. In this regard, it recommends that the aspects of aesthetics evaluated during the environmental, visual and social impact assessment of road infrastructure projects should be considered according to the various categories of users, affecting the sampling designs. For instance, when assessing the user perceptions toward road naturalness, care should be taken to critically evaluate the views of both genders as the study shows that they differ in opinions.

Furthermore, as pedestrians do not share a similar perception as motorcyclists and drivers toward road coherence and naturalness, the survey should be well-tailored to capture this difference. Finally, when reviewing road imageability, practitioners should take note of not only the type of road users but also the frequency of road use since the respondents who are likely to yield useful results are those who use the roads daily. This recommendation guides the sampling criteria for these surveys. Thus, the results of this study can inform the selection of respondents when carrying out Social Impact Assessments for urban road projects to provide valuable information to transportation planners, policymakers and other stakeholders in the effort to plan for SERs.

Practically, the study identifies the variations in perception among different categories of road users. This observation highlights the importance of integrating aesthetics into road design to enhance user experience and safety. Moreover, the observed differences in how categories of users perceive aesthetic elements on the road point out the varying sensitivities to aesthetic elements and highlight the importance of designing roads that cater to diverse needs and



preferences. This observation points out the need to propose a framework to guide planners in engaging stakeholders while carrying out social impact assessments for infrastructure projects and, more specifically, when handling matters related to aesthetics. By incorporating aesthetic considerations into road design, transportation planners and engineers can create environments that not only meet functional requirements but also enhance user satisfaction, promote active transportation modes, and contribute to a sense of place and community identity. This approach can lead to safer and more attractive urban roads that benefit all users and contribute to the overall quality of urban environments.

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### 6.1 Funding

None

### 6.2 General acknowledgement

None.

### 6.3 Conflict of interest

None.

## 6.4 Ethical considerations

All participants gave their informed consent for inclusion before they participated in the study. The study was conducted in accordance with the Science, Technology and Innovation (Research Licensing) Regulation 2014 and approved by the Ethics Committee (Ref JKU/IERC/02316/0194).

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