

Aesthetic Indicators for Sustainable Road Development in Kenya

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Abstract

Existing frameworks in Kenya recognize road aesthetics as crucial for transportation but lack clarity on the applicable criteria for assessing road environments. Current techniques, such as planting trees and grass, only indicate road attractiveness through greenery. Therefore, there is a need to clarify road aesthetic indicators for sustainable infrastructure development in Kenya. This paper aims to investigate the aspects of aesthetics used in road environment evaluation by conducting a systematic literature review to identify empirical evidence of descriptive verbs utilized as indicators for road aesthetics. The careful selection of these indicators aims to demonstrate the multifaceted benefits of integrating aesthetics into sustainable road development, and serves as a foundation for defining road aesthetics. This study examined relevant, peer-reviewed empirical studies dating back to 2010 that emphasized the visual character and quality of road environments. A qualitative meta-synthesis study reviewing the aesthetic descriptions was conducted. A search of the databases yielded 191 articles; however, only nine articles met the eligibility and quality criteria. A list of specific verbs from the eligible articles was created using content analysis, text mining, and Euclidean regularisation. The paper identifies coherence, imageability, naturalness, legibility, and maintenance as the most frequently used to evaluate road aesthetics. These findings provide a well-structured set of variables that can be used as crucial indicators of the aesthetic quality of roads in Kenya. The paper also recommends the urgent development of comprehensive policies that prioritize aesthetics in road development, mandating the inclusion of aesthetic considerations in all stages of road planning, design, and construction.

Keywords

Aesthetic Dimensions, Coherence, Euclidean Regularisation, Naturalness, Term Frequency, Text Mining

1. Introduction

With a rising emphasis on sustainability, stakeholder interest in preserving and enhancing the road environment is growing. According to [Matijošaitienė and Stankevičė \(2014\)](#), road users are like the traditional consumer, looking for aesthetics as a way to enhance road usage utility. In Maslow's hierarchy of needs, cognitive and aesthetic needs are necessary for societal growth ([McLeod, 2007, 2018](#); [Mozer, 1988](#)). As a result, the need to create high-quality roadside design components contributes to the achievement of this goal.

The aesthetics of roadways is the primary link to the environment since the urbanized global population primarily engages with natural landscapes visually through their movement along roads. Multiple variables have been used to define this connection, with [Armstrong et al. \(2013\)](#) advancing natural terrain features, human-enhanced topography, design of road signs and road-safety measures. Therefore, planners must seek to balance the natural world and human-built forms to produce aesthetic roads. These would have to consider the demands of highway users, the roadway owners, and the preservation or improvement of the natural and cultural surroundings. Since creating excellent and pleasant road designs is vital for road planning professionals, there is a need to identify clear and concise definitions of attractive roads from the perspectives of road development experts and users.

Road aesthetics encompasses not only qualities of beauty that relate to its form, the proportions of spaces, lines, and mass, but also the preferences of road users ([Blumentrath & Tveit, 2014](#); [Qin et al., 2023](#)). [Blumentrath and Tveit \(2014\)](#) identified three aspects of road design that are applied in defining the visual attributes of a road: the visual characteristics of the road as an independent structure, the visual characteristics of the surroundings, and the traveller's movement. In past visual assessment studies ([Chon & Shafer, 2009](#); [Clay & Smidt, 2004](#); [Mok et al., 2006](#)), different characteristics in various social and cultural contexts have been identified and used to incorporate aesthetic dimensions into the planning and development of infrastructure. The studies apply social science methods to construct descriptive models representing people's responses to the environment's visual aspects. Therefore, this paper synthesizes existing empirical studies on the visual aspects of the road through content analysis and text mining. The intention is to identify the most commonly used dimensions for evaluating road aesthetics in different social and cultural contexts.

2. Literature Review

2.1. Importance of Aesthetic Evaluation of Road Environments

Aesthetic evaluation of road environments is essential in shaping the quality, safety and user experience in urban areas. Historically, road aesthetics in the early nineteenth century lay in the driving experience ([Passonneau, 1996](#)). Most roads functioned as recreational parks ([Appleyard et al., 1964](#); [Havlick, 2002](#);

Wilson, 2019). The roads were an organic integration of surrounding landscape design, engineering, and architecture. As automobile speeds increased, parkways began to turn into wider roads. The continued growth of the transport system then made the inclusion of visual aspects into road planning and design necessary. The focus gradually shifted to the impact of roads on urban areas, leading to the development of guidelines for integrating aesthetic elements into road forms (Blumentrath, 2016; Hornbeck et al., 1969; Hornbeck & Okerlund, 1972; Passonneau, 1996; Schutt et al., 2001).

Road aesthetics is important to road design, particularly regarding traffic safety, because it affects users' perceptions and behaviour (Drottenborg, 1999; Matijošaitinė & Navickaitė, 2012; Mok et al., 2006). Anciaes (2023) and Matijošaitinė & Navickaitė (2012) highlight a probable link between aesthetics and safety in interdisciplinary studies on arts and aesthetics, environmental psychology, and transportation safety. Engineers and planners aim to maximize the safety and efficiency of transportation functions. Likewise, designers seek to create pleasurable user experiences and may use subtle aspects of road design to help plan for an aesthetically pleasing road environment. Aesthetically pleasant roads contribute to a positive experience for road users, making the journeys enjoyable and reducing stress (Parsons et al., 1998; Passonneau, 1996; Wilde, 2009), linking them to mental health and wellbeing. Therefore, understanding road aesthetics requires a critical analysis of user perceptions, the visual quality of the surrounding environment, and signed communication effectiveness (Chon & Shafer, 2009; Nasar, 1992; Sanoff, 2016).

Road planning, design, and maintenance decisions are guided by understanding how people perceive and use road environments. Lamberti, Russo, and Dell'Acqua (2010) argue that the public's preferences inform their perceptions, as the aesthetics reflect the local culture and values. Thus, it is essential to involve the community in the development of road aesthetics. By integrating aesthetic considerations in road management practices, policymakers, urban planners, and all the professionals involved in transportation planning can enhance the overall quality of life and wellbeing of the urban population while promoting economic vitality and environmental sustainability.

2.2. Predictors of Road Aesthetics

Schutt, Phillips and Landphair (2001) applied the Landscape Preference Matrix developed by Kaplan & Kaplan (1989) to discuss road aesthetics. This matrix describes four informational factors by which road users may perceive road environments: coherence, complexity, legibility and mystery. These factors combine to predict a specific response from observers as Rosa and Collado (2019) suggested that a positive link exists between direct experiences in nature and people's environmental attitudes and behaviours. The matrix also aids in understanding how the environment affects people, as it is based on the human need to understand and explore, which informs the gathering of spatial information

and simultaneous evaluation of the scene.

Coherence, the matrix's first factor, is synonymous with harmony. According to [Martín, Ortega, Otero and Arce \(2016\)](#), coherence is measured in terms of the unity of a scene and the similarity of land uses. It could also describe the ease with which one can organize or comprehend a scene. Coherence is the ability to see and comprehend the pattern inherent in a scene within the road environment ([Bell, 2019](#); [Blumentrath & Tveit, 2014](#); [Ernawati, 2021](#); [Tveit et al., 2006](#)), and the degree of unity and visual order achieved through patterns and linkage of scene components ([Hunter & Askarinejad, 2015](#)). Logical areas are defined as distinct units to create visually discernible scenes and infuse environmental harmony into a road's visual pattern. This description correlates to the assertions of Gestaltian psychology, which stresses the whole being more significant than the parts ([Antrop & Van Eetvelde, 2017](#); [Guberman, 2017](#)), further supporting arguments that readily identifiable objects result in greater coherence. Thus, aspects of the road layout within a specific segment help create greater harmony with the environment.

The second factor, complexity, refers to how much is going on in a scene and is commonly measured using indicators for the shape of elements that make up a landscape ([Martín et al., 2016](#); [Simensen et al., 2018](#)). Complexity is determined by the diversity and richness of a road environment and the number of perceivable elements therein. [Hunter and Askarinejad \(2015\)](#) attribute diversity to the physical structure and observed physical content. It is also defined as the number of elements in a scene and their distinctiveness, the richness of elements and features, and the interspersed patterns ([Simensen et al., 2018](#)) that emerge from the variety of line types, forms, textures or colours. Empirical studies have shown that as the number of elements in a scene increases, more effort is required to discern the scene.

Legibility and mystery explain how humans use complexity and coherence to decide how to behave ([Blumentrath & Tveit, 2014](#); [Bogucka, 2021](#); [Rosa & Collado, 2019](#); [Taylor, 2009](#)). Legibility is making sense of a scene to function safely within that space. It describes the ability of a space to be understood by an observer. The legibility of a scene is affected by the depth of perception, spatial definition, and orientation ([Nasar, 1997](#)). Highly legible scenes are easy to understand, allowing for the quick formation of cognition maps since they have depth and well-defined spaces. In the context of a road environment, legibility allows observers to form accurate mental maps quickly and clearly distinguish where they are and where they are going while also considering their safety concerns. [Kaymaz \(2012\)](#) links legibility to mental image formation and highlights its influence on environmental cognition, the perception, understanding, and retrieval of spatial information. These are essential aspects of planning safe transportation corridors.

Legibility is critical in evaluating road aesthetics and allows for safe road use. In the prospect-refuge theory, "refuge" relates to a landscape's legibility ([Guy,](#)

2015). It also refers to the possibility of making sense within a 3-dimensional space, as it concerns the interpretation and perception of coherence within a space. Finally, one may argue that legibility connotes the character of an environmental scene, specifically as it relates to its capability to be seen and understood by users. In this sense, we also determine legibility by the clarity of information that a road section and its attendant designs and layout communicate to the viewer. The viewer uses such information to understand what surrounds them and decide how best to perform or react as they navigate such an environment. The fourth factor of the Kaplan matrix, mystery, refers to anticipating what comes next based on the present scene. Mystery allows for continuity, connecting what is seen and anticipated, and is an essential consideration in road planning. However, different suggestions continue to indicate that Kaplan's preference model and its relationship with responses is a simple method of evaluating the aesthetics of a roadway. Within this point of divergence, this paper seeks to clarify the concept of road aesthetics.

3. Method

Framing the Analysis

Li, Xie, Daim and Huang (2019) propose a framework that uses scientific papers and patents as data resources and integrates text mining and expert judgment approaches to identify technology evolution paths. These then form the basis for forecasting technology development trends within the short term. This study explores the descriptive dimensions of road aesthetics, reviewing previous studies that apply specific terms in evaluating such concerns. The paper begins the search process by predefining the criteria for including or excluding studies related to the subject. On inclusion, chosen studies emphasized the dimensions in their results, with the database search limiting the inclusion to peer-reviewed sources published no earlier than 2010 and available as full texts in English.

We queried seven databases in disciplines ranging from transportation planning to urban studies. In addition, we undertook a search of accessible electronic databases and screened titles and abstracts. The journals included the Journal of Environmental Management, Journal of Environmental Research, Landscape and Urban Planning, Transport Research Part A & B, the International Journal for Traffic and Transport Engineering, and the Journal for Sustainable Architecture and Civil Engineering. Keywords to identify relevant papers were collected by reviewing primary literature studies on the beauty of roads. After reviewing the titles, abstracts, and keywords in several journals, the results were classified based on their relevance to road beauty into two keyword themes. The first theme included the visual characteristics of roads, while the second featured the synonyms of road aesthetic dimensions used in previous research.

The search process began by predefining the criteria for including or excluding the articles of interest. The criteria for article selection were timeliness, relevance, completeness and accuracy. Hence, the study selected articles hig-

highlighting aesthetic dimensions for further evaluation. The systematic study exclusion process, which complemented the record selection process, was informed by the methodology established by [Abdi and Lamiquiz-Dauden \(2020\)](#). The process ranged from record identification, appraisal, and screening, as shown in [Figure 1](#). The study identified one hundred ninety-one records by searching the database.

The study selected one hundred sixty-one records for abstract screening after removing duplications. The initial selection then decreased further to nine. The reasons for excluding articles included lack of access to the full text, articles only available in a foreign language and articles whose discussion sections did not provide a precise evaluation of the dimensions for measuring road aesthetics. The references and bibliographies of the selected papers were also examined to identify relevant studies before proceeding with the quality appraisal. The examination did not find additional records. Consequently, we thoroughly reviewed the final articles, exclusively analyzed the findings from each article, and utilized the findings in the text mining procedure, as depicted in [Figure 2](#).

We synthesized the nine articles through content analysis, text mining, manual systematic coding, and analysis of word frequencies and associations. As content analysis systematically analyses documents and texts in a replicable

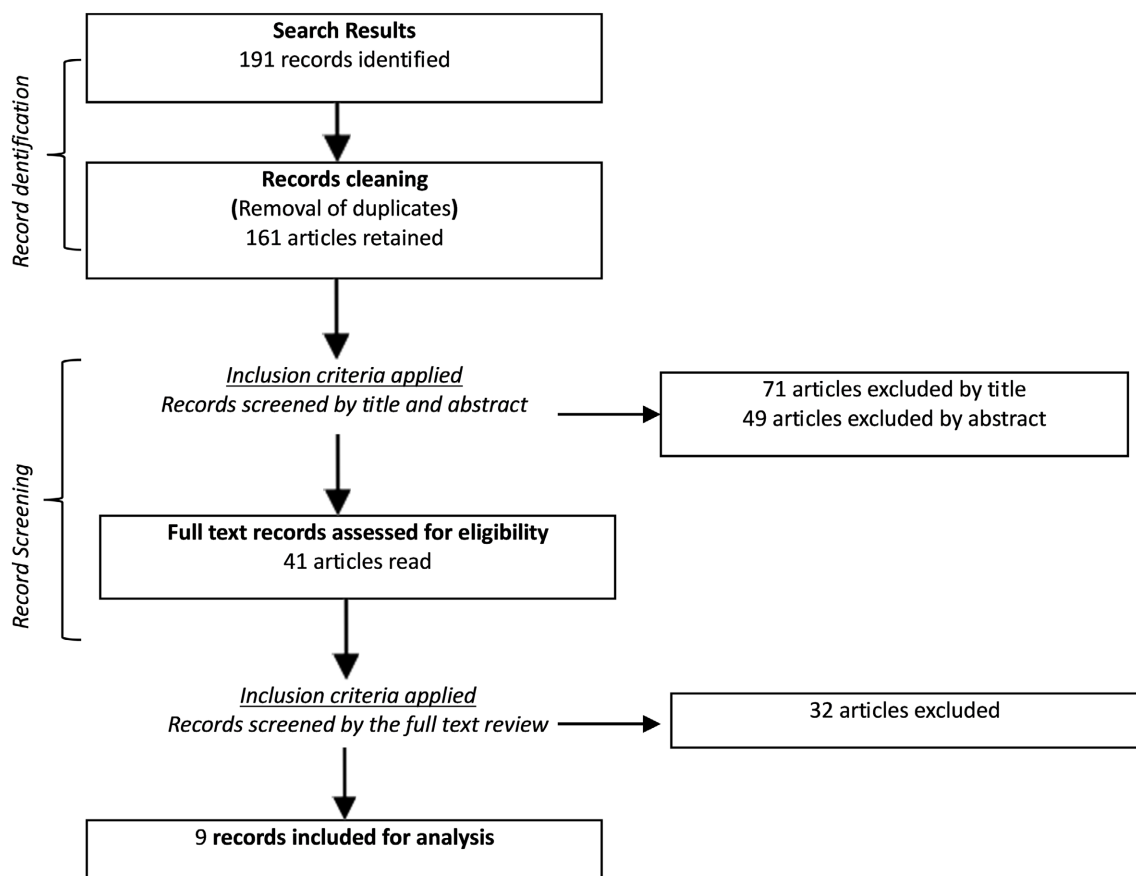


Figure 1. Flowchart for retrieval of record for identifying road aesthetic dimensions.

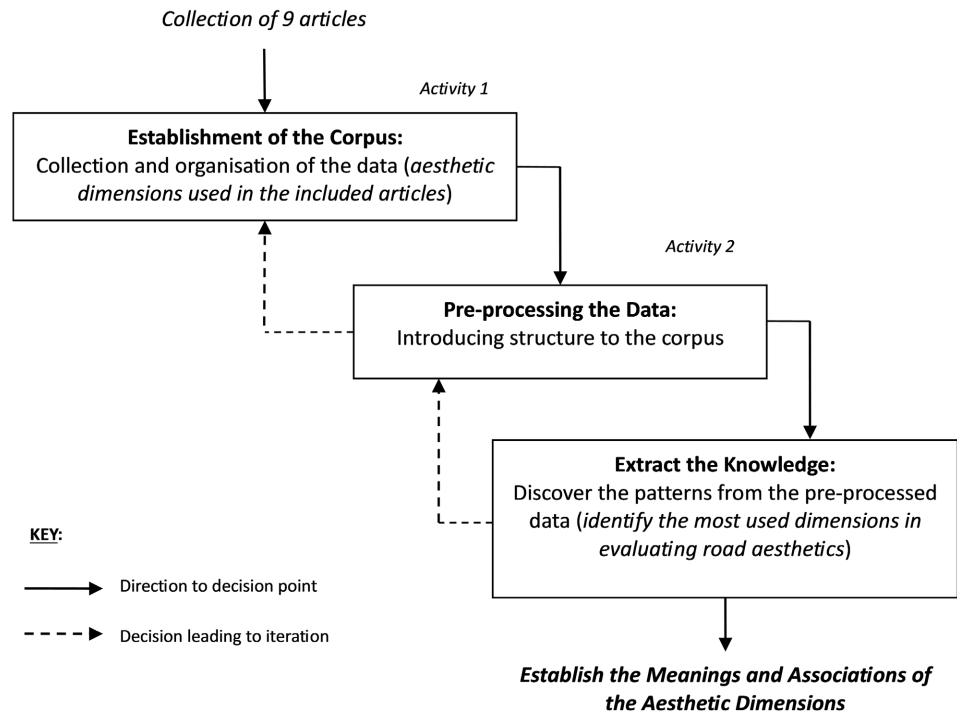


Figure 2. Flowchart for the text mining procedure.

manner and quantifies content in terms of predetermined categories, we carried out text mining for the dimensions. Furthermore, we undertook a search for words used in previous related empirical studies on road aesthetics by conducting a manual systematic text coding of defined theoretical concepts of interest using supervised text classification in OrangeTM an open-source data mining software. Word frequency and associations were analyzed. This synthesis revealed terms used in assessing road aesthetics and their descriptions.

Moreover, in this study, we transformed the textual data into constructive knowledge, where the meanings of identified terms were reviewed further using Roget's Thesaurus and descriptions from previous studies. Terms with similar meanings were recorded using a common term. In analyzing the term relevance to establish the terms most used in evaluating road aesthetics, euclidean regularisation, useful in efficiently determining objects of similarity, was used to establish the term frequencies (TF), which represents how frequently a term appears in an article, inverse document frequency (IDF), which measures the rarity of the term across all articles in a corpus, and finally, the term frequency/inverse document frequency (TF-IDF), a numerical statistic that reflects the importance of a term in a corpus of documents, to make the judgement. In this study, the corpus of documents comprised nine articles that evaluated road aesthetics. Hence, the TF-IDF score of a term was calculated by multiplying its TF with its IDF. A high TF-IDF score for a term indicated that it was both frequent in a particular document and rare in the corpus, suggesting its importance. The weighting of terms allows for dimension reduction and identifying the most relevant

terms critical to assessing road aesthetics. Hence its relevance to this study.

4. Results

The nine articles that met the inclusion criteria were reviewed. A synthesis of the articles through manual systematic coding revealed aesthetic dimensions used in assessing roads, as depicted in **Table 1**. These articles highlighted studies undertaken in diverse regions and settings, whose main objectives were to evaluate the aesthetics of roads and their surrounding environments. For instance, **Blumentrath (2016)** identified characteristics of importance for reviewing the aesthetic quality of roads from expert and layperson perspectives.

Using ATLAS.ti v8, we collated the list of identified descriptors of road aesthetics and used a single term to record variations of terms that were deemed similar. For instance, coherency and coherent design were recorded as coherence;

Table 1. List of descriptive terms used in the evaluation of road aesthetics.

Article (Author and Objective)	Case Study Location	Descriptors of Road Aesthetics
Blumentrath (2016) To identify characteristics of roads deemed to have good aesthetic quality from both the laypersons' and experts' perspectives.	Norway	<ul style="list-style-type: none"> • Coherent design • Functionality • Harmony • Legibility • Naturalness • Personal memories • Variety • Visibility
Martín, Ortega, Otero & Arce (2016) To design a methodology for evaluating the character and scenic quality of the landscape viewed from the motorway.	Spain	<ul style="list-style-type: none"> • Coherence • Complexity • Disturbance • Ephemera • Historicity • Imageability • Naturalness • Stewardship • Visual scale
Matijošaitienė & Stankevičė (2014) To propose a framework for the creation of a desirable road landscape for driving.	Lithuania	<ul style="list-style-type: none"> • Beautiful • Harmony • Interesting • Majestic • Naturalness • Outstanding • Pleasurability • Relaxing • Safety • Skittishness • Sophistication • Vividness

Continued

<p>Blumentrath & Tveit (2014) To provide suggestions for more consistent terminology and present a theoretical framework for assessing the visual quality of roads.</p>	Norway	<ul style="list-style-type: none"> • Aesthetics of flow • Coherence • Contrast • Imageability • Integration • Legibility • Maintenance • Naturalness • Orientation • Simplicity • Variety • Visibility
<p>Wang, Shen, Meng, Qin, & Wang (2013) To analyze and evaluate the landscape resources along a highway to guide future highway landscape design and management.</p>	China	<ul style="list-style-type: none"> • Coherency • Proportion • Repetition • Rhythm • Simplicity • Unity
<p>Matijošaitinė & Navickaitė (2012) To analyze road safety through aesthetic features of a landscape.</p>	Lithuania	<ul style="list-style-type: none"> • Beautiful • Coherence • Harmonious • Interesting • Majestic • Natural • Outstanding • Pleasant • Relaxing • Skittish • Sophisticated • Visually safe • Vividness
<p>Dell'Acqua, Mauro & Russo (2011) To validate the recognized ability of predictor variables to reproduce untrained observers' preferences in identifying scenic roads.</p>	Italy	<ul style="list-style-type: none"> • Intactness • Unity • Vividness
<p>Mohamed and Abdel-Gawad (2011) To evaluate the nature of aesthetic treatments and elements used or may have application within the roadway in Egypt.</p>	Egypt	<ul style="list-style-type: none"> • Consistency • Identity • Maintenance • Uniqueness
<p>Sezen & Yilmaz (2010) To evaluate the possibility of using the E-97 route in Erzurum-Bayburt-Of (Trabzon) D925 state highway as a scenic road.</p>	Türkiye	<ul style="list-style-type: none"> • Authenticity • Harmony • Naturalness • Uniqueness • Vitality

harmonious was recorded as harmony, natural as naturalness, skittish as skittishness and sophisticated as sophistication. An analysis using Orange™, an open-source data mining software, produced the term frequencies as depicted in **Figure 3** and **Table 2**; naturalness was the most used term in the evaluation of road aesthetics with six occurrences, followed by coherence and imageability, which appeared in five and four instances, respectively.

Furthermore, we assessed descriptions of terms used in the various studies. Some terms used in the various studies had similar conceptual meanings; hence, we undertook word association and categorization and reviewed term descriptions provided in the selected articles with the aid of Roget’s (2022) thesaurus. Terms with similar descriptions and meanings were recorded using a surrogate term, as shown in **Table 3**. This assessment revealed meanings associated with the terms and aided in creating a new corpus used to run the term frequency operation and produce a term-by-document matrix (**Table 4**).

An inspection of the term-by-document matrix revealed that more than 50%



Figure 3. Word cloud of term frequency in selected articles.

Table 2. Term frequency in selected articles.

Term/Descriptor of Road Aesthetics	Frequency of Occurrence
Naturalness	6
Coherence	5
Harmony	4
Legibility, Imageability, Beautiful, Interesting, Majestic, Outstanding, Pleasant, Maintenance, Unity, Uniqueness	2
Functionality, Personal memories, Variety, Visibility, Complexity, Disturbance, Ephemera, Historicity, Stewardship, Relaxing, Aesthetics of flow, Contrast, Integration, Proportion, Repetition, Rhythm, Simplicity, Intactness, Vividness, Consistency, Identity, Authenticity, Vitality	1

Table 3. Assessment of aesthetic dimensions used in the articles.

Descriptors of road aesthetics	Related synonyms	Terms used in identified articles and their description
Coherence: Ease of comprehension due to unity in a scene and repeating patterns of colour and textures	<ul style="list-style-type: none"> • Order • Harmony • Uniformity • Integration • Proportion • Good fit 	<ul style="list-style-type: none"> • Coherence, Coherency, Coherent design • Harmony: <i>displaying oneness, regularity, and order</i> • Integration: <i>displaying good fit and less disturbance</i> • Proportion • Unity: <i>the power to produce coherence and harmony as well as homogeneity</i>
Ephemera: Changes in the season, weather, or other temporal effects		<ul style="list-style-type: none"> • Ephemera
Imageability: Creating a lasting impression and strong visual image in the observer	<ul style="list-style-type: none"> • Identity • Sense of place • Character • Distinctness • Uniqueness • Distinguishable • Memorable 	<ul style="list-style-type: none"> • Imageability • Outstanding: <i>distinguished and memorable</i> • Uniqueness: <i>particular and rare</i> • Vividness: <i>intense scenes that are clear and brilliant to view</i> • Majestic: <i>Impressive, splendid and sublime</i> • Beautiful: <i>pleasing, sublime, splendid, fascinating, attractive</i> • Pleasantness: <i>pleasing, engaging</i>
Legibility: Understandable, self-explaining road	<ul style="list-style-type: none"> • Simplicity 	<ul style="list-style-type: none"> • Aesthetics of flow: <i>positive travel experience for all road users, portraying rhythm and balance, allowing for the experience of sequence, mystery and surprise in a user</i> • Consistency: <i>Providing rhythm</i> • Functionality: <i>linked to the aesthetics of flow</i> • Legibility • Orientation: <i>easy to understand and provides sequences</i> • Rhythm: <i>with regularity, pattern and uniformity</i> • Repetition: <i>with duplication and rhythm</i> • Simplicity: <i>minimalist</i>
Maintenance: Good workmanship and care given to the roads, a sense of order	<ul style="list-style-type: none"> • Stewardship • Upkeep 	<ul style="list-style-type: none"> • Maintenance • Stewardship: <i>A sense of order and reflecting human care through active and careful management</i>
Naturalness: Closeness to the preconceived natural state	<ul style="list-style-type: none"> • Greenery • Intactness 	<ul style="list-style-type: none"> • Natural • Naturalness • Intactness: <i>Free from intrusions</i>
Variety: Diversity of landscape elements and richness of elements along the road	<ul style="list-style-type: none"> • Complexity • Diversity • Heterogeneity 	<ul style="list-style-type: none"> • Complexity: <i>Intricacy</i> • Variety • Vitality: <i>attractive space appropriate to the activities</i> • Contrast: <i>Divergence, heterogeneity</i>
Visibility: Observable spaces	<ul style="list-style-type: none"> • Visual scale • Openness 	<ul style="list-style-type: none"> • Visibility • Visual scale: <i>size, shape, diversity and degree of openness of the perceptual units or landscape rooms</i>
Historicity: Historical continuity and richness, with different layers of time and diversity of cultural elements	-	<ul style="list-style-type: none"> • Authenticity: <i>originality and historicity</i>
Safety: Reduced risk of accident		<ul style="list-style-type: none"> • Safe • Visually safe

Continued

Skittishness: Exciting and whimsical	•	Interesting	• Interesting: <i>appealing, attractive, captivating</i> • Skittish • Skittishness
Sophistication	•	Intricate • Elaborate • Refined	• Sophisticated
Vitality	•	Intensity • Continuity • Robustness	• Vitality
Disturbance	•	Disorder	• Disturbance
Pleasant	•	Acceptable • Engaging	• Pleasant
Relaxing	•	Calming	• Relaxing

Table 4. Term-by-document matrix.

	Article 1	Article 2	Article 3	Article 4	Article 5	Article 6	Article 7	Article 8	Article 9
Coherence	1	1	1	1	0	1	1	1	1
Disturbance	0	0	0	1	0	0	0	0	0
Ephemera	0	0	0	1	0	0	0	0	0
Historicity	0	0	0	1	0	0	0	0	1
Imageability	0	1	1	1	1	0	1	1	1
Interesting	0	1	0	0	0	0	1	0	0
Legibility	1	0	0	0	1	1	0	1	0
Maintenance	0	0	0	1	1	0	0	1	0
Naturalness	1	1	0	1	0	0	1	1	1
Personal Memories	1	0	0	0	0	0	0	0	0
Pleasant	0	1	0	0	0	0	1	0	0
Relaxing	0	1	0	0	0	0	1	0	0
Safety	0	1	0	0	0	0	1	0	0
Skittishness	0	1	0	0	0	0	1	0	0
Variety	1	1	0	1	0	0	1	1	0
Visibility	1	0	0	1	0	0	0	1	0
Vitality	0	0	0	0	0	0	0	0	1

Note: 1 = existence of the term in an article; 0 = term does not exist in the article.

of the studies reviewing road aesthetics discussed coherence, imageability, naturalness and variety. Legibility, maintenance, and visibility were also common terms, with 30% - 44% of the articles considering them as descriptors critical in

reviewing aesthetics (Figure 4).

The percentage occurrence of terms per document and the concept of optimal weighting using Euclidean regularisation were used to process and identify terms most relevant in evaluating road aesthetics. As a result, we generated the term frequencies, inverse document weighting and the TF-IDF (term frequency-inverse document frequency). These operations efficiently determined objects of similarity and reduced the dimensionality of the identified road aesthetics descriptors. First, the textual data obtained from evaluating meanings created a term frequency matrix (Table 5). Each term within an article was assigned a weight (tf_i) determined by Equation (1).

$$\text{Term frequency}(tf_i) = \frac{\text{Number of occurrences of a term}}{\text{Total relevant terms reviewed in the articles}} \quad (1)$$

In this regard, the more relevant terms within an article had higher weighting. For example, Figure 5 indicates that eight articles accessed roads for coherence. Therefore, this term had the highest cumulative term frequency weighting. Legibility had the second-highest cumulative weighting and was assessed in four articles. Imageability ranked third, having been reviewed in seven articles, while naturalness and variety had similar weighting. However, six articles reviewed naturalness, compared to five that reviewed variety.

Each term's Inverse Document Frequency (IDF) was calculated using Equation (2), and their weights were noted (Table 6). IDF measured the probability of relevance of the terms related to the corpus, where a higher weighting indicated that the term was occurring less frequently, while a lower IDF weight was obtained for frequently occurring terms in the corpus.

$$\text{IDF}_{i,j} = \log\left(\frac{N}{df_i}\right) \quad (2)$$

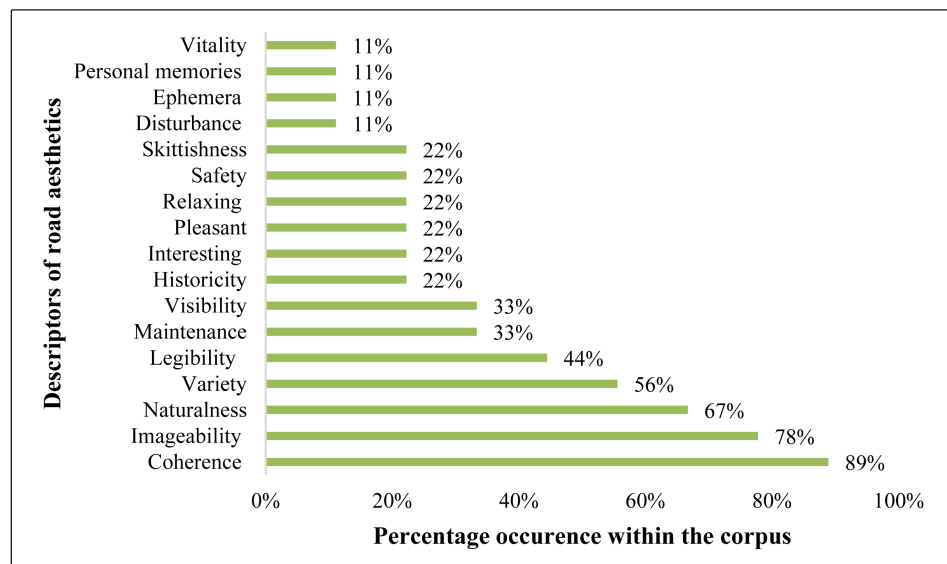


Figure 4. Percentage occurrence of the descriptors of road aesthetics in reviewed articles.

Table 5. Term frequency matrix.

	Article 1	Article 2	Article 3	Article 4	Article 5	Article 6	Article 7	Article 8	Article 9
Coherence	0.33	0.25	1.00	0.11	0	1.50	0.13	0.29	0.20
Disturbance	0	0	0	0.11	0	0	0	0	0
Ephemera	0	0	0	0.11	0	0	0	0	0
Historicity	0	0	0	0.11	0	0	0	0	0.20
Imageability	0	0.50	0.50	0.11	0.67	0	0.50	0.14	0.20
Interesting	0	0.13	0	0	0	0	0.13	0	0
Legibility	0.33	0	0	0	0.33	3.50	0	0.57	0
Maintenance	0	0	0	0.11	0	0	0	0.14	0
Naturalness	0.17	0.13	0	0.11	0	0	0.13	0.14	0.20
Personal memories	0.17	0	0	0	0	0	0	0	0
Pleasant	0	0.13	0	0	0	0	0.13	0	0
Relaxing	0	0.13	0	0	0	0	0.13	0	0
Safety	0	0.13	0	0	0	0	0.13	0	0
Skittishness	0	0.13	0	0	0	0	0.13	0	0
Variety	0.17	0.13	0	0.11	0	0	0.13	0.29	0
Visibility	0.17	0	0	0.11	0	0	0	0.14	0
Vitality	0	0	0	0	0	0	0	0	0.20

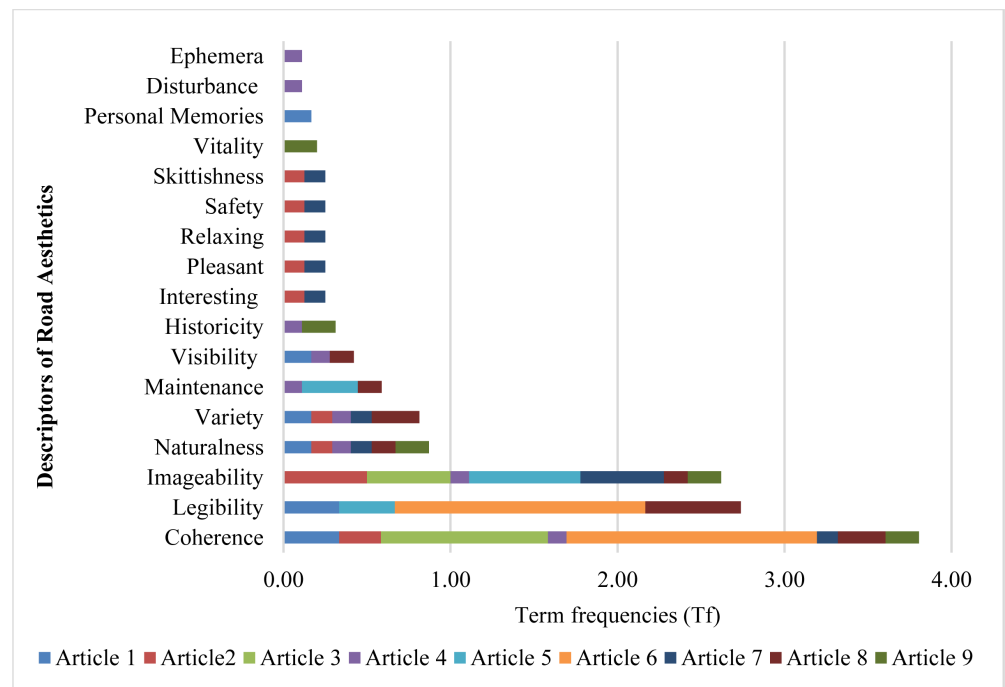


Figure 5. Comparative evaluation of term frequency per article.

Table 6. IDF scores for the descriptors of road aesthetics.

Descriptors of Road Aesthetics	Occurrence of Terms in the Corpus (%)	Inverse Document Frequency (Weight)
Coherence	89	0.05
Imageability	78	0.11
Naturalness	67	0.18
Variety	56	0.26
Legibility	44	0.35
Maintenance	33	0.48
Visibility	33	0.48
Interesting	22	0.65
Pleasant	22	0.65
Skittishness	22	0.65
Historicity	22	0.65
Relaxing	22	0.65
Safety	22	0.65
Disturbance	11	0.95
Ephemera	11	0.95
Personal memory	11	0.95
Vitality	11	0.95

Where,

i = term used in an article to evaluate road aesthetics

j = article discussing the evaluation of road aesthetics

df_i = Number of articles containing ' i '

N = Total number of articles

Finally, the TF-IDF formula, as shown in Equation (3), was used to determine the TF-IDF for each term per article and to develop the TF-IDF matrix (**Table 7** and **Figure 6**).

$$\text{TF-IDF}_{i,j} = \text{TF}_{i,j} \times \log\left(\frac{N}{df_i}\right) \quad (3)$$

The TF-IDF matrix revealed that legibility had the highest cumulative weight and was evaluated in four articles. It was followed by imageability and maintenance, which were evaluated in seven and three articles, respectively. The study determined the final list of relevant terms by considering the three highest-ranking terms according to the percentage occurrence of terms per article, term frequencies, inverse document frequency weighting, and the TF-IDF (term frequency-inverse document frequency) outputs (**Table 8**).

Based on the four ranking criteria, the study identified coherence, imageability,

Table 7. TF-IDF matrix for aesthetic dimensions identified in the nine articles.

	Article 1	Article 2	Article 3	Article 4	Article 5	Article 6	Article 7	Article 8	Article 9
Coherence	0.02	0.01	0.05	0.01	0	0.08	0.01	0.01	0.01
Disturbance	0	0	0	0.11	0	0	0	0	0
Ephemera	0	0	0	0.11	0	0	0	0	0
Historicity	0	0	0	0.11	0	0	0	0	0.20
Imageability	0	0.05	0.05	0.01	0.07	0	0.05	0.02	0.02
Interesting	0	0.08	0	0	0	0	0.08	0	0
Legibility	0.12	0	0	0	0.12	0.53	0	0.02	0
Maintenance	0	0	0	0.05	0.16	0	0	0.07	0
Naturalness	0.03	0.02	0	0.02	0	0	0.02	0.03	0.04
Personal memories	0.16	0	0	0	0	0	0	0	0
Pleasant	0	0.08	0	0	0	0	0.08	0	0
Relaxing	0	0.08	0	0	0	0	0.08	0	0
Safety	0	0.08	0	0	0	0	0.08	0	0
Skittishness	0	0.08	0	0	0	0	0.08	0	0
Variety	0.04	0.03	0	0.03	0	0	0.03	0.07	0
Visibility	0.08	0	0	0.05	0	0	0	0.07	0
Vitality	0	0	0	0	0	0	0	0	0.19

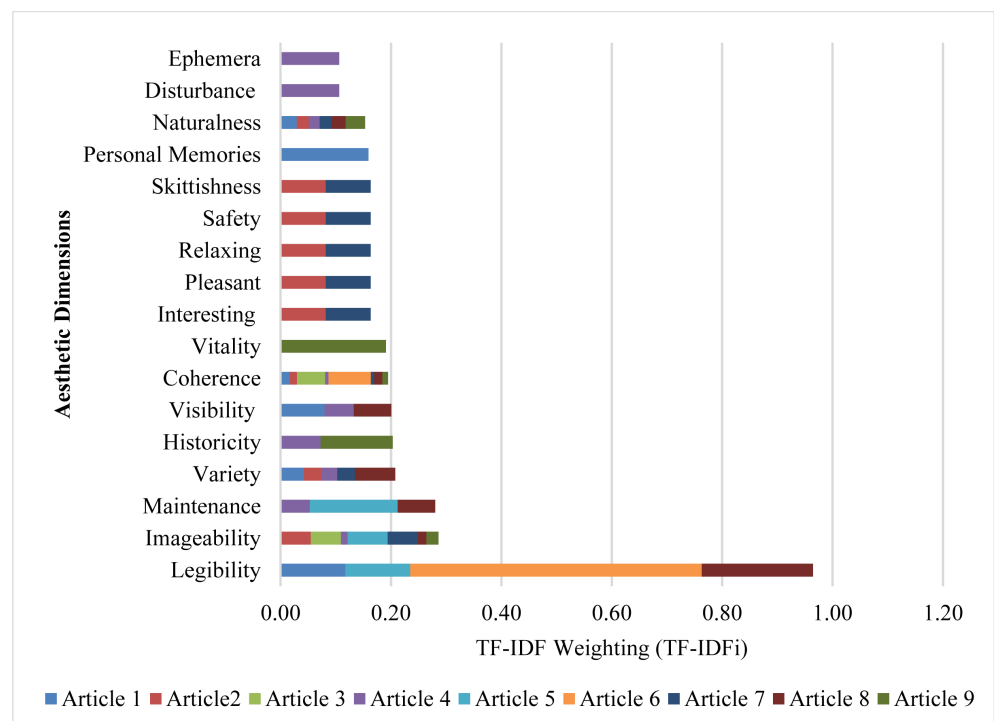


Figure 6. Comparative evaluation of TF-IDF per article.

Table 8. Identification of critical descriptors of road aesthetics.

Ranking Criteria	Percentage occurrence of terms per article	Term Frequency (TF)	Inverse Document Frequency (IDF)	Term Frequency-Inverse Document Frequency (TF-IDF)
Rank 1	Coherence	Coherence	Coherence	Legibility
Rank 2	Imageability	Legibility	Imageability	Imageability
Rank 3	Naturalness	Imageability	Naturalness	Maintenance

legibility, naturalness, and maintenance as the most relevant descriptive terms in evaluating road aesthetics.

5. Discussion

This synthesis sought to identify the most relevant terms or descriptors useful in clarifying how to achieve aesthetics for transportation planners in Kenya. As a result, the synthesis carried out in this study provided a meaningful list of relevant and appropriate aesthetic dimensions for evaluating road environments and outlined them as follows: coherence, which is the ability to see and comprehend the pattern within a scene related to scale and proportion (Tveit et al., 2006), imageability; the expression connoting the ability of a scene to create a strong visual image in an observer (Clemente & Ewing, 2005), naturalness; described by the type of nature content and measured in road environments by the appearance of natural elements such as vegetated roadside areas (Blumentrath & Tveit, 2014), legibility, which refers to the ability of a road to be understood by the observer, who then makes sense of it to allow for safe functioning, and finally maintenance, represented by the tidiness of the road environment, the quality of materials used, and excellent workmanship (Blumentrath et al., 2015; Blumentrath & Tveit, 2014).

The assessment of meanings revealed a similarity in some dimensions. For instance, coherence, described as the quality of design and layout that creates a clear and understandable urban environment for its inhabitants (Lynch, 1960), was also described as the degree of harmony, consistency, and logical connection between different elements and aspects of an environment. It encompasses the urban environment's overall organization, layout, and design, aiming to create a sense of unity and cohesion. Hence, coherence relates to dimensions such as order, harmony, uniformity, integration, proportion and good fit.

Imageability, which is the quality of an environment's elements that trigger lucid images in an observer and the ease with which people can form a mental image of a place (Appleyard et al., 1964; Lynch, 1960; Nasar, 1998), related to the descriptions provided for identity, sense of place, character, distinctness, uniqueness, distinguishability and memorability. In road planning, imageability refers to the design and layout of road networks that enhance the visual appeal and legibility of a city or urban area. It involves creating streetscapes and transportation systems that are aesthetically pleasing, easily navigable, and conducive to

human-scale activities (Gehl, 2013; Van der Hoeven et al., 2008).

Legibility is defined as the clarity and comprehensibility of an urban environment's spatial layout and organization. It focuses on how easily people can navigate and understand a city's physical structure, landmarks, and transportation networks (Lynch, 1960). In road planning, legibility refers to the clarity and ease with which road users can understand and navigate a road network. It encompasses clear signage, well-designed intersections, logical route numbering, and easily comprehensible road markings. For instance, Pasetto & Barbati (2012) showed that improved road markings led to a better perception of the road and a general reduction in average speed. Legibility in road planning aims to provide a road network that minimizes confusion and enhances safety for all users (Appleyard et al., 1964; Wilson, 2019). This dimension relates to simplicity, aesthetics of flow, consistency, functionality, orientation, rhythm and repetition.

Naturalness related to greenery and intactness was described as an environment's closeness to a perceived natural state (Kaplan & Kaplan, 1989; Orians, 2022; Tveit et al., 2006). It is an important aesthetic dimension in road planning that integrates natural elements, such as trees, vegetation, and open spaces, which can enhance the visual appeal of roadways and create a more pleasant and harmonious environment for drivers and pedestrians. Finally, maintenance, linked to stewardship and upkeep, is the ongoing care and upkeep of urban spaces to ensure their visual appeal and functionality. It involves cleaning, repairing, and regularly maintaining infrastructure, public spaces, and landscapes (Gehl, 2013; Jacobs, 1961; Lynch, 1984).

The results of the TF-IDF shown in **Figure 6** suggest that despite coherence being the most used descriptive term in studies exploring road aesthetics, legibility had a higher weighting, suggesting a link between the legibility of a road and the need for self-explaining roads, as discussed by Theeuwes (2021) and Chowdhury (2014). The link between self-explaining roads (SERs) and road legibility lies in the shared goal of promoting efficient and safe navigation within road environments. Road legibility contributes to the nature of SERs through the provision of visual cues and navigational aids that help road users understand road layouts and anticipate reactions. Moreover, SERs result in high road legibility as this principle prioritizes simplicity, clarity and ease of understanding of road scenes (Chaudhary, 2020; Cunningham, 2018). Imageability and maintenance are then ranked second and third regarding the TF-IDF weighting. However, this result should be interpreted cautiously, as more research into how different users perceive these dimensions is needed to assess their importance in the Kenyan context better.

Moreover, it is important to consider conflicts and synergies between aesthetics and other sustainability indicators in road development to create a balanced and effective infrastructure. One major potential conflict is the impact on the environment, particularly in terms of the naturalness of the road. Greening requires significant water and maintenance resources (Liu & Jensen, 2018). How-

ever, integrating aesthetic values can enhance environmental benefits. For example, using vegetated swales and native plants that support local biodiversity can reduce maintenance needs and costs (O'Sullivan et al., 2017; Phillips et al., 2020; Säumel et al., 2016). In addition, we identify notable synergies in community engagement and user experiences. Understanding road coherence, imageability, and legibility from the user's perspective enhances user experiences and increases safety. Therefore, it is critical to adopt an integrated design approach that considers all sustainability indicators (Suprayoga et al., 2020; Yang et al., 2020) and implements adaptive management practices for ongoing monitoring and adjustment of road design to address emerging conflicts, such as the recent flooding experience in Kenya.

6. Conclusions and Recommendations

While the provision of aesthetics is legally recognized as one of the elements concerning the environment in Kenya, there is no clear demonstration of criteria that planners can use to assess it. For road planning entities, existing criteria are limited to strategies involving tree planting and grassing road reserves. This approach impedes sustainability in providing aesthetics to the users of roads. Road aesthetics is a product that road consumers should receive, hence the need for clarity in its achievement. Clarifying what constitutes road aesthetics provides planners with a quantifiable way of assessing it, which, in turn, improves the health and safety of the population and increases the sustainability of planning transport infrastructure. By reviewing the terms used in measuring road aesthetics from previous empirical studies, this paper establishes that road aesthetics is the character a road has in terms of its spaces' ability to be seen and understood by the users.

The study integrated multiple techniques to synthesize and evaluate the study data. It leveraged the statistical properties of term frequencies (TF) and inverse document frequencies (IDF) and a qualitative assessment of terms to comprehensively determine the most frequently used and relevant aesthetic dimensions for evaluating road environments. Through this, the study systematically identified critical descriptors of aesthetics for future analyses of the beauty of a road environment, such as coherence, imageability, naturalness, legibility, and maintenance. Based on these findings, this study proposes recommendations that will ensure that road projects are functional, sustainable, and visually appealing, thus contributing to the overall wellbeing of communities and road users. First, planners should seek to develop further guidelines that establish consistent design themes, ensuring visual coherence across road elements such as barriers, lighting, and greening.

Second, there is a need to identify unique landmarks and incorporate them to enhance distinctive visual elements and make roads more memorable and easily recognizable. Third, road designs should ideally follow the natural contours while integrating natural landscapes and features. Additionally, native plants

should be used for landscaping to promote biodiversity and reduce maintenance costs. Fourth, road agencies should prioritize improving navigational clarity by ensuring that road layouts, signage, and markings are intuitive and easy to understand for all road users. Fifth, rigorous and regular maintenance schedules are crucial, addressing both functional and aesthetic aspects.

Moreover, relevant agencies should allocate adequate resources for cleaning, repair, upkeep, signage, and landscaping. Sixth, it is important to incorporate sustainable practices, ensuring that aesthetic improvements contribute to the reduction of carbon footprints and enhance biodiversity. Finally, comprehensive policies must be developed that prioritize aesthetics in road development. These policies should mandate the inclusion of aesthetic considerations in all stages of road planning, design, and construction. These policies can be achieved by incorporating and outlining aesthetic requirements in regulatory frameworks and funding criteria for road projects and providing training and resources for planners and road designers to integrate aesthetics into their work effectively.

However, the study notes that the meta-synthesis did not indicate the most crucial dimension or the degree of combination that results in the most aesthetic road; it identifies the most relevant in evaluating road aesthetics. As such, future inquiry into such concerns is necessary. Nevertheless, the findings provide a starting point for reviewing the aesthetic dimensions and determining the dimensions of interest for planning road aesthetics in Kenya. Moreover, a limitation of this study is the low number of articles used in the corpus generation. The study only included articles published since 2010. Future studies should consider reviewing this criterion and determining whether including articles published prior to 2010 would yield the same results.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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