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Designing Wayfinding and Signage to Promote Environmental Cleanliness in the Densely Populated Coastal Areas of North Makassar

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Abstract

This study investigates the role of wayfinding and signage systems in promoting environmental cleanliness in densely populated coastal areas of Makassar, Indonesia. A quantitative comparative design was applied across four coastal locations: Dermaga Cambaya Utara, Pantai Tanjung Bayang, Pelabuhan Paotere, and Pantai Barombong. Data were collected from 174 respondents using a structured questionnaire measuring environmental cleanliness, navigation and orientation, signage effectiveness, and design preference. Descriptive statistics, reliability testing, MANOVA, ANOVA, post hoc analysis, and geometrical design analysis were employed. The results show that environmental cleanliness received the lowest mean score, while signage effectiveness and design preference were rated highly. ANOVA results indicate significant location-based differences in environmental cleanliness, signage effectiveness, and design preference, but not in navigation and orientation. Pantai Barombong showed the lowest cleanliness score despite having the highest signage effectiveness and design preference scores. These findings reveal a gap between visual communication quality and actual pro-environmental behavior. The geometrical framework indicates that signage should move beyond visual appeal by incorporating structured color systems, action-oriented symbols, persuasive messages, and strategic placement. The study proposes signage as a behavior-oriented communication intervention for coastal environmental management.

Keywords: Wayfinding Design; Signage Systems; Environmental Cleanliness; Coastal Urban Areas

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1. Introduction

Coastal settlements in rapidly urbanizing regions across Makassar City to face significant environmental pressures, particularly in areas characterized by high population density and limited urban infrastructure (Arifin et al., 2025). These environments commonly experience problems such as water pollution, solid waste accumulation, and inadequate sanitation systems, which are further intensified by unplanned urban growth. In coastal contexts, these challenges are compounded by activities related to marine transportation, coastal industries, and dense residential occupation, leading to environmental degradation and increased vulnerability to climate-related impacts.

In Makassar, one of Indonesia’s fastest-growing coastal cities, these conditions are especially evident in densely populated shoreline communities. Rapid spatial and demographic expansion has resulted in compact settlements with limited access to basic services. Narrow pathways closely arranged housing, and insufficient waste management infrastructure contribute to environmental deterioration. These conditions not only pose risks to public health but also reduce the overall quality of life and hinder sustainable urban development (Brosset et al., 2008a).

Addressing environmental cleanliness in such contexts requires approaches that extend beyond conventional infrastructure-based solutions. While effective waste management strategies are essential, their success is closely tied to human behavior, awareness, and community participation (Brosset et al., 2008b; van Lierop et al., 2020a). Environmental cleanliness is not only a technical issue but also a behavioral and social challenge, where public perception, daily habits, and shared responsibility play critical roles. Therefore, strategies that can influence behavior and encourage environmentally responsible actions are increasingly needed.

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One promising approach lies in the integration of communication design within the built environment, particularly through wayfinding and signage systems (Hamilton et al., 2024a; Sahrir et al., 2012a; Verdonk et al., 2017). These systems serve as visual communication tools that guide movement, organize spatial understanding, and deliver targeted messages in public spaces. When designed effectively, they can function as continuous environmental cues that influence behavior, reinforce social norms, and prohhhmote awareness of cleanliness and sustainability.

Wayfinding systems, which include directional signage, spatial markers, and visual navigation cues, help users interpret and navigate complex environments. Their effectiveness depends on clarity, legibility, and the integration of local cultural elements that enhance user engagement (Kong et al., 2024; Wan et al., 2019). In densely populated settlements, where spatial complexity and limited visibility often create confusion, well-designed wayfinding systems can improve spatial orientation and contribute to a sense of order and environmental awareness.

Similarly, signage plays a crucial role in communicating specific messages related to environmental cleanliness, public behavior, and community responsibility. Beyond providing information, signage can influence attitudes and actions through persuasive visual elements such as color, typography, symbols, and language (Kim et al., 2023; Lukito & Arvanda, 2017). However, poorly designed signage may lead to misunderstanding, resistance, or reduced effectiveness, highlighting the importance of context-sensitive and user-centered design approaches.

In this context, the integration of geometrical pattern in wayfinding design presents a significant opportunity to enhance the design and effectiveness of wayfinding and signage systems. Visual appealing design can support the design process by analyzing user behavior, environmental conditions, and spatial patterns, enabling the generation of more adaptive, responsive, and context-aware visual communication solutions (Djirong & Erlangga Makawi, n.d.; Mohammed et al., 2025). Additionally, visual enaging design can facilitate the development of more effective visual strategies by optimizing layout, readability, and user engagement based on data-driven insights. This approach allows designers to move beyond conventional static design methods toward more dynamic and evidence-based solutions.

Despite the growing potential of geometrical design, its application in environmental communication within densely populated coastal settlements remains limited. Existing studies have primarily focused on infrastructure or policy-based approaches, with less attention given to the integration of intelligent design systems that address both spatial navigation and environmental behavior (Choi & Zhang, 2024; Luck & Aylett, 2000; Shafik, 2025). This gap highlights the need for research that combines wayfinding design, signage systems, and geometrical design methodologies to promote environmental cleanliness in complex urban contexts.

The present study addresses this gap by designing and evaluating wayfinding and signage systems aimed at promoting environmental cleanliness in densely populated coastal areas of Makassar, Indonesia. The research focuses on four coastal sites—Dermaga Cambaya Utara, Pantai Tanjung Bayang, Pelabuhan Paotere, and Pantai Barombong. This is to examine community perceptions of environmental conditions, spatial navigation, and visual communication effectiveness. Furthermore, this study explores how visual appealing design can be integrated into the design process to enhance the functionality, clarity, and impact of wayfinding and signage systems.

2. Literature Review

Wayfinding is crucial for improving the quality of life in coastal communities, especially in densely populated areas. Many studies have taken place in design process, visual design, design for urban communities, and design for road visibilities (Bin Zolkefil & Talib, 2022; Dubey et al., 2021; Sivaji et al., 2020; Tjan et al., 2005; van Lierop et al., 2020b). However, these studies have never explored the potential of wayfinding for coastal communities to improve their life in terms of cleanlines and persuasing them to engage in a more ethical personalities to change their perseption of coastal areas. It is highly important that this studied to be carried out to improve the quality of life for people who lived in coastal areas.

Moreover, the design of signage often to be design for specific purposes only such as for cycling, directions, and providing information (Ding et al., 2010; Liu et al., 2023). Signage is a powerful tool for building awareness for people to change their behaviour (Hamilton et al., 2024b; Wu et al., 2018). Therefore, designing wayfinding and signage to promote environmental cleanliness is not a new approach for designing. In fact this is relatively common for designers to persuade behavioural change within the viewers. One of the most crucial part of designing is to change the perception of the viewers.

After that, having all these studies it is found that there is no studies related to behavioural change in coastal communities to engage the visitors and local people to be more aware of cleanliness in their coastal communities. Thus, this study aims to provide a new approach to change the behaviour of coastal communities and visitors and tourists to be more aware of the importance of clanliness in coastal communities.

Futhermore, the design of wayfinding and signage will utilise the geometrical framework. Geometrical design is an important approach to provide a better understanding of visual information (Boi, 2021; Gelabert, 2020). Studies on geometry is rellevant for coastal communities in Makassar. Makassar city as a region that embedded into a culture will have a significant influence on cultural approach. For example, previous studies have analyzed that societies withing the cultural context will easily understand the language and cultural background based information (Nugraha, 2019; Sudirman et al., 2020)

3. Methods

3.1. Research Design

This study employed a quantitative comparative research design integrated with a geometrical design analysis to investigate how wayfinding and signage systems contribute to environmental cleanliness in densely populated coastal areas. The research was organized into two interconnected phases. The first phase involved empirical data collection through a structured questionnaire and statistical analysis to examine community perceptions of environmental cleanliness, navigation and orientation, signage effectiveness, and design preference. The second phase involved a systematic visual analysis of existing signage using a geometrical framework to identify visual patterns, evaluate design weaknesses, and develop context-sensitive signage improvement recommendations.

A cross-sectional survey approach was used to capture respondents' perceptions across multiple locations at a single point in time. This design was considered appropriate because the study aimed to compare perceptual differences among coastal areas with different spatial, social, and environmental characteristics. The comparative design also enabled the identification of variables that may explain the gap between the perceived effectiveness of signage and the actual condition of environmental cleanliness.

3.2. Research Sites

The study was conducted in four coastal areas in Makassar, Indonesia: Dermaga Cambaya Utara, Pantai Tanjung Bayang, Pelabuhan Paotere, and Pantai Barombong. These locations were selected because they represent densely populated coastal environments characterized by complex spatial configurations, intensive human activity, and varying environmental conditions. Makassar is a rapidly developing coastal city where urban expansion has contributed to compact settlements along the shoreline. In these areas, environmental cleanliness is affected not only by infrastructure limitations, such as waste management and sanitation facilities, but also by public behavior, spatial organization, and the effectiveness of environmental communication.

Each selected site represents different spatial and functional characteristics. Pelabuhan Paotere and Dermaga Cambaya Utara are associated with port-related mobility, trade, and economic activity, while Pantai Tanjung Bayang and Pantai Barombong are influenced by recreational and tourism-related activities. These differences create variations in user movement, environmental pressure, waste behavior, and visual communication needs. In addition, narrow pathways, irregular spatial layouts, high-density activity, and limited visibility in coastal settlements create challenges for navigation and for the placement of effective signage. These characteristics make the study locations relevant for examining how signage and wayfinding systems can support environmental awareness and behavioral guidance.

3.3. Respondents and Sampling Technique

Data were collected through a structured questionnaire involving 174 respondents distributed across the four selected locations. A purposive sampling technique was used to ensure that respondents had direct experience with the study areas, either as residents, workers, traders, visitors, or frequent users of the site. This sampling strategy was considered appropriate because the study required contextually informed responses from individuals who interacted directly with the spatial and environmental conditions of each location.

The respondents represented diverse demographic backgrounds, including differences in age, gender, occupation, and frequency of site use. These characteristics were considered important because environmental perception, spatial familiarity, and responsiveness to signage may vary across different user groups. Frequent users may develop stronger spatial familiarity, while occasional visitors may rely more heavily on signage, visual cues, and directional information.

3.4. Research Variables and Instrument

The questionnaire measured four key variables that represent both environmental and visual communication dimensions:

a) *Environmental Cleanliness (X1):* perceptions of waste presence, hygiene conditions, environmental order, and cleanliness management.

b) *Navigation and Orientation (X2):* ease of movement, clarity of spatial layout, directional understanding, and spatial orientation.

c) *Signage Effectiveness (X3):* visibility, readability, clarity of message, placement, and communicative impact of signage.

d) *Design Preference (X4):* user responses to visual elements, including color, typography, symbols, layout, contrast, and visual attractiveness.

Each variable consisted of several indicators measured using a five-point Likert scale, ranging from strongly disagree to strongly agree. The use of a Likert scale enabled the quantification of subjective perceptions related to environmental conditions, navigation experience, signage performance, and visual preference. The instrument was designed to capture both functional dimensions, such as navigation clarity and signage visibility, and behavioral-perceptual dimensions, such as environmental awareness, attention, and willingness to respond to visual messages.

3.5. Instrument Validity and Reliability

To strengthen the credibility of the research instrument, validity and reliability testing were conducted before the main analysis. Content validity was first assessed through conceptual alignment between each questionnaire item and the theoretical constructs of environmental cleanliness, wayfinding, visual communication, and behavior-oriented signage. This process ensured that each item represented the intended construct and was relevant to the coastal environmental context.

In addition, item-total correlation was used as an empirical screening procedure to examine whether each item contributed consistently to its respective variable. Items with weak item-total correlation or conceptual ambiguity were reviewed and considered for revision or removal. This approach was used as a preliminary item validation procedure rather than as the sole basis for determining construct validity.

Reliability testing was conducted using Cronbach's Alpha to assess the internal consistency of each variable. A Cronbach's Alpha value of $\alpha \geq 0.60$ was considered acceptable for exploratory research, while $\alpha \geq 0.70$ indicated good internal consistency. Reliability testing was important because the variables in this study were perceptual in nature and required consistency across multiple indicators. A reliable scale indicates that the items within each variable measured the same underlying construct in a stable and coherent manner.

3.6. Data Analysis Procedure

The quantitative data were analyzed through several statistical procedures. First, descriptive statistics were used to summarize the distribution of respondent perceptions across the four variables. Mean, standard deviation, minimum, and maximum values were calculated to identify general trends and differences in perception. This stage provided an overview of whether environmental cleanliness, navigation, signage effectiveness, and design preference were perceived positively or negatively across the study locations.

3.6.1. Descriptive Statistics

Descriptive analysis was used to summarize the overall distribution of respondent perceptions across all variables. The analysis included mean, standard deviation, minimum, and maximum values. These descriptive results provided an initial overview of dominant patterns and potential disparities between variables and locations. This stage was important for identifying whether environmental cleanliness, navigation and orientation, signage effectiveness, and design preference were perceived differently across the four coastal areas.

3.6.2. Assumption Testing

Before applying multivariate analysis, several assumption tests were conducted. Multivariate normality was examined using Mahalanobis distance to identify potential multivariate outliers. The distribution of Mahalanobis distance values was compared with the chi-square threshold based on the number of dependent variables. Homogeneity of covariance matrices was assessed using Box's M test, while homogeneity of variance for each dependent variable was evaluated using Levene's test.

Because survey data based on Likert-scale responses may not always fully satisfy parametric assumptions, the robustness of the analysis was interpreted carefully. The study did not rely solely on the assumption that MANOVA is robust because of sample size. Instead, the results of assumption tests were examined in relation to group size, variance patterns, outlier structure, and consistency of statistical findings. When assumptions were partially violated, Pillai's Trace was prioritized as the multivariate test statistic because it is generally considered more robust under moderate violations of assumptions. In addition, the interpretation of MANOVA results was supported by descriptive statistics, effect size values, and univariate follow-up tests to avoid overdependence on significance values alone.

3.6.3. Multivariate Analysis of Variance

Multivariate Analysis of Variance, or MANOVA, was used to examine whether there were statistically significant differences among the four study locations across the combined dependent variables: environmental cleanliness, navigation and orientation, signage effectiveness, and design preference. MANOVA was appropriate because the study examined several interrelated perceptual variables simultaneously. This method provided a broader understanding of whether location-based differences existed in the combined perception of environmental and signage-related conditions.

3.6.4. Univariate ANOVA

When significant multivariate differences were identified, univariate ANOVA tests were conducted to determine which specific variables contributed to the differences among locations. This analysis helped identify whether differences were mainly related to environmental cleanliness, navigation, signage effectiveness, or design preference. Effect sizes were also considered to evaluate the practical magnitude of the differences, not only their statistical significance. This step was important for determining which aspects of the signage and wayfinding system required design intervention.

3.6.5. Post Hoc Analysis

Post hoc analysis was conducted to identify specific differences between locations. The Bonferroni test was used when the assumption of homogeneity of variance was met, while the Games–Howell test was used when the assumption of equal variance was not met. This procedure allowed for more accurate comparison between locations and supported the development of site-specific design recommendations.

3.7. Geometrical Framework for Signage Analysis

In addition to the quantitative analysis, this study applied a geometrical framework to analyze existing signage designs in the selected coastal areas. The geometrical framework was used not merely as a descriptive design principle, but as a structured visual analysis procedure. The analysis focused on five visual-geometrical dimensions: shape structure, directional alignment, visual hierarchy, spatial placement, and symbolic clarity. These dimensions were selected because they directly influence how users notice, read, interpret, and respond to signage in complex coastal environments.

The geometrical analysis was conducted through the following steps. First, existing signage in each location was documented through field observation and visual recording. Second, each signage object was categorized based on its function, such as directional signage, warning signage, cleanliness reminder signage, prohibition signage, or informational signage. Third, the visual structure of each signage was analyzed by identifying dominant geometric forms, line orientation, compositional balance, figure-ground contrast, text-image relationship, and the position of symbols within the layout. Fourth, the placement of signage was evaluated in relation to user movement patterns, visibility range, decision points, and environmental obstacles. Fifth, the identified visual patterns were compared with the quantitative findings to determine whether the design weaknesses corresponded to user perceptions of cleanliness, navigation, signage effectiveness, and design preference.

3.8. Integration of Quantitative Findings and Geometrical Analysis

The purpose of the geometrical framework was to produce design recommendations that were traceable and reproducible. For example, if a location showed low environmental cleanliness but high signage preference, the analysis examined whether the signage was visually attractive but lacked action-oriented symbols, persuasive messages, or strategic placement near waste-disposal points. If a location showed low navigation clarity, the analysis examined whether the signage lacked directional arrows, consistent color coding, spatial sequencing, or clear visual hierarchy.

In this way, the design recommendations were derived from both empirical perception data and systematic visual analysis. The quantitative findings identified the perceptual and behavioral gaps, while the geometrical analysis explained how visual design elements could be improved to address those gaps.

3.9. Behavior-Oriented Signage Framework

The proposed signage improvement framework was developed as a behavior-oriented communication system. This means that signage was not treated only as an informational tool, but also as a visual intervention intended to influence public behavior. Each design recommendation was linked to a specific behavioral mechanism.

A structured color system was proposed to increase attention and recognition. Action-oriented symbols were proposed to reduce ambiguity and guide immediate behavior. Persuasive messages were proposed to strengthen environmental responsibility. Improved placement was proposed to increase visibility at points where users make decisions or perform waste-related actions. Through this approach, the framework aimed to address the behavioral gap identified in the quantitative findings, particularly the condition in which signage was perceived as effective and visually appealing but had not yet translated into improved cleanliness behavior.

3.10. Future Pilot Testing and Evaluation

This study acknowledges that the proposed design framework requires further empirical testing. Therefore, future research should include pilot testing of redesigned signage in selected coastal locations to evaluate its real-world impact on environmental cleanliness. Such evaluation may include pre-test and post-test observation, behavioral mapping, waste accumulation measurement, user interviews, and comparison between locations with and without redesigned signage intervention.

This future testing would make it possible to assess whether the proposed signage framework can influence actual behavior beyond perception. The findings of this study are context-specific to Makassar, but the framework may inform signage and environmental communication strategies in other rapidly urbanizing coastal regions facing similar problems of spatial complexity, waste behavior, and limited public environmental infrastructure.

Struktur heading ini sudah lebih kuat karena memisahkan dengan jelas antara metode kuantitatif, uji instrumen, uji asumsi statistik, geometrical framework, dan hubungan signage dengan perilaku.

4. Result and Discussion

4.1. Descriptive Statistics and Reliability

The descriptive statistics show that the respondents perceived environmental cleanliness at a relatively low level compared with the other dimensions. The mean score for environmental cleanliness was 2.75, indicating that cleanliness conditions in the selected coastal areas were not perceived as optimal. In contrast, navigation and orientation obtained a moderate-to-high mean score of 3.82, while signage effectiveness and design preference received high mean scores of 4.25 and 4.48, respectively.

These results suggest an important gap between visual communication performance and actual environmental conditions. Although signage was generally perceived as clear, visible, and visually appealing, this perception did not necessarily correspond to better environmental cleanliness.

Table 1. Descriptive Statistics and Reliability of Research Variables

Dimension	N	Minimum	Maximum	Mean	SD	Cronbach's Alpha	Interpretation
Environmental Cleanliness	174	1.33	4.83	2.75	0.72	0.703	Acceptable
Navigation and Orientation	174	1.40	5.00	3.82	0.65	0.621	Acceptable for exploratory research
Signage Effectiveness	174	1.50	5.00	4.25	0.68	0.867	Strong
Design Preference	174	1.17	5.00	4.48	0.56	0.838	Strong

The reliability results indicate that all variables met the minimum threshold for internal consistency. Environmental cleanliness showed acceptable reliability, while signage effectiveness and design preference demonstrated strong reliability. Navigation and orientation produced a lower Cronbach's Alpha value, but it remained acceptable for exploratory research. This suggests that the questionnaire items were sufficiently consistent in measuring the intended constructs.

4.2. Descriptive Results by Location

The mean scores across the four coastal locations show clear differences in environmental cleanliness, signage effectiveness, and design preference. Pantai Barombong recorded the lowest mean score for environmental cleanliness, while Pelabuhan Paotere recorded the highest cleanliness score. However, Pantai Barombong showed the highest mean score for signage effectiveness and design preference. This finding indicates that a location may have visually effective signage but still face poor cleanliness conditions.

Table 2. Mean Scores of Research Variables by Location

Dimension	Dermaga Cambaya Utara	Pantai Tanjung Bayang	Pelabuhan Paotere	Pantai Barombong	Highest Score	Lowest Score
Environmental Cleanliness	2.89	2.94	3.16	2.02	Pelabuhan Paotere	Pantai Barombong
Navigation and Orientation	3.89	3.76	3.68	3.92	Pantai Barombong	Pelabuhan Paotere
Signage Effectiveness	4.17	4.08	4.08	4.65	Pantai Barombong	Pelabuhan Paotere
Design Preference	4.65	4.38	4.18	4.66	Pantai Barombong	Pelabuhan Paotere

The results indicate that the main problem in the study areas is not the absence of visual appeal or signage visibility, but the limited behavioral impact of signage on environmental cleanliness. Pantai Barombong is the most important example of this gap because it received the highest scores in signage effectiveness and design preference but the lowest score in environmental cleanliness. This suggests that signage may be visually attractive and recognizable, yet it may not be sufficiently designed to trigger pro-environmental behavior.

4.3. Descriptive Statistics by Location

To provide a more detailed understanding of the distribution of scores across locations, the Table 3 presents the mean and standard deviation of each variable by location.

The descriptive findings show that signage-related dimensions consistently received higher scores than environmental cleanliness. This pattern indicates that the signage systems in the selected coastal areas may already be visible and visually acceptable, but they have not yet functioned effectively as behavioral interventions. Therefore, the improvement of signage should focus not only on aesthetics and readability, but also on behavioral guidance, persuasive messaging, and strategic placement.

Table 3. Mean and Standard Deviation by Location

Dimension	Location	N	Mean	SD	Interpretation
Environmental Cleanliness	Dermaga Cambaya Utara	49	2.89	0.55	Moderate-low
Environmental Cleanliness	Pantai Tanjung Bayang	45	2.94	0.68	Moderate-low
Environmental Cleanliness	Pelabuhan Paotere	37	3.16	0.49	Moderate
Environmental Cleanliness	Pantai Barombong	43	2.02	0.59	Low
Navigation and Orientation	Dermaga Cambaya Utara	49	3.89	0.57	High
Navigation and Orientation	Pantai Tanjung Bayang	45	3.76	0.58	High
Navigation and Orientation	Pelabuhan Paotere	37	3.68	0.73	Moderate-high
Navigation and Orientation	Pantai Barombong	43	3.92	0.74	High
Signage Effectiveness	Dermaga Cambaya Utara	49	4.17	0.75	High
Signage Effectiveness	Pantai Tanjung Bayang	45	4.08	0.71	High

Dimension	Location	N	Mean	SD	Interpretation
Signage Effectiveness	Pelabuhan Paotere	37	4.08	0.46	High
Signage Effectiveness	Pantai Barombong	43	4.65	0.58	Very high
Design Preference	Dermaga Cambaya Utara	49	4.65	0.26	Very high
Design Preference	Pantai Tanjung Bayang	45	4.38	0.53	High
Design Preference	Pelabuhan Paotere	37	4.18	0.71	High
Design Preference	Pantai Barombong	43	4.66	0.60	Very high

4.4. MANOVA Results

Before conducting MANOVA, assumption testing was performed to evaluate whether the data were suitable for multivariate analysis. Multivariate normality was examined using Mahalanobis distance. The correlation between Mahalanobis distance and chi-square quantiles showed a strong positive relationship, indicating that most data points followed the expected multivariate pattern. However, several observations appeared in the upper tail of the distribution, suggesting the presence of moderate deviations from multivariate normality.

Table 4. Summary of Multivariate Assumption Testing

Assumption	Test/Indicator	Result	Interpretation
Multivariate normality	Mahalanobis distance and chi-square quantile relationship	$r = 0.858$, $p < 0.001$	Strong linear pattern, with some upper-tail deviations
Multivariate outliers	Mahalanobis distance plot	Several extreme values detected	Data were not perfectly normal
Analytical robustness	Use of MANOVA with Pillai's Trace emphasis	Applied cautiously	Appropriate when interpreted with supporting ANOVA and descriptive results
Interpretation strategy	Descriptive statistics, ANOVA, effect size, and post hoc analysis	Used together	Reduces overreliance on p-values alone

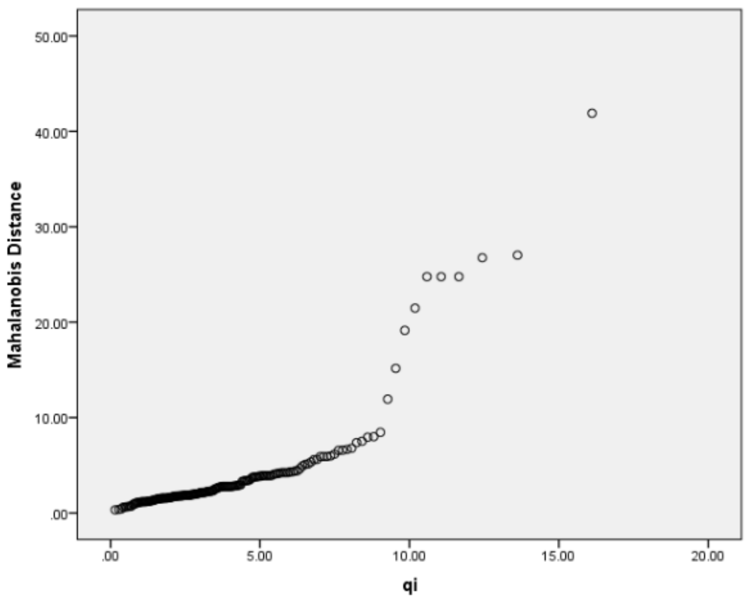

Figure 1. Manova Results Multivariat

The assumption testing indicates that the data were not perfectly normally distributed. Therefore, the MANOVA results should be interpreted cautiously. Instead of relying only on the assumption that MANOVA is robust due to sample size, the interpretation was supported by descriptive patterns, univariate ANOVA results, post hoc comparisons, and effect size values. This approach strengthens the validity of the analysis and addresses the possibility of moderate deviations from multivariate normality.

4.5. ANOVA Results

The ANOVA results show that location had a statistically significant effect on three variables: environmental cleanliness, signage effectiveness, and design preference. However, location did not have a significant effect on navigation and orientation.

Table 5. ANOVA Results by Variable

Dependent Variable	df Between	df Within	F	Sig.	Partial Eta Squared	Interpretation
Environmental Cleanliness	3	170	30.695	< 0.001	0.351	Significant; large location effect
Navigation and Orientation	3	170	1.172	0.322	0.020	Not significant
Signage Effectiveness	3	170	7.594	< 0.001	0.118	Significant; moderate location effect
Design Preference	3	170	7.509	< 0.001	0.117	Significant; moderate location effect

The strongest location effect was found in environmental cleanliness, with a partial eta squared value of 0.351. This indicates that differences in cleanliness perception were strongly associated with location. Signage effectiveness and design preference also showed significant location-based differences, although with moderate effect sizes. Navigation and orientation did not differ significantly across locations, suggesting that users perceived basic spatial navigation conditions relatively similarly across the four coastal areas.

These findings confirm that the main issue is not navigation, but the relationship between signage, visual communication, and environmental behavior. The results suggest that environmental cleanliness varies substantially between locations, while signage effectiveness and design preference also differ depending on local visual and spatial conditions.

4.6. Post Hoc Analysis

Post hoc analysis was conducted to identify which locations differed significantly from one another. The results indicate that significant differences were mainly found in environmental cleanliness, signage effectiveness, and design preference.

Table 6. Summary of Significant Post Hoc Differences

Variable	Significant Location Differences	Direction of Difference	Interpretation
Environmental Cleanliness	Pantai Barombong vs Dermaga Cambaya Utara	Barombong lower	Barombong had significantly poorer cleanliness perception
Environmental Cleanliness	Pantai Barombong vs Pantai Tanjung Bayang	Barombong lower	Barombong had significantly poorer cleanliness perception
Environmental Cleanliness	Pantai Barombong vs Pelabuhan Paotere	Barombong lower	Barombong had the lowest cleanliness condition
Navigation and Orientation	No significant differences	—	Navigation perception was relatively similar across locations
Signage Effectiveness	Pantai Barombong vs other locations	Barombong higher	Barombong signage was perceived as more effective
Design Preference	Pelabuhan Paotere vs Dermaga Cambaya Utara	Paotere lower	Paotere had lower visual design preference
Design Preference	Pelabuhan Paotere vs Pantai Barombong	Paotere lower	Paotere had lower visual design preference

The post hoc results strengthen the descriptive findings. Pantai Barombong had significantly lower environmental cleanliness than the other locations, but it also had higher signage effectiveness and design preference. This contrast is important because it indicates that attractive or visible signage does not automatically lead to cleaner environmental behavior. In other words, signage may succeed visually but fail behaviorally.

For design preference, Pelabuhan Paotere received lower scores than Dermaga Cambaya Utara and Pantai Barombong. This indicates that the visual quality of signage in Pelabuhan Paotere requires greater attention, especially in terms of color, typography, layout, and symbolic clarity.

4.7. Geometrical Pattern Analysis for Signage Improvement

The geometrical framework was used to analyze the visual structure of existing signage and to identify design weaknesses that may limit behavioral impact. The analysis focused on color composition, iconography, message clarity, spatial placement, contextual adaptation, and behavioral impact.

Table 7. Design Evaluation and Improvement Recommendations Based on Geometrical Framework

Design Aspect	Identified Issue	Design Improvement	Behavioral Mechanism	Expected Outcome
Color Composition	No clear color hierarchy	Apply a structured color system for visibility and priority	Increases attention and visual recognition	Users can quickly identify important environmental messages
Iconography and Geometry	Icons are decorative but not instructive	Simplify forms and add action-oriented symbols	Reduces ambiguity and supports immediate action	Users understand what action is expected
Message and Typography	Text is unclear or not persuasive	Add concise text with strong visual hierarchy	Improves message comprehension and recall	Users can read and remember the instruction more easily
Spatial Placement	Signage has no clear placement strategy	Place signage at entry points, intersections, and waste-disposal areas	Reaches users at decision-making points	Signage becomes more relevant to actual behavior
Contextual Adaptation	Decorative elements are excessive	Simplify while maintaining coastal and local identity	Balances cultural identity and functional clarity	Signage remains attractive but easier to understand
Behavioral Impact	Lack of persuasive and behavioral cues	Add persuasive messages, emotional appeals, and behavioral prompts	Encourages responsibility and pro-environmental action	Signage functions as a behavioral intervention, not only information

The geometrical analysis shows that the current signage designs have strong visual potential but require refinement to function effectively as behavior-oriented communication systems. The main limitation is not visual attractiveness, but the absence of clear behavioral cues. Many signage elements are decorative and visually appealing, yet they do not sufficiently guide users toward specific actions, such as disposing of waste properly, maintaining cleanliness, or following environmental rules.

4.8. Integration of Quantitative Results and Design Findings

The integration of statistical findings and geometrical analysis reveals a critical gap between visual perception and environmental behavior. The quantitative results showed that signage effectiveness and design preference were rated highly, while environmental cleanliness remained relatively low. This means that signage may be visually successful but behaviorally insufficient.

Pantai Barombong provides the clearest example. It had the highest mean scores for signage effectiveness and design preference, but the lowest score for environmental cleanliness. This indicates that signage in this location may attract attention and be considered visually appealing, but it does not yet produce the intended behavioral response. Therefore, the design framework needs to move beyond aesthetics and readability toward behavioral intervention.

The geometrical framework helps explain this gap. The analysis indicates that signage should not only be designed to be seen, but also to direct action. Color systems should establish priority and urgency. Icons should represent specific actions. Typography should support fast comprehension. Placement should correspond to user movement and waste-disposal behavior. Persuasive messages should be used to strengthen emotional and social responsibility.

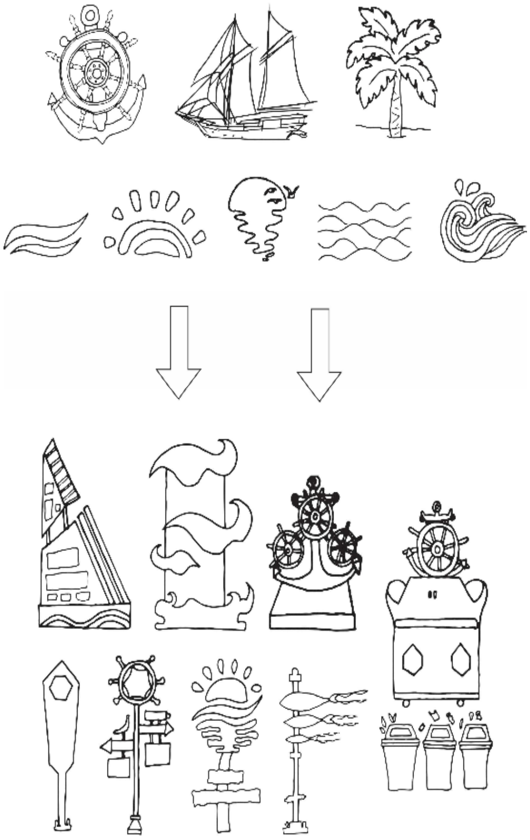

Figure 2. Design Sketch Based on Geometrical Framework

4.9. Discussion

The findings demonstrate that signage and wayfinding systems have potential to support environmental cleanliness in coastal areas, but their effectiveness depends on their ability to influence behavior. The high scores for signage effectiveness and design preference show that respondents generally recognized the presence and visual quality of signage. However, the low score for environmental cleanliness indicates that visual communication alone is not sufficient to change environmental behavior.

This study contributes to the understanding of signage as a behavior-oriented communication system (Sahrir et al., 2012a; Wu et al., 2018). In coastal settlements, signage should not be treated merely as an informational object. It should function as a visual intervention that connects spatial guidance, environmental awareness, and behavioral instruction. This is particularly important in densely populated coastal areas, where waste problems are influenced by daily routines, spatial constraints, public habits, and limited environmental facilities.

The significant differences in environmental cleanliness across locations suggest that local context matters. Pantai Barombong requires stronger behavioral signage because cleanliness perception was lowest despite high signage preference. Pelabuhan Paotere requires improvement in visual design quality because its design preference score was relatively lower. Dermaga Cambaya Utara and Pantai Tanjung Bayang require balanced improvements that combine visual clarity, environmental instruction, and strategic placement (Ari & Nuriarta, 2024; Tjan et al., 2005).

The non-significant result for navigation and orientation indicates that spatial navigation may not be the main problem across the four locations. Users may already be able to move through the areas without major difficulty. However, this does not mean that signage is fully effective. Rather, the findings suggest that the main weakness lies in the limited ability of signage to transform awareness into action (Hamilton et al., 2024a; Li et al., 2023a; Sahrir et al., 2012b).

Figure 3. Design Results

4.10. Implications for Signage Design and Policy

The findings have several implications for environmental communication and coastal management. First, signage design should be developed as part of a broader public environmental strategy, not as a standalone visual object (Dubey et al., 2021; Li et al., 2023b). Second, government and community stakeholders should consider signage as a behavioral intervention tool that can support waste management, cleanliness campaigns, and public engagement (Bin Zolkefil & Talib, 2022; Zhou et al., 2024). Third, signage should be evaluated not only based on visual appeal, but also based on measurable behavioral outcomes (Martin et al., 2015).

Future signage interventions should be pilot-tested in selected coastal areas. The effectiveness of redesigned signage can be evaluated through pre-test and post-test observation, waste accumulation measurement, behavioral mapping, and user interviews. This would allow researchers and policymakers to determine whether improved signage can reduce littering behavior and increase public compliance with cleanliness practices.

Although this study was conducted in Makassar, the proposed framework may be relevant to other rapidly urbanizing coastal regions facing similar challenges. Coastal settlements with dense populations, irregular spatial layouts, tourism activity, port activity, and limited sanitation infrastructure may benefit from signage systems that combine visual clarity, local identity, persuasive communication, and behavioral guidance.

5. Conclusion

This study concludes that signage and wayfinding systems in coastal areas have strong potential to support environmental cleanliness, but their effectiveness depends on their ability to influence behavior. The findings show that respondents generally perceived signage as effective and visually appealing, yet environmental cleanliness remained relatively low. This indicates that attractive signage alone is insufficient to encourage pro-environmental action. Location had a significant effect on environmental cleanliness, signage effectiveness, and design preference, while navigation and orientation showed no significant difference across sites. Pantai Barombong presented the clearest behavioral gap, with the highest signage scores but the lowest cleanliness perception. Therefore, signage improvement should focus on behavioral intervention rather than visual enhancement alone. The proposed geometrical framework provides a systematic basis for improving signage through color hierarchy, simplified icons, persuasive messages, clearer typography, and strategic placement. Future studies should conduct pilot testing to measure the actual impact of redesigned signage on cleanliness behavior in coastal communities.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study. Written informed consent has also been obtained from the participants for the publication of anonymized responses and illustrative materials.

Data Availability Statement: The data supporting the findings of this study including anonymized survey responses, observation checklists, and interview transcripts-will be made publicly available in the Institutional Repository of Universitas Negeri Makassar prior to publication. Due to ethical restrictions, personal identifiers and audio recordings are not shared.

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