Design Indicators for Green Book Covers: An Integrated Quality Function Deployment and Grey Relational Analysis Evaluation

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Abstract. With increasing emphasis on sustainability and low-carbon development, consumer values have shifted toward ecological responsibility. Books serve not only as knowledge carriers but also as effective media for promoting sustainable awareness. The book cover, as an interface between readers and environmental messages, must balance aesthetic appeal with symbolic meaning. However, systematic evaluation methods for green book cover design indicators remain limited. This study integrates Quality Function Deployment (QFD) and Grey Relational Analysis (GRA) to investigate and prioritize design criteria for green-themed book covers. QFD systematically links consumer requirements with technical attributes, while GRA ranks these indicators under conditions of limited and uncertain data. Empirical findings reveal that material selection and copywriting that minimize resource waste are the most influential factors in conveying sustainable concepts. The study contributes theoretically by providing a structured evaluation framework and practically by offering actionable guidelines for designers and publishers. The integrated QFD–GRA approach ensures that sustainable design criteria are objectively weighted and effectively implemented, supporting the broader goal of promoting sustainability in publishing.

Keywords: Design for Sustainable Behavior, Low-carbon publishing, QFD–GRA.

1 Introduction

The design of a product can significantly influence users' willingness to engage in sustainable behaviors [6]. Environmental quality largely depends on human behavioral patterns. Effective sustainable design should enable users to clearly perceive its ecological intent while prompting them to reflect on the environmental consequences of their own actions. Designers may strategically employ various techniques to create persuasive arguments that implicitly reshape unsustainable behaviors, thereby enabling products to serve as triggers for sustainable practices.

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Green books may represent one such product capable of guiding or stimulating sustainable behaviors. For example, Cradle to Cradle was designed under the principles of not cutting down a single tree and avoiding any waste of natural resources [8], principles that were consistently embedded in both product and packaging design. Nevertheless, books that focus on sustainability face a critical challenge: attracting readers' visual attention while simultaneously stimulating purchase intention. Without effective design, even books that convey crucial messages on sustainable development may fail to fulfill their purpose of transforming unsustainable behaviors.

Book covers play a central role in communicating with readers, functioning simultaneously as marketing tools and as carriers of ideological meaning [3]. While the textual content of a book may invite multiple interpretations, cover design often emphasizes genre conventions rather than the core message, potentially leading to incomplete communication or misinterpretation. Visual and textual elements, including cover design and introductory text, strongly shape how target readers perceive and engage with the content [1]. With the rapid growth of book publishing, publishers must adopt strategies to capture readers' attention. Hence, understanding the factors that influence purchasing decisions—including preferences for physical attributes such as size, cover design, title, color, and imagery, along with other relevant variables—is essential [7].

To enhance the market effectiveness of green book products, packaging and cover design must convey sustainability values while stimulating purchase intention. This study develops and evaluates design criteria for green book covers by integrating Quality Function Deployment (QFD) with Grey Relational Analysis (GRA). QFD systematically translates consumer needs into technical attributes [5, 11], while GRA prioritizes these attributes under conditions of limited or uncertain data [2, 9, 10]. This integrated framework provides a structured approach for evaluating green book cover design, ensuring an effective balance between ecological responsibility and market demand.

2 Methods

2.1 Quality Function Deployment

Quality Function Deployment (QFD), first proposed by Yoji Akao in 1966, is a structured methodology that systematically translates customer requirements into technical attributes. By reducing design errors, shortening development time, and lowering costs, QFD ensures that customer expectations are accurately reflected in product specifications. Its primary tool, the House of Quality, links consumer requirements ("what") to technical attributes ("how") through a correlation matrix, thereby prioritizing design decisions to meet key customer needs throughout the product development process.

2.2 Grey Relational Analysis

The method quantifies the degree of association between data sequences, allowing the identification of key factors and their relative importance within complex systems. It is based on Grey System Theory and is particularly suitable for analyzing systems with

incomplete or uncertain information. The GRA process involves data normalization, calculation of grey relational coefficients, and determination of grey relational grades to rank technical attributes objectively under limited or uncertain conditions. By integrating GRA with QFD, re-searchers can prioritize design criteria even when empirical data are scarce or uncertain, providing a robust decision-making framework for product development and evaluation.

3 Research Framework and Case Study

The research framework was designed to systematically translate sustainability principles into actionable green book cover design criteria (Figure 1). The study began with a comprehensive review of literature on green packaging design, supplemented by field observations of existing products, practitioners, and consumers to identify potential design criteria. Insights were then consolidated through focus group discussions, where participants evaluated the relevance of each criterion and assigned preliminary weights.

Subsequently, the QFD "House of Quality" was employed to translate these weighted requirements into corresponding technical attributes. A relationship matrix was constructed to quantify the correlations between consumer-driven requirements and technical attributes, ensuring that design priorities were systematically mapped.

Recognizing the limitations of independent scoring methods—particularly under conditions of limited or uncertain data—GRA was applied to objectively rank technical attributes. This integration of QFD and GRA not only enhances the reliability of priority-setting but also guides designers in selecting optimal solutions. Finally, empirical cover designs reflecting the prioritized criteria were developed to provide concrete references for sustainable book cover implementation.

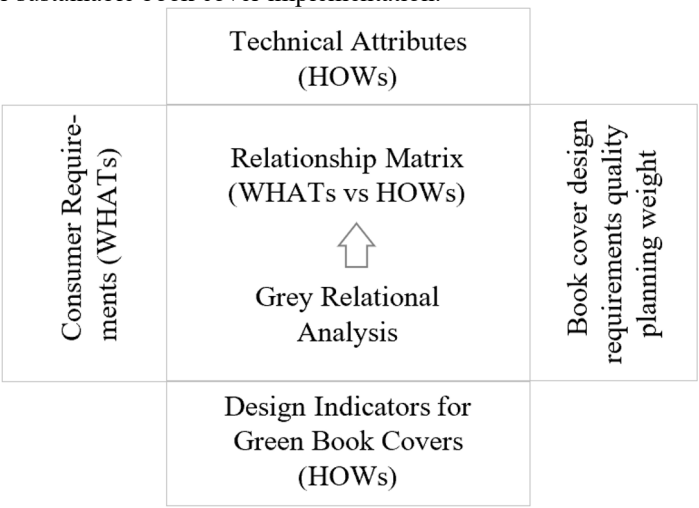

Fig. 1. Research Framework.

A practical case study was conducted to illustrate the applicability of the proposed framework.

Step 1: Identification of Consumer Requirements and Mapping to Technical Attributes. A focus group of three domain experts was convened to identify six consumer requirements for green book covers: (1) convey sustainability appeal, (2) demonstrate creativity, (3) appropriate color scheme, (4) well-organized text-image layout, (5) stimulate purchase intention, (6) display certified eco-label. These requirements were then mapped to nine corresponding technical attributes (Table 1). During this process, the technical attribute corresponding to requirement (3) could not be definitively determined. To address this, five additional respondents were randomly interviewed and presented with nine examples of sustainable book covers. The results consistently indicated that green was perceived as the most suitable color to represent sustainability.

Table 1. Matrix of Consumer Requirements and Technical Attributes for Green Cover Design.

	Consumer Requirements (WHATs)					
Technical Attributes (HOWs)	(1)	(2)	(3)	(4)	(5)	(6)
1. “No Tree Was Harmed” messaging	◎	◎			◎	
2. Waste-free design messaging	◎	○			△	
3.Cradle-to-Cradle messaging	◎	△				
4. Circular ecology imagery	○			◎	△	
5. Life experience imagery				◎	○	
6. Survival meaning imagery	△			◎	○	
7. Color	○		◎		○	
8. Typography: size and shape				◎	△	
9. Eco-labels	○				△	◎

Note. Symbols indicate the strength of correlation between consumer requirements and technical attributes: strong (◎ = 5), medium (○ = 3), and weak (△ = 1). Consumer requirements: (1) convey sustainability appeal, (2) demonstrate creativity, (3) appropriate color scheme, (4) well-organized text-image layout, (5) stimulate purchase intention, (6) display certified eco-label.

Step 2: Integration of QFD and GRA for Deriving Design Indicators. The focus group assessed the strength of association between the six consumer requirements and nine technical attributes using a three-level scale. The reference sequence (consumer requirements) and comparative sequences (technical attributes) were then established, and grey relational generation was performed using the improved method proposed by Hsia and Wu [4], based on the “larger-the-better” formulation; Finally, grey relational coefficients and grades were calculated (Table 2), and the attributes were ranked according to their grades to establish the priority of design indicators. Designers can refer to the grey relational grade or the grey relational ordinal ranking to guide the development of optimal green book cover designs (Table 3).

Table 2. Computation of Grey Relational Grade.

	Consumer Requirements (WHATs)					
Technical Attributes (HOWs)	(1)	(2)	(3)	(4)	(5)	(6)
1. "No Tree Was Harmed" messaging	0.10	0.24	0.10	0.02	0.29	0.07
2. Waste-free design messaging	0.10	0.17	0.10	0.02	0.16	0.07
3.Cradle-to-Cradle messaging	0.10	0.13	0.10	0.02	0.14	0.07
4. Circular ecology imagery	0.07	0.12	0.10	0.05	0.16	0.07
5. Life experience imagery	0.05	0.12	0.10	0.05	0.20	0.07
6. Survival meaning imagery	0.05	0.12	0.10	0.05	0.20	0.07
7. Color	0.07	0.12	0.19	0.02	0.20	0.07
8. Typography: size and shape	0.05	0.12	0.10	0.05	0.16	0.07
9. Eco-labels	0.07	0.12	0.10	0.02	0.16	0.14

Note. Consumer requirements: (1) convey sustainability appeal, (2) demonstrate creativity, (3) appropriate color scheme, (4) well-organized text-image layout, (5) stimulate purchase intention, (6) display certified eco-label.

Table 3. Grey Relational Order of Technical Design Attributes for Green Book Covers.

Technical Attribute (HOWs)	Grey Relational Grade	Overall Rank	Category Rank
Copywriting			
1. "No Tree Was Harmed" messaging	0.810	1	1
2. Waste-free design messaging	0.615	3	2
3. Cradle-to-Cradle messaging	0.561	6	3
Imagery			
4. Circular ecology imagery	0.560	7	3
5. Life experience imagery	0.585	5	2
6. Survival meaning imagery	0.590	8	1
Others			
7. Color	0.677	2	1
8. Typography: size and shape	0.540	9	3
9. Eco-labels	0.608	4	2

Note: The Grey Relational Order was calculated using Grey Relational Grade based on consumer requirements for green book covers. Higher values indicate greater effectiveness in conveying sustainability concepts and stimulating purchase intention. Category rankings represent the relative importance within each attribute type (copywriting, imagery, others).

4 Conclusions

This study emphasizes the pivotal role of books as channels for promoting sustainability awareness, highlighting the necessity of integrating ecological responsibility into design and marketing strategies. By combining QFD with GRA, a structured framework was developed to evaluate and prioritize green book cover design indicators under

conditions of limited and uncertain data. Empirical findings demonstrate that material selection, effective use of color, and copywriting that minimizes resource waste are critical factors in conveying sustainable concepts and stimulating consumer purchase intentions. The proposed QFD–GRA integration not only provides an objective and systematic approach for translating consumer needs into technical attributes but also offers actionable design guidelines for designers and publishers. The study contributes theoretically by advancing a structured evaluation methodology for sustainable design and practically by informing the development of book covers that balance aesthetic appeal with ecological responsibility. Future research could extend this framework by incorporating market segmentation, willingness-to-pay analyses, and innovation-driven design strategies, further enhancing the commercialization and societal impact of green products.

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