Age-Friendly Metro Signage Design Under the Background of Aging Society

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Abstract. As urban populations continue to age, metro signage systems frequently exhibit poor readability, semantic ambiguity, and unfriendly interaction for elderly passengers. This study examines existing obstacles in signage design across information acquisition, semantic understanding, and physical interaction dimensions. Orthogonal experiments collect user ratings under multiple constraints, combined with AHP for weight ranking and Fuzzy Comprehensive Evaluation to quantify feedback. A set of age-friendly signage design guidelines is distilled, providing reference for urban rail transit retrofitting.

Keywords: population aging, metro signage, inclusive design, form design

1 Introduction

1.1 Research Background

Global population aging accelerates, with the population aged 60 and above projected to exceed 2 billion by 2050 [1]. China crossed the aging society threshold in 2021, and this proportion continues to climb rapidly. Sensory decline due to aging, particularly weakened vision, slower information processing, limited mobility, and difficulties with digital operations, significantly impacts elderly wayfinding efficiency in urban transportation [2]. The metro system occupies an important position in daily travel due to its transport efficiency and punctuality, but existing in-station signage is generally designed based on adult-centered logic. Many signs suffer from overly dense fonts, weak figure-ground contrast, and improper installation heights. Abstract graphic symbols deviate from elderly cognitive habits, causing wayfinding difficulties and anxiety [2]. Updating signage design language with elderly needs as a core consideration has become urgent[3].

1.2 Research Objectives

This study identifies elderly pain points in sign recognition, semantic understanding, and smart device interaction through field research. Age-friendly design guidelines are constructed, focusing on four core elements: sign scale, color contrast, graphic simplicity, and installation position [5]. Orthogonal experiment, AHP, and Fuzzy

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B. P. Siba et al. (eds.), *Proceedings of the 2026 5th International Conference on Public Service, Economic Management and Sustainable Development (PESD 2026)*, Advances in Economics, Business and Management Research 411,
https://doi.org/10.2991/978-94-6239-825-2_32

Comprehensive Evaluation are combined to quantify data and form an implementable optimization plan. While ensuring basic guidance functions, the study improves wayfinding efficiency for the elderly, alleviates travel anxiety, and provides a complete research framework for inclusive signage design in urban rail transit.

2 Literature Review

In the field of age-friendly metro signage design, Europe, the United States, Japan, and South Korea started earlier and have more comprehensive empirical systems, while domestic research in China started later but has developed rapidly in recent years. Overseas research has evolved from visual perception and behavioral quantitative observation to the synergistic adaptation of physiology and psychology. Early environmental psychology research established a foundational theoretical framework for spatial wayfinding in the elderly [6]. Korean scholars Kim and Lee, after surveying Seoul's transfer stations, pointed out that redundant signage and inconsistent color symbols increase cognitive load in the elderly, overturning the convention of high-saturation color design and confirming that low-saturation, receding colors are more suitable for the visual degradation characteristics of the elderly [7]. Japanese scholar Tsujimura, considering Japan's aging context, constructed an audio-visual integrated signage plan, quantitatively defining thresholds for font size, color contrast, and voice broadcast adaptation [8].

With the popularization of eye-tracking and VR simulation technologies, overseas research has fully transitioned to objective quantitative empirical methods. Peng et al., through eye-tracking experiments, proved that the visual recognition efficiency of the elderly is lower than that of young and middle-aged adults, with women over 55 showing the most prominent wayfinding difficulties [9]. Wei et al., relying on eye-tracking indicator modeling, verified the crucial role of signage layout in wayfinding efficiency [10]. Hu and Xu, using VR experiments, confirmed that a layout combining ground arrows with wall guidance strips better aligns with the spatial memory of the elderly [11]. At the conceptual level, Kong et al., through a literature review, proposed that international research has shifted from purely physiological compensation to a composite paradigm that parallels physiological adaptation and psychological care for the elderly, while cautiously avoiding the digital divide brought by smart navigation [12]. European scholar Labus focused on multimodal transportation connectivity, improving cross-scenario signage continuity design standards [13].

Domestic research in this area started relatively late, gradually moving from basic surveys to empirical research and standardization. Liu et al. pioneered the introduction of service design and ZigBee sensing technology into the study of elderly wayfinding behavior, establishing a research path for data-driven signage optimization in China [4]. Fang et al., from the perspective of information processing, analyzed the impact of signage information arrangement on the cognitive load of the elderly [14]. Wang and Wu, through case studies of urban metro systems, addressed practical pain points such as station signage adaptation and transportation connection signage discontinuity [15, 16]. The implementation of the Design Standard for Age-Friendly

Guidance Signage Systems in Metro Stations in 2024 marked the official entry of this field into the standardized design phase in China [17]. Overall, domestic research largely borrows established international theories and experimental paradigms for localization and validation, but there are still shortcomings in original quantitative systems and research on the psychology of the elderly. The mature visual threshold standards, behavioral observation paradigms, and emotional design approaches from international research can provide sufficient reference for the age-friendly signage iteration of China's high-density metro network.

3 Problem Analysis

Many Chinese regions have introduced age-friendly metro signage policies. Beijing improved facility standards in public transportation [18]. Shanghai Metro enlarged fonts, improved color contrast, and added ground guidance signs [19]. Guangzhou deployed voice inquiry terminals to compensate for visual recognition shortcomings [20]. Shenzhen piloted dynamic electronic guidance screens adjusting display priorities by passenger flow [21]. However, retrofitting remains fragmented without unified national standards. Visual styles differ across cities and lines, forcing elderly passengers to repeatedly adapt to new visual logic when traveling [17]. Smart device interfaces designed for younger users create significant digital barriers for the elderly.

Three core obstacles hinder retrofitting. First, China only has a recommended specification for age-friendly signage, lacking mandatory standards with quantitative indicators adapted to elderly visual and auditory decline, resulting in inconsistent retrofitting quality [17]. Second, no empirical priority ranking of design elements exists. Aging leads to retinal cone cell degeneration, reducing color and brightness perception, yet current retrofitting relies on designer subjectivity, causing parameter conflicts and wasted costs [22]. Third, design is disconnected from real elderly behavioral data. Key parameters such as information preferences and eye-level height lack unified conclusions. The orthogonal experiment and AHP method proposed in this study addresses this gap by providing quantitative size decision-making support [5].

4 Research Methodology

This study selects Guangzhou Metro Gongyuanqian Station as the research site, employing field investigation, orthogonal experiment with AHP, and Fuzzy Comprehensive Evaluation. Gongyuanqian Station is a core transfer hub for Lines 1 and 2 in the old city center, surrounded by residential areas, commercial districts, and hospitals, ensuring diverse elderly passenger samples for wayfinding behavior collection.

4.1 Field Investigation

Non-participatory observation records elderly stopping, hesitating, and asking-for-directions behaviors during ticketing, entry, transfer, and exit. Semi-structured inter-

views collect subjective evaluations and improvement suggestions regarding signage. First-hand behavioral and needs data provide real-world evidence for variable setting in subsequent quantitative experiments.

4.2 Design Element Optimization and Weight Analysis

The orthogonal experiment incorporates four factors, size, color contrast, graphic simplification, and installation position, into one experimental plan. Range analysis screens for the optimal factor combination with best overall performance, while AHP calculates element weights through expert judgment matrices, clarifying primary and secondary relationships among the four elements. Together they form a complementary mechanism of optimal solution screening plus element weight ranking.

4.2.1 Research Question Definition.

Field investigation indicates that unclear visibility is the primary obstacle faced by elderly passengers [22]. However, signage size is not simply bigger is better. Ceiling height limits, visual pressure, manufacturing costs, and layout focus necessitate balancing clear visibility against excess. The core question is: under metro environment constraints, what panel size achieves the best overall performance?

4.2.2 Orthogonal Experiment Design.

This study plans to use an orthogonal experimental method at the transfer corridor of Gongyuanqian Station. The orthogonal experiment incorporates size, color contrast, graphic simplification, and installation position into the same experimental plan, using range analysis to determine the primary and secondary effects of each factor on visual clarity and identify the optimal level for each factor.

(1) Factor and level setting

The basis for the three size levels is: 80 cm represents the typical scale of existing standard signage; 140 cm represents the theoretical upper limit constrained by ceiling height (the transfer corridor at Gongyuanqian Station is approximately 3 meters high; with at least 40 cm reserved for mounting structure above and 2.2 m clearance for passenger passage below, the maximum panel height is about 140 cm); 110 cm is the midpoint. The three color levels are selected based on the findings of Kim and Lee [7]. The three graphic levels are based on the preference feedback from the elderly in the field investigation. The three position levels are determined based on the common installation forms of in-station signage.

Table 1. Factor and level setting.

Factor	Level 1	Level 2	Level 3
A. Sign size	80 cm	110 cm	140 cm
B. Color contrast	Yellow-black	Black-white	Blue-white
C. Graphic simplification	Pictogram	Simplified line	Solid graphic
D. Installation position	Hanging	Wall-mounted	Floor-based

The L9(3^4) orthogonal array is selected, requiring only 9 experimental runs to cover all combinations of the four factors at three levels. Each experimental run plans to recruit 15 elderly subjects aged 60-75. After completing wayfinding tasks in the transfer corridor of Gongyuanqian Station, they will rate the following dimensions on a 1-5 scale:

Table 2. Evaluation dimensions and preset weights.

Evaluation dimension	Criterion	Preset weight
Visual clarity	Legibility of text/graphics	0.50
Visual pressure (reversed)	Whether the sign appears too large or oppressive	0.20
Layout focus	Whether information is concentrated and easy to read	0.15
Spatial coordination	Proportional coordination with the surrounding environment	0.15

Note: The weights in the table are a preset scheme. In actual research, they will be reassessed through expert scoring.

$$\text{Score} = 0.50 \times \text{Clarity} - 0.20 \times \text{Pressure} + 0.15 \times \text{Focus} + 0.15 \times \text{Coordination} \quad (1)$$

Through range analysis, the mean comprehensive scores and range R values for each factor at each level are calculated. A larger R value indicates a more significant influence of that factor on the comprehensive score, allowing the selection of the optimal factor combination under constraints including ceiling height (maximum 140 cm), visual pressure (negative indicator, weight 0.20), and spatial coordination (positive indicator, weight 0.15).

4.3 Analytic Hierarchy Process

The orthogonal experiment identifies the optimal combination of levels but does not answer which of the four elements is more important to elderly users. The Analytic Hierarchy Process (AHP), a multi-criteria decision-making method proposed by Saaty [23], is introduced in this study. Its core idea is to decompose complex decision problems into an ordered hierarchical structure and transform qualitative judgments into quantitative weights through pairwise comparisons, making it suitable for research scenarios involving the ranking of design element importance.

(1) Hierarchical structure model

A three-layer structure is constructed: the goal layer is Age-Friendly Metro Signage Optimization, the criteria layer consists of sign size, color contrast, graphic simplification, and installation position, and the alternative layer comprises the specific design options under each criterion (i.e., the three levels in the orthogonal experiment).

(2) Judgment matrix and weight calculation

Five experts in rail transit and accessible design will be invited to perform pairwise comparisons of the four criteria using Saaty's 1-9 scale [23]. The scale meanings are:

1 for equal importance, 3 for slight importance, 5 for strong importance, 7 for very strong importance, 9 for extreme importance, with 2, 4, 6, and 8 as intermediate values. For example, if an expert considers graphic simplification to be strongly more important than sign size, a value of 5 is assigned in the corresponding position of the matrix; conversely, 1/5 is assigned. Through the geometric mean method, the judgment matrices from all experts are aggregated. The geometric mean of each row in the judgment matrix is calculated and then normalized to obtain the weight of each element. Subsequently, the maximum eigenvalue and the consistency index (CI) are calculated, ultimately yielding the consistency ratio CR = CI/RI (consistency is acceptable when CR < 0.10). The weight ranking will clarify the primary and secondary relationships among the elements, cross-validating with the range analysis results from the orthogonal experiment to provide a more comprehensive basis for design decisions.

(3) Application of weight results

The weight ranking will clarify the primary and secondary effects of the four elements on the visual clarity of elderly users. If graphic simplification has the highest weight, design optimization should prioritize simplifying graphic symbols; if color contrast has the highest weight, enhancing color visibility should be prioritized. The weight results will be cross-validated with the range analysis results from the orthogonal experiment. If both methods yield consistent rankings, the reliability of the conclusions is strengthened; if discrepancies exist, the reasons (e.g., differing focus between users and experts) should be analyzed, providing a more comprehensive perspective for design decisions.

4.4 Fuzzy Comprehensive Evaluation

Both the orthogonal experiment and AHP fall within the category of objective analysis and do not incorporate the subjective feelings of elderly users. This study introduces Fuzzy Comprehensive Evaluation to transform subjective user evaluations into quantifiable data. The evaluation factor set U = {Visual Clarity, Ease of Understanding, Aesthetic Preference} and the comment set V = {Very Satisfied, Satisfied, Neutral, Unsatisfied, Very Unsatisfied} are established. Questionnaires are planned to be distributed to 50 elderly users aged 60-75 to construct a fuzzy relationship matrix. Combined with the AHP weights, a weighted average membership vector is calculated to obtain a comprehensive evaluation value, which is then cross-validated with the orthogonal experiment data.

5 Research Summary

This study focuses on the core issue of metro signage design under the background of an aging society. Starting from the triple dilemma faced by elderly passengers, unclear visibility, incomprehensibility, and inability to find guidance, it has developed a complete research framework from problem identification to solution optimization and effect validation. At the problem identification level, field investigation through

observation and user interviews at Guangzhou Metro Gongyuanqian Station accurately pinpoints the age-friendly shortcomings of the existing signage system in terms of sign scale, color contrast, graphic semantics, and installation position, providing real-world behavioral data support for subsequent research. At the solution optimization level, the combined method of orthogonal experiment and AHP is employed. The orthogonal experiment incorporates size, color, graphics, and position into a single experimental framework, using range analysis to identify the optimal factor combination that performs best under multiple constraints. The AHP, through expert judgment matrices, calculates the weight of each element, clarifying the primary and secondary relationships among the four elements. Together, they form a complementary mechanism of optimal solution screening plus element weight ranking. At the effect validation level, Fuzzy Comprehensive Evaluation converts elderly users' perceptual evaluations of visual clarity, ease of understanding, and aesthetic preference into quantifiable data, cross-validating with the objective results of the orthogonal experiment to ensure the final recommended solution possesses both objective efficiency advantages and subjective user acceptance. The entire research design forms a complete chain of evidence. The final integration of all data can distill a set of age-friendly signage design guidelines covering specific recommendations for size, color, graphics, and installation position, providing a quantifiable reference and design framework for age-friendly retrofitting of metro systems in Guangzhou and similar cities in China.

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