

Article

Design and Evaluation of Historically and Culturally Integrated Metro Spaces: A Case Study of Xi'an Metro Stations

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Abstract

Subways play an irreplaceable role in alleviating urban traffic congestion and showcasing a city's historical and cultural heritage. Their speed and environmental benefits make them a vital component of sustainable urban development. Historical and cultural expression has become a focal point of subway spatial design and a core component of station planning. Building on this, the present study develops an evaluation system for metro station space that integrates history and culture and is grounded in the theory of *genius loci* (spirit of place). The Analytic Hierarchy Process (AHP) and Fuzzy Comprehensive Evaluation (FCE) are used to derive indicator weights and conduct quantitative assessment. AHP results indicate that visual design, auditory elements, and cultural identity are the core priorities within the Xi'an metro station evaluation system. Design strategies integrate visual elements with historical and cultural contexts to create multisensory experiences encompassing form, color, sound, and touch. FCE further analyzes the indicators and shows that the overall design quality of the sampled Xi'an metro stations is generally high: auditory and visual elements are dominant, spiritual (psychological) experience and cultural identity approach excellence, and tactile elements show somewhat weaker performance. These findings suggest that metro space design requires deeper consideration across multiple dimensions. The proposed methodology can be applied to the design and evaluation of metro stations, providing practical guidance for culturally integrated metro spaces.



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Keywords: metro station design; *genius loci*; cultural integration; Analytic Hierarchy Process (AHP); fuzzy comprehensive evaluation (FCE)

1. Introduction

Against the backdrop of economic development, the sustained growth of urban populations has made transportation increasingly vital, with the metro system acting as the “main artery of urban traffic.” Countries worldwide have been actively promoting metro construction [1]. In the process of metro development, the integration of urban historical and cultural elements has positively influenced metro station design. Meanwhile, metro network expansion has effectively driven urban spatial restructuring, and historical and cultural elements have further become a key guide for metro station design trends—a phenomenon that has brought relevant design challenges to the forefront of designers' attention [2]. However, extracting appropriate historical and cultural elements is not suitable for every city, region, or individual station. This highlights the need for a systematic, effective, and operable design methodology to provide guidance for practitioners.

Numerous representative studies have been conducted on metro station spatial design. For example, studies by Katarzyna Jasińska [3], Xiaoxia Yang [4], and Suryakant Buchunde [5] primarily take passenger experience as the core, examining station space design from different perspectives. On the other hand, research by Zhengcong Wei [6], Qian Zhang [7], and Plácido González Martínez [8] explores metro station design from historical and cultural perspectives. Qian Zhang focuses on cultural expression and perception mechanisms in metro space design, Zhengcong Wei investigates the overall quality, characteristics, and shortcomings of cultural space construction in metro stations and proposes targeted design optimization strategies based on the findings, and Plácido González Martínez discusses how metro stations can showcase urban cultural heritage through spatial design. These studies collectively provide valuable insights for the innovative development of metro station design. Regarding design decision-making and comprehensive evaluation methods, multiple factors should be thoroughly considered.

China's metro station design started relatively late. In 1969, Beijing Metro, China's first metro line, was completed and opened to traffic, marking a breakthrough in the history of urban rail transit in China. Currently, a total of 54 cities in China have opened metro operations, with an operational mileage that has exceeded 10,000 km [9]. Against this backdrop, people's demands for various aspects of metro station space have gradually increased, and more and more people are focusing on the integration of metro station space with culture. Developing a systematic framework for integrating cultural and historical elements into metro station design has become a pressing issue in China, which is essential for guiding future engineering and architectural practices. Therefore, this study intends to establish a scientific evaluation system for integrating history and culture, offering methodological references and practical suggestions for future metro station design.

Xi'an, a renowned historical and cultural city in China, boasts rich historical relics and is an ancient capital of thirteen dynasties. Consequently, the integration of history and culture into the design of Xi'an Metro is of profound significance to urban development. Meanwhile, as the largest city in Northwest China [10], Xi'an has a large resident and floating population. The fast-paced urban lifestyle has thus created an urgent demand for multidimensional spiritual sustenance from public facilities. Against this backdrop, this study introduces "Genius Loci" as its core concept [11]. Based on the theoretical framework of multisensory design concepts, it evaluates the design of Xi'an Metro stations across multiple dimensions. To enrich existing evaluation indicators, avoid oversimplification, and deepen theoretical research, this study employs the AHP-FCE model to evaluate and analyze the spatial design of metro stations. This combination couples quantitative weighting with qualitative indicators, providing a more rigorous empirical research theory for the design of Xi'an Metro stations.

This paper is structured as follows. Section 1 is the introduction, including the research significance and literature review. Section 2 details the proposed conceptual framework, details the research samples, and presents the research methodology. Section 3 utilizes the Delphi method, the Analytic Hierarchy Process (AHP), and the Fuzzy Comprehensive Evaluation (FCE) for performing calculations, data analysis, and model validation. Section 4 discusses the research findings, draws key conclusions, and proposes future research directions.

Literature Review

With the rapid pace of urbanization, subway construction has become a hallmark of modern urban development. While meeting diverse commuting needs, subways have evolved into vital hubs for the convergence of human traffic. Consequently, subway station spaces have acquired greater significance, prompting increasing research in this field.

Scholar Liu Yang examined two subway stations in Nanjing, China, analyzing the impact of differing designs on surrounding public spaces and proposing design recommendations based on findings [12]. Daniel Vega's research focused on the necessity of subway stations in enhancing passenger emotional experiences, grounded in user sentiment [13]. Won-Ji Kim examined the interior landscape design of subway stations in Busan, South Korea, investigating its impact on passengers' psychological and physiological responses. Findings indicated that interior landscape design elicits positive emotional effects in users [14]. Scholar Zihan Wu developed an evaluation system for the environmental suitability of the transfer space. Using fuzzy comprehensive evaluation, he assessed eight sample sites in Shanghai. The study found environmental suitability is significantly influenced by safety and convenience, while practicality, comfort, and aesthetics have relatively weaker impacts [15]. Shekoufeh Aghajani et al. analyzed the space of the Tabriz Metro Station. Using Kaplan's information-processing theory, the study calculated public visual preferences within the metro station space [16].

Overall, scholars such as Liu Yang, Daniel Vega, Won-Ji Kim, Zihan Wu, and Shekoufeh Aghajani have conducted systematic research on the spatial design of subway stations. At the historical and cultural level, the station areas of some countries' subways, developed over many years, have become significant carriers of cultural heritage dissemination, for instance, the Moscow Metro, with its profound historical legacy. Scholar Jae Min Lee examined three Moscow Metro stations, conducting detailed case studies of historical relics within the stations to explore their historical and architectural value [17]. Scholar Karen L. Kettering, meanwhile, investigated Stalin-era Soviet architecture within the Moscow Metro, delving into decorative details to analyze the cultural and historical significance of Russian metro stations [18]. Scholar Emma Waterloo analyzed the century-old New York subway system, revealing how station designs across different lines documented architectural style shifts from the 1940s onward [19]. Zhang Qian examined how subway station spaces in Beijing's historic Old City neighborhoods effectively convey urban history and culture through environmental design [20]. An Jiacheng analyzed Qingdao's subway stations as a case study, exploring spatial optimization strategies that integrate Shandong's historical and cultural heritage [21].

At the methodological level, this study employs an AHP-FCE composite model to conduct a quantitative analysis of spatial design in Xi'an subway stations. Regarding AHP-FCE research, Huiying (Cynthia) Hou constructed a resident-oriented performance evaluation framework using a Dutch student residence as a case study, employing an AHP-FCE-designed questionnaire to assess this framework [22]. Yang Hu evaluated the livability of outdoor spaces in old residential areas of Suzhou, China, using the AHP-FCE method, providing a reference for urban managers [23]. Congxiang Tian addressed deficiencies in landscape construction quality and the lack of green concepts in urban development environments by establishing an evaluation methodology system and employing the AHP-FCE method for assessment research [24]. Weishu Zhao's improved AHP-FCE method was used to determine the weight of each sub-indicator. The feasibility of the evaluation system was ultimately validated through case studies, and several recommendations were proposed to enhance the overall benefits of green buildings [25]. Researchers from diverse fields integrated their expertise to evaluate proposals using the AHP-FCE model. This approach mitigates the subjectivity inherent in traditional evaluation methods reliant on decision-makers' experience, enabling more precise weighting of evaluation factors and yielding quantitative outcomes through fuzzy comprehensive assessment.

Therefore, this study focuses on two core issues: it introduces and establishes an evaluation index system for subway station spaces. The research framework is based on the theory of place spirit combined with the concept of multisensory design. The theory of place

spirit was elaborated by Norwegian architectural phenomenologist Christian Norberg-Schulz in his monograph *Genius Loci: Towards a Phenomenology of Architecture*, where he classified it as architectural phenomenology [26]. Specifically, Amir Shaghaghi et al. examined the impact of place spirit on the durability of urban spatial texture, highlighting the importance of integrating diverse cultural contexts and case studies [27]. Scholar Hu Xiao, integrating China's national context, delved into the manifestations of place spirit, demonstrating its theoretical and practical value [28]. Guided by place spirit theory, subway station design should transcend mere esthetic pursuits to grasp the essence of place, creating culturally and historically integrated spaces imbued with place spirit.

This research focuses on Xi'an subway stations. Xi'an is a renowned tourist city in China, honored as the ancient capital of thirteen dynasties and recognized as one of the six ancient capitals of civilization. The city has a profound cultural heritage and abundant historical relics. According to the Xi'an Urban Rail Transit Management Regulations, subway construction and operation should prioritize preserving and promoting the city's cultural atmosphere [29]. Additionally, the Several Policies on Addressing Shortcomings and Accelerating the Development of Xi'an's Cultural Industry advocate vigorously developing Xi'an's cultural resource advantages to establish a high-quality cultural industry. This policy plays a significant role in fostering an atmosphere conducive to urban historical and cultural creativity. As public spaces, subway stations can bring the city's culture and art into the public eye [7].

2. Materials and Methods

2.1. Sample Overview

This study focuses on five representative metro stations: Zhonglou, Daminggong, Nanshaomen, Epanggong Nan, and Qinglongsi. Each station is located near a significant cultural heritage site: the Xi'an Bell Tower, the Daming Palace Heritage Park, the Xi'an Museum, the Epang Palace Ruins, and the Qinglong Temple, respectively (Figure 1).

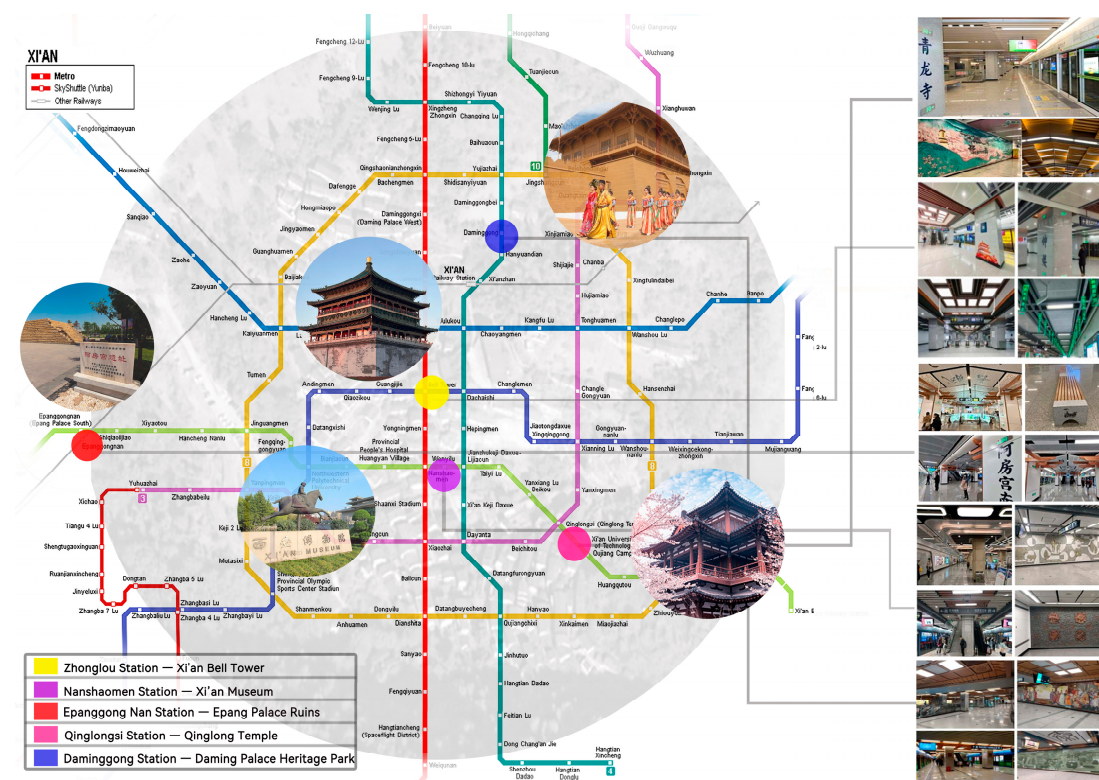


Figure 1. Xi'an Metro Station Samples (Source: Authors).

The Xi'an Bell Tower was first constructed in 1384 during the Ming Dynasty, originally situated at what is now the crossing of Guangji Street. It was moved to its present location in 1582. The structure underwent several major renovations over the following centuries, including those in the 5th year of the Qianlong reign (1740) and the 20th year of the Daoguang reign (1840), and ultimately forming the landmark we see today. Its name comes from the "Jingyun Bell," a Tang Dynasty artifact housed inside, which was historically used to sound the time [30].

The Tang Daming Palace Ruins were included in the first group of state-protected cultural heritage sites in China. As a vital representation of Tang culture, the site boasts extraordinary historical, scientific, and artistic value [31]. It was later recognized as a key component of the Silk Road transnational World Heritage application and has been inscribed as a UNESCO World Heritage site.

Xi'an Museum, the main museum of the Xi'an Museum Complex, is the core exhibition venue of a large modern institution that integrates the historical Jianfu Temple—known for the Small Wild Goose Pagoda—with museum collections and a public park [32]. It houses a wide range of historical artifacts and is one of the most visited museums in Shaanxi Province.

Qinglong Temple, once a major temple of Esoteric Buddhism during the Tang Dynasty, was originally located in the southeastern corner of Xinchang Fang (a Tang-era administrative division) inside Yanxing Gate of Chang'an, the ancient capital of the Tang Dynasty. Today, it is located on Leyou Plateau in the southern suburbs of Xi'an. The temple underwent repeated destruction and reconstruction throughout history and was completely abandoned between the Northern Song and mid-Ming dynasties. In 1979, archeological excavations helped identify the site's boundaries [33]. Today, Qinglong Temple is a peaceful and solemn place with deep courtyards, lingering incense smoke, attracting numerous pilgrims and tourists every day.

The Epang Palace Ruins, along with the surrounding architectural remains of the Shanglin Garden from the Qin and Han dynasties, form one of the earliest surviving rammed-earth palace foundations in Chinese history [34]. They serve as symbols and representatives of the Qin Dynasty's palatial and garden architecture and are a vital component of Xi'an's historical framework, playing an important role in the city's identity as a historic and cultural capital.

2.2. Delphi Method

The Delphi method is a structured, iterative research procedure aimed at achieving expert consensus: the research team first assembles an expert panel based on clear inclusion criteria, then conducts multiple rounds of anonymous questionnaires centered on the research topic [24]. This study used the Delphi method (DM) to select design indicators. Fifteen experts were invited to evaluate the importance of the indicators on a five-point Likert scale. The scoring criteria for the experts were defined as follows: Very Important, Important, Neutral, Not Important and Very Not Important. The questionnaire was designed based on the preliminary set of indicators. Data were collected through expert scoring, with indicators being retained if they had an average score greater than 4.0 and a coefficient of variation (CV) of less than 0.22. Indicators that failed to meet these standards were excluded. The final set of design evaluation indicators was determined through two rounds of the Delphi method. The study employed email communication and distributed paper questionnaires. All 15 experts completed the questionnaires over two rounds spanning two months, achieving a 100% response rate in both rounds and indicating high expert engagement (Table 1).

Table 1. Summary of Delphi Questionnaire Distribution and Response Rate.

Research Stage	Questionnaires Distributed	Questionnaires Returned	Response Rate
First Round	15	15	100%
Second Round	15	15	100%

Factors influencing expert authority include: The basis for evaluating and recommending solutions; Practical experience: expertise in subway station design-related fields; Theoretical analysis capabilities; Theoretical and academic background; Peer knowledge: achievements in relevant fields and understanding of consensus and points of contention among peer experts. Intuitive judgment: Experts possess discernment when confronting complex issues, drawing upon long-term knowledge and experience. In the practical application of the Delphi method, an Authority Coefficient (Cr) is introduced to quantify expert authority.

Based on the data in the Tables 2 and 3, the familiarity coefficient (Cs) for the questionnaire among the 15 experts is 0.89. The judgment basis score is $Ca = 0.89$. Therefore, according to the formula $Cr = \frac{Cs+Ca}{2}$. The expert authority coefficient is calculated to be 0.893, indicating a high level of expert authority.

Table 2. Expert Familiarity Level and Coefficient (Cs).

Familiarity Level	Not Familiar	Slightly Familiar	Moderately Familiar	Familiar	Very Familiar
Number of Experts	0	0	1	6	8
Expert Familiarity Weight	0.2	0.4	0.6	0.8	1
Expert Familiarity Coefficient (Cs)	$Cs = (1 \times 0.6 + 6 \times 0.8 + 8 \times 1.0)/15 = 0.893 \approx 0.89$				

Table 3. Expert Judgment Basis and Coefficient (Ca).

Judgment Basis	High (Count)	High (Weight)	Medium (Count)	Medium (Weight)	Low (Count)	Low (Weight)	Score
Practical Experience	10	0.5	5	0.4	0	0.3	0.47
Theoretical Analysis	7	0.3	5	0.2	3	0.1	0.23
Knowledge of Peers (Domestic and International)	0	0.1	8	0.1	7	0.1	0.10
Intuition	0	0.1	10	0.1	5	0.1	0.10
The overall judgment basis coefficient is calculated as: $Ca = 0.8934 \approx 0.89$							

Calculating the coefficient of variation (CV_j) and the weighting coefficient (W) enables us to determine whether there is significant divergence in the experts' evaluations of individual indicators, thereby assessing the reliability of the scoring results from this round of expert consultation. The table below shows the ranges of the CV and W for indicators at each level, based on the findings from both rounds of expert consultation (Table 4).

In the first round, the coordination coefficients (W) for the Level I, Level II and Level III indicators were 0.732, 0.637 and 0.671, respectively. All of these passed the significance test at $p < 0.001$. This indicates a high degree of consensus among experts. In the second round, expert opinions stabilized, with the chi-square test remaining significant ($p = 0.0223$), which further demonstrates that the indicator system is becoming increasingly rational and refined. The coordination coefficients for the secondary and tertiary indicators were 0.434 and 0.494, respectively, with significant chi-squared values ($p < 0.001$), indicating consistent expert evaluations even at a more granular level. In summary, the two rounds of Delphi

consultation effectively enhanced the scientific rigor, coordination and representativeness of the indicators, providing robust data to support the construction of a spatial design evaluation system for subway stations.

Table 4. Results of the Delphi Method Coordination and Consistency Tests.

Round	Evaluation Level	Sample Size (n)	Kendall's W	Chi-Square (χ^2)	df	p-Value
Round 1	Primary Indicator Level	15	0.627	43.917	4	<0.001
Round 1	Secondary Indicator Level	15	0.640	143.350	15	<0.001
Round 1	Tertiary Indicator Level	15	0.701	402.385	40	<0.001
Round 2	Primary Indicator Level	15	0.163	11.412	4	0.022
Round 2	Secondary Indicator Level	15	0.432	84.674	13	<0.001
Round 2	Tertiary Indicator Level	15	0.514	259.281	35	<0.001

2.3. Analytic Hierarchy Process (AHP)

Professor Sati, a renowned American mathematician, proposed the Analytic Hierarchy Process (AHP) in the 1970s. The AHP is characterized by its comprehensive and systematic approach, ease of operation, and rigorous structure, and has been widely adopted by scholars for research purposes [25]. To establish an objective and reliable hierarchical structure model, an Analytic Hierarchy Process (AHP) was conducted after the Delphi study.

A judgment comparison matrix was constructed to serve as the fundamental component of the AHP methodology. Within this matrix, elements at the same level are compared with each other and assigned specific values. Typically, a nine-point scale ranging from 1 to 9 is used to quantify the relative importance of each indicator. The scale meanings and corresponding numerical values are as follows (Table 5):

Table 5. Saaty's Fundamental Scale (AHP).

No.	Verbal Meaning (<i>i</i> vs. <i>j</i>)	Ratio
1	<i>i</i> and <i>j</i> are equally important	$a_{ij} = 1$
2	<i>i</i> is moderately more important than <i>j</i>	$a_{ij} = 3$
3	<i>i</i> is strongly more important than <i>j</i>	$a_{ij} = 5$
4	<i>i</i> is very strongly more important than <i>j</i>	$a_{ij} = 7$
5	<i>i</i> is extremely (absolutely) more important than <i>j</i>	$a_{ij} = 9$
6	Intermediate values between adjacent judgments	$a_{ij} = 2, 4, 6, 8$
7	Reciprocity rule: if a_{ij} is the importance of <i>i</i> over <i>j</i> , then $a_{ji} = 1/a_{ij}$	—

By evaluating each pair of elements in the matrix according to the scale above, we obtain an *n*-order comparison matrix *A*.

$$A_{n \times n} = \begin{bmatrix} a_{11} & a_{12} & a_{1..} & a_{1n} \\ a_{21} & a_{22} & a_{2..} & a_{2n} \\ a_{..} & a_{..} & a_{..} & a_{..} \\ a_{n1} & a_{n2} & a_{n..} & a_{nn} \end{bmatrix} \quad (1)$$

Merge the expert matrices by applying the geometric mean method. This involves multiplying the scoring matrices formed by *k* experts ($k = 1, 2, \dots, m$) element-wise and raising the result to the *m*th power to obtain a single ensemble matrix $\bar{A}$. $\bar{A}$, the element in the matrix, is the geometric mean of the *m* decision matrices, which is calculated as follows:

$$\bar{A} = \left(\prod_{k=1}^m a_{ij}^k \right)^{\frac{1}{m}} \quad (2)$$

Calculate the relative weights of the decision matrix. For the integrated unique matrix, calculate the weights using the geometric mean method (also known as the square root method) as follows:

$$W_i = \frac{(\prod_{j=1}^n a_{ij})^{\frac{1}{n}}}{\sum_{i=1}^n (\prod_{j=1}^n a_{ij})^{\frac{1}{n}}}, i = 1, 2, 3, \dots, n \quad (3)$$

To assess the consistency of a judgment matrix, experts may reach different conclusions when comparing indicators pair by pair. Therefore, consistency tests must be conducted on existing judgment matrices to ensure the rationality of indicator weights [26].

$$CR = \frac{CI}{RI} = \frac{\lambda_{\max} - n}{(n - 1)RI} \quad (4)$$

To determine the maximum eigenvalue ($\lambda_{\max}$) of a matrix, the calculation formula is as follows:

$$\lambda_{\max} = \sum_{i=1}^n \frac{[\bar{A}W]_i}{nW_i} \quad (5)$$

The RI value is related to the order of the matrix. The specific values are as follows (Table 6):

Table 6. Random Index (RI) Values for Consistency Test.

Matrix Order	1	2	3	4	5	6	7	8	9	10	11	12
RI	0	0	0.52	0.89	1.12	1.26	1.36	1.41	1.46	1.49	1.52	1.54

2.4. Fuzzy Critical Event Analysis (FCE)

Fuzzy comprehensive evaluation converts qualitative assessments into quantitative ones using fuzzy mathematics and membership theory. This method provides a way of quantitatively evaluating subjective, fuzzy concepts, offering clarity, objectivity and accuracy [27]. This study uses the FCE method to evaluate the program, thereby enhancing the scientific rigor and practical value of the analysis by combining the strengths of the Analytic Hierarchy Process (AHP) and FCE.

- (1) Create sets of fuzzy evaluation factors and weights. Based on the hierarchical structure of the indicators and their respective weights, create separate sets for the evaluation factors and their respective weights.
- (2) Create a set of evaluation comments. This set should comprise all possible evaluation outcomes for each indicator. Depending on the characteristics and actual conditions of the evaluated object, different grading levels can be set. In this paper, the comment set is defined as $V = \{\text{Excellent, Good, Average, Poor, Bad}\}$, with each evaluation grade corresponding to a specific score.
- (3) Construct a fuzzy evaluation matrix. Invite multiple evaluators to assess indicator layers using the comment set. After quantifying the indicators, determine the membership degree of factor i for evaluation j , where the membership degree F represents the proportion of evaluators who assigned evaluation j to factor i out of the total number of evaluators. This establishes the fuzzy relationship matrix.

$$F_i^j = \begin{bmatrix} F_1^1 & F_1^2 & F_1^3 & \dots & F_1^j \\ F_2^1 & F_2^2 & F_2^3 & \dots & F_2^j \\ \dots & \dots & \dots & \dots & \dots \\ F_i^1 & F_i^2 & F_i^3 & \dots & F_i^j \end{bmatrix} \quad (6)$$

- (4) Calculate membership degrees by applying a weighted average operator model to the weights W_i . Fuzzy Matrix F_i^j Chengde Second-Level Indicator Subordination Matrix Z_i^j . Then, based on the above steps, calculate the membership degrees for the primary indicators and the target layer, one step at a time.

$$Z_i^j = W_i * F_i^j = [z_{ij}^1 z_{ij}^2 z_{ij}^3 \dots z_{ij}^n] \quad (7)$$

2.5. AHP–FCE Comprehensive Evaluation Model

The AHP–FCE model combines the Analytic Hierarchy Process (AHP) and Fuzzy Comprehensive Evaluation (FCE) to balance qualitative and quantitative analysis effectively. First, an AHP model is constructed. Then, based on the AHP calculation results, the FCE method is applied to evaluate the case. The model then examines subway space design cases that integrate history and culture using the data analysis outcomes. The specific research pathway is illustrated in the Figure 2.

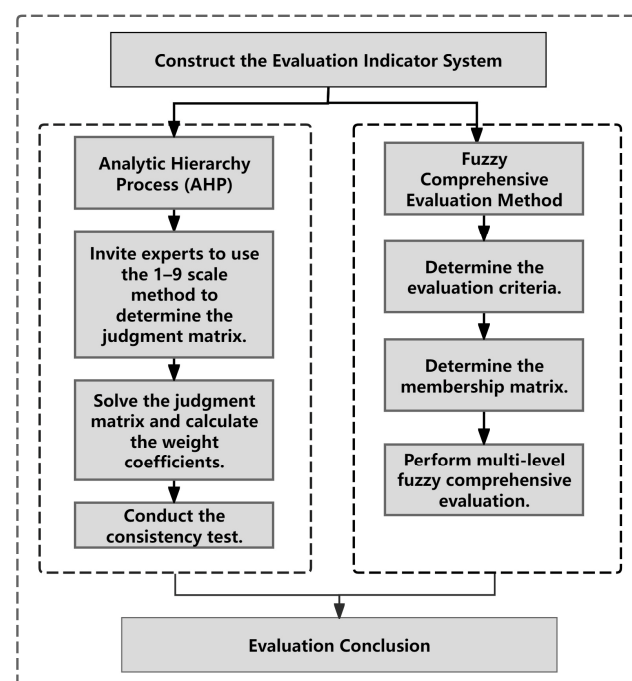


Figure 2. Evaluation Framework of the AHP–FCE Combined Model (Source: Authors).

3. Data Analysis and Results

3.1. Analysis of the Spiritual Indicator System for Spatial Places

Divergent social and cultural contexts across different periods in the West have given rise to distinct architectural expressions—such as Deconstructivism, High-Tech Architecture, and Expressionism—yet many architectural designs are merely hollow representations that neglect human perceptual experiences. In the 1970s, Christian Norberg-Schulz proposed and articulated the theory of Genius Loci (The Spirit of Place) to address this gap in the humanities. His seminal work, *Genius Loci: Towards an Architectural Phenomenology* (1980), systematically examines the phenomena, structure, classification, and theoretical underpinnings of “place”, establishing the Genius Loci theory through in-depth case analyses. By examining human spatial perception of place, the work explores individuals’ sense of orientation and identity within environments, emphasizing the cultivation of a place-specific spirit of belonging [11].

In research on Genius Loci (the spirit of place), philosopher Maurice Merleau-Ponty proposed the phenomenology of perception, which established a systematic theoretical framework of embodied cognition. He elaborated on the existential significance inherent to place and orientation, arguing that humans generate perceptions and gain an understanding of spatial characteristics through interaction with space [35]. World-renowned architect Steven Holl explored the relationship between architecture and place in his work *Anchoring*, demonstrating how architectural forms are shaped by distinctive sites. He integrated five sensory experiences into design dimensions, and facilitated the shift in theoretical discourse from abstract speculation to embodied perception [36]. Jeff Malpas combined Heideggerian phenomenology with the concept of place spirit, emphasizing “place” as a fundamental dimension of human existence [37]. Amirshaghghi, S. and Nasekhian, S., explore how the spirit of place influences the durability of urban fabric [27]. At the 16th General Assembly of the International Council on Monuments and Sites (ICOMOS) in 2008, the thematic focus was “Preservation of the Spirit of Place,” which resulted in the adoption of the Québec Declaration on the Preservation of the Spirit of Place. This declaration defines the “spirit of place” as a synthesis of tangible elements (architecture, ruins, landscapes, paths, objects) and intangible elements (memories, narratives, documents, rituals, festivals, traditional knowledge, values, textures, colors, scents, etc.)—the unity of material and spiritual elements that endow a place with meaning, value, emotion, and a sense of mystery [38].

Building upon the aforementioned research context, this study explores innovative approaches to the application of the theory of place spirit in subway spatial design. Focusing on the three core dimensions proposed by Christian Norberg-Schulz—sense of direction, sense of identity, and sense of belonging—and connecting them to the perceptual dimension, this research integrates and draws on relevant literature and existing research findings. Through theoretical construction, it shifts spatial research from abstract geometric concepts toward place-making imbued with humanistic warmth, forging correspondences between sensory perception and theoretical frameworks (Figure 3).

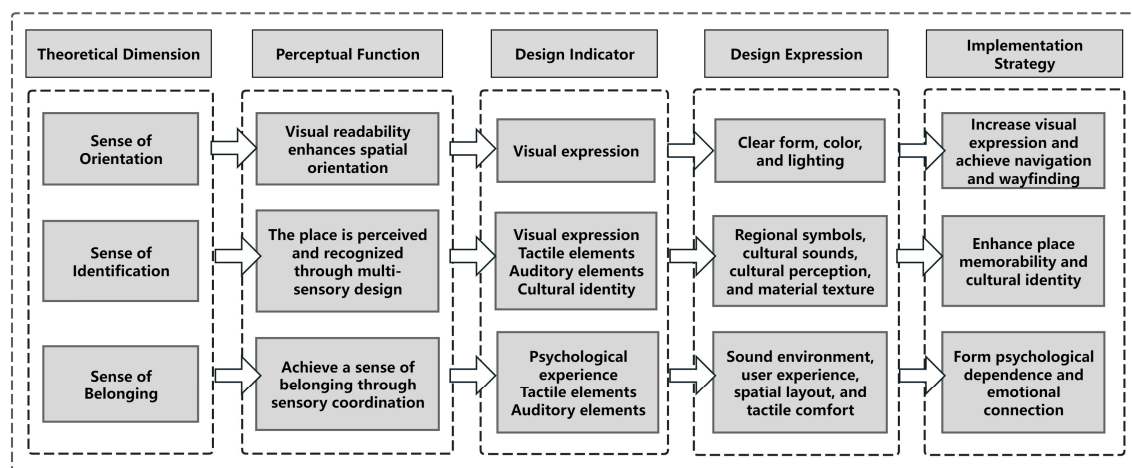


Figure 3. Place Spirit-Indicator Framework (Source: Authors).

Research and analysis of Xi'an Metro's Zhonglou Station, Daminggong Station, Nan-shaomen Station, Epanggong Nan Station and Qinglongsi Station revealed that these stations are designed to incorporate Xi'an's natural landscapes, historical relics and cultural features. This design approach reveals the soul of the city and is crucial for integrating the underground and above-ground environmental zones, creating distinct artistic styles. Furthermore, this study references the latest version of the 'National Standard of the People's Republic of China GB50157-2013 [39] Design Code for Subway Systems', implemented

for subway space design in 2014 [40]. Relevant specifications include emphasizing the coordination of the architectural context with the surrounding environment to ensure harmony with urban form, landscape and pedestrian flow [41]. Finally, an analysis of the indicator system is conducted based on the five core dimensions of spatial spirit (Figure 4).

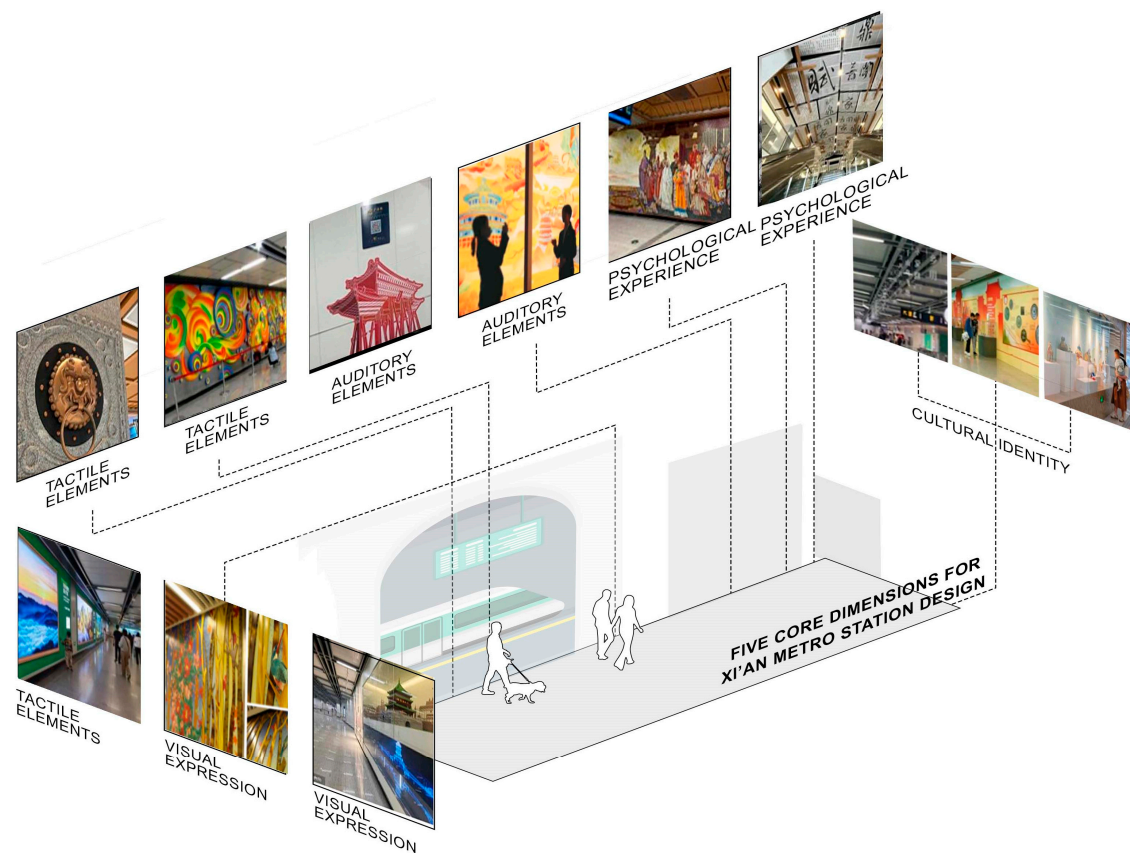


Figure 4. Five Core Dimensions for Xi'an Metro Station Design (Source: Authors).

Visual Expression: Vision is one of the primary channels through which the human brain receives external information. It is stimulated by elements such as color, light and shadow, and form, which together create a rich sensory experience. In the case of Xi'an metro station design, visual differentiation between lines is achieved through the use of distinct colors within stations, complemented by various decorative hues and modern lighting and shadow technologies.

Tactile Elements: Touch can be regarded as a primal physiological experience. It is not limited to perceptions felt through the fingers, but encompasses sensations involving the entire body. Even slight stimuli can excite the superficial receptors of the skin. Tactile experiences mainly arise from the perception of texture, temperature, humidity, and hardness. In the case of Xi'an metro station design, tactile engagement is enhanced through the use of decorative materials with varied textures, walls that invite physical interaction, and traditional interactive installations.

Auditory Elements: human physiological needs, and changes in these needs directly affect people's attitudes and behaviors. Regardless of cultural background, the presence of sound evokes emotional responses—its tone and rhythm can generate feelings of joy, sadness, or anxiety, thereby shaping diverse senses of place. In the design of Xi'an metro stations, auditory perception is stimulated through various means, such as scanning QR codes to listen to Xi'an's history, live cultural narrations, and the broadcasting of metro information in local dialects.

Psychological Experience: Spiritual experience is primarily manifested as the imaginative transformation of artistic expression, grounded in direct sensory perception and mediated by emotional experience. It involves infusing personal life experiences, ideals, and attitudes into the space, thereby evoking feelings, inspiration, or resonance. In the design of Xi'an metro stations, spiritual perception is stimulated through the integration of calligraphy and classical poetry representing specific station locations, as well as the incorporation of Tang Dynasty architectural elements. These design strategies aim to engage passengers' minds and evoke deeper emotional and cultural connections.

Cultural Identity: There exists a certain isomorphic relationship between culture and human emotions. When traditional elements, cultural patterns, and colors in a space resonate with users, they instinctively experience emotional information from the spiritual realm. By reinforcing cultural recognition through expressions of culture and history, a deeper sense of belonging and identity is cultivated. In the case of Xi'an metro station design, cultural identity is enhanced through the integration of exhibition artifacts, artworks, and traditional cultural elements into the metro space, strengthening passengers' emotional and cultural connection to the environment.

3.2. Delphi Method Screening Criteria

To collect initial indicators, this study selected major literature databases. The keyword “subway station design” was used to retrieve and analyze literature from these databases, and representative literature was screened for further analysis. To extract relevant information from the literature, word frequency analysis was employed. The statistically extracted keywords were then subjected to a comparative analysis [42]. After discussions by the expert panel, a preliminary system for evaluating the spatial design of Xi'an subway stations was ultimately established.

The screening criteria employed a two-round Delphi methodology involving 15 domain experts. To ensure familiarity with the city's historical and cultural context, all experts were selected from institutions closely related to Xi'an metro planning and architectural design. All experts had over five years of professional experience and in-depth expertise in their fields. Expert details are provided in Table 7.

Table 7. Details of the Experts (Delphi Panel; Author's Compilation).

Number	Professional Title	Work Years	Expertise Area
Expert 1	Senior Engineer	10–20	Rail Transit Design
Expert 2	Associate Professor	10–20	Architectural Design
Expert 3	Professor	10–20	Urban Planning
Expert 4	Senior Engineer	10–20	Rail Transit Design
Expert 5	Associate Professor	10–20	Environmental Design
Expert 6	Senior Engineer	10–20	Architectural Design
Expert 7	Senior Engineer	20–30	Urban Planning
Expert 8	Associate Professor	10–20	Transportation Design
Expert 9	Senior Engineer	10–20	Rail Transit Design
Expert 10	Senior Engineer	10–20	Environmental Design
Expert 11	Engineer	1–10	Interior Design
Expert 12	Associate Professor	1–10	Interior Design
Expert 13	Engineer	1–10	Environmental Design
Expert 14	Professor	10–20	Urban Planning
Expert 15	Professor	10–20	Interior Design

From 10 January to 10 February 2025, the first round of survey data collection and statistical analysis was conducted by distributing questionnaire notifications via email. Then, from 15 February to 20 February 2025, the second round of expert questionnaires

was administered. Data optimization continued through consultation, feedback, analysis, and expert consensus until the final evaluation metrics were established. The results from both rounds of Delphi data analysis are presented below (Table 8):

Table 8. Primary Indicators: Delphi R1–R2 Statistics (Author’s Compilation).

Primary Indicator	SD (R1)	M (R1)	CV (R1)	Result (R1)	SD (R2)	M (R2)	CV (R2)	Result (R2)
B1 Visual Expression	0.2582	4.9333	0.0523	Reserve	0.3519	4.8667	0.0723	Reserve
B2 Tactile Elements	0.5164	4.5333	0.1139	Reserve	0.7037	4.2667	0.1649	Reserve
B3 Auditory Elements	0.5164	4.1333	0.1249	Reserve	0.5071	4.4	0.1152	Reserve
B4 Psychological Experience	0.7432	4.4667	0.1664	Reserve	0.8165	4.3333	0.1884	Reserve
B5 Cultural Recognition	0.488	4.6667	0.1046	Reserve	0.4577	4.7333	0.0967	Reserve

SD = Standard Deviation; M = Mean; CV = Coefficient of Variation; “Reserve” = Retained; “Delete” = Removed.

According to the statistical results of the first round of expert consultations, the average score for each of the five first-level indicators was above 4.0, suggesting that the experts considered these indicators to be of great importance. The coefficient of variation (CV) for each indicator was below 0.22, demonstrating good consistency in expert ratings and the representativeness of the overall indicator system. A second round of expert evaluations further optimized the performance of the first-level indicator system. Following this optimization, the first-level indicator system exhibited stable performance in terms of importance and consistency (Table 9):

Table 9. Secondary Indicators: Delphi R1–R2 Statistics (Author’s Compilation).

Secondary Indicators	SD (R1)	M (R1)	CV (R1)	Result (R1)	SD (R2)	M (R2)	CV (R2)	Result (R2)
C1 Form	0.2582	4.9333	0.0523	Reserve	0.488	4.6667	0.1046	Reserve
C2 Color	0.2582	4.9333	0.0523	Reserve	0.2582	4.9333	0.0523	Reserve
C3 Light and Shadow	0.488	4.3333	0.1126	Reserve	0.3519	4.8667	0.0723	Reserve
C4 Texture	0.3519	4.8667	0.0723	Reserve	0.8452	4.0	0.2113	Reserve
C5 Material and Touch	0.488	4.6667	0.1046	Reserve	0.3519	4.8667	0.0723	Reserve
C6 Usage Experience	0.7432	4.1333	0.1798	Reserve	0.8452	4.0	0.2113	Reserve
C7 Cultural Sounds	0.5164	4.4667	0.1156	Reserve	0.3519	4.8667	0.0723	Reserve
C8 Sound Environment	0.7368	3.6	0.2047	Delete	-	-	-	-
C9 Guidance and Information	0.2582	4.9333	0.0523	Reserve	0.7037	4.2667	0.1649	Reserve
C10 Spatial Identity	0.7432	4.1333	0.1798	Reserve	0.5164	4.5333	0.1139	Reserve
C11 Emotional Comfort	0.2582	4.9333	0.0523	Reserve	0.5936	4.0667	0.146	Reserve
C12 Safety and Order	0.7432	3.5333	0.2103	Delete	-	-	-	-
C13 City Spirit Conveyance	0.5936	4.2667	0.1391	Reserve	0.5164	4.5333	0.1139	Reserve
C14 Tradition-Modern Integration	0.5936	4.7333	0.1254	Reserve	0.3519	4.8667	0.0723	Reserve
C15 Cultural Perception	0.488	4.6667	0.1046	Reserve	0.3519	4.1333	0.0851	Reserve

SD = Standard Deviation; M = Mean; CV = Coefficient of Variation; “Reserve” = Retained; “Delete” = Removed.

In the first round of expert consultation data, 13 of the 15 secondary indicators evaluated using the Delphi method achieved average scores above 4.0 with coefficients of variation (CV) below 0.22, demonstrating high retention value. Only two indicators—C8 ‘Acoustic Environment’ and C12 ‘Safety and Order’—were recommended for deletion due to low scores or significant expert disagreement. The second round of expert evaluation statistically analyzed the importance and consistency of each secondary indicator, continu-

ing to use ‘an average score of at least 4.0 and a CV of no more than 0.22’ as the selection criteria. Overall, the indicator system demonstrated high scientific rationality, with expert consensus and evaluation showing strong consistency and importance across multiple dimensions. Thirteen indicators were retained (Table 10):

Table 10. Tertiary Indicators: Delphi R1–R2 Statistics (Author’s Compilation).

Tertiary Indicators	SD (R1)	M (R1)	CV (R1)	Result (R1)	SD (R2)	M (R2)	CV (R2)	Result (R2)
D1 Cultural Symbols	0.2582	4.9333	0.0523	Reserve	0.2582	4.9333	0.0523	Reserve
D2 Xi’an Regional Form	0.4577	4.7333	0.0967	Reserve	0.414	4.8	0.0863	Reserve
D3 Spatial Theme	0.2582	4.9333	0.0523	Reserve	0.2582	4.9333	0.0523	Reserve
D4 Regional Colors	0.488	4.6667	0.1046	Reserve	0.7432	4.4667	0.1664	Reserve
D5 Color and Form	0.3519	4.8667	0.0723	Reserve	0.2582	4.9333	0.0523	Reserve
D6 Functional Color Integration	0.5071	4.6	0.1102	Reserve	0.5071	4.6	0.1102	Reserve
D7 Lighting Atmosphere	0.3519	4.8667	0.0723	Reserve	0.488	4.6667	0.1046	Reserve
D8 Light–Shadow Interaction	0.6172	4.6667	0.1323	Reserve	0.7432	4.5333	0.1639	Reserve
D9 Theme Recognition	0.6172	4.3333	0.1424	Reserve	0.3519	4.8667	0.0723	Reserve
D10 Perceptible Texture	0.2582	4.9333	0.0523	Reserve	0.8837	4.0667	0.2173	Reserve
D11 Cultural Coordination	0.488	4.6667	0.1046	Reserve	0.8837	4.0667	0.2173	Reserve
D12 Tactile Comfort	0.5606	4.8	0.1168	Reserve	0.3519	4.8667	0.0723	Reserve
D13 Regional Craft	0.5164	4.5333	0.1139	Reserve	0.488	4.6667	0.1046	Reserve
D14 Durable and Easy Maintenance	0.5936	4.7333	0.1254	Reserve	0.2582	4.9333	0.0523	Reserve
D15 Auxiliary Facilities	0.4577	4.7333	0.0967	Reserve	0.414	4.8	0.0863	Reserve
D16 Emotional Belonging	0.488	4.6667	0.1046	Reserve	0.8997	3.6667	0.2454	Delete
D17 Accessibility Friendly	0.4577	4.7333	0.0967	Reserve	0.2582	4.9333	0.0523	Reserve
D18 Regional Cultural Sound	0.5071	4.6	0.1102	Reserve	0.6399	4.5333	0.1412	Reserve
D19 Cultural Scene Creation	0.4577	4.7333	0.0967	Reserve	0.7988	4.2667	0.1872	Reserve
D20 Noise Control	0.8619	3.8	0.2268	Delete	-	-	-	-
D21 Sound Comfort	0.9155	3.5333	0.2591	Delete	-	-	-	-
D22 Broadcast Clarity	0.5164	4.5333	0.1139	Reserve	0.2582	4.9333	0.0523	Reserve
D23 Accessible Voice Aid	0.488	4.6667	0.1046	Reserve	0.3519	4.8667	0.0723	Reserve
D24 Visual Sign Clarity	0.3519	4.8667	0.0723	Reserve	0.7432	3.5333	0.2103	Delete
D25 Cultural Identity	0.6399	4.4667	0.1433	Reserve	0.2582	4.9333	0.0523	Reserve
D26 Urban Spirit Expression	0.2582	4.9333	0.0523	Reserve	0.6325	4.6	0.1375	Reserve
D27 Memorability and Recognition	0.2582	4.9333	0.0523	Reserve	0.5071	4.6	0.1102	Reserve
D28 Spatial Affinity	0.5164	4.5333	0.1139	Reserve	0.5606	4.8	0.1168	Reserve
D29 Art–Nature Integration	0.5164	4.5333	0.1139	Reserve	0.2582	4.9333	0.0523	Reserve
D30 Waiting Comfort	0.4577	4.7333	0.0967	Reserve	0.488	4.6667	0.1046	Reserve
D31 Spatial Openness	0.9759	3.6667	0.2662	Delete	-	-	-	-
D32 Clear Layout	0.8837	3.7333	0.2367	Delete	-	-	-	-
D33 Sense of Security	0.7988	3.7333	0.214	Delete	-	-	-	-
D34 Cultural Character	0.414	4.8	0.0863	Reserve	0.3519	4.8667	0.0723	Reserve
D35 Public Memory	0.3519	4.8667	0.0723	Reserve	0.8997	3.6667	0.2454	Delete
D36 City Symbol Elements	0.7432	4.5333	0.1639	Reserve	0.2582	4.9333	0.0523	Reserve
D37 Innovation of Tradition	0.3519	4.8667	0.0723	Reserve	0.7368	4.4	0.1675	Reserve
D38 Material and Craft Innovation	0.5071	4.6	0.1102	Reserve	0.2582	4.9333	0.0523	Reserve
D39 Digital Cultural Display	0.414	4.8	0.0863	Reserve	0.5164	4.4667	0.1156	Reserve
D40 Cultural Resonance	0.5071	4.4	0.1152	Reserve	0.3519	4.8667	0.0723	Reserve
D41 Artistic Appeal	0.2582	4.9333	0.0523	Reserve	0.6399	4.4667	0.1433	Reserve
D42 City Recognition	0.4577	4.7333	0.0967	Reserve	0.2582	4.9333	0.0523	Reserve

SD = Standard Deviation; M = Mean; CV = Coefficient of Variation; “Reserve” = Retained; “Delete” = Removed.

In the first round of Delphi expert scoring, the importance and consistency of 42 third-level indicators were evaluated. Based on the screening criteria of an average score of at least 4.0 and a coefficient of variation (CV) of no more than 0.22, five indicators failed to pass: D20 Noise Control, D21 Acoustic Comfort, D31 Spatial Openness, D32

Layout Clarity and D33 Sense of Security. The first-round screening process further refined and stabilized the indicator system. Subsequently, in the second round of expert review, the average scores for D16 Emotional Belonging, D24 Visual Recognition Clarity and D35 Public Memory all fell below 4.0. Experts recommended deleting these relatively subjective indicators, as they proved difficult to agree upon. Following two rounds of expert feedback and rigorous data screening, the tertiary indicator system achieved overall reliability and practical value.

3.3. Weight Analysis Based on the Analytic Hierarchy Process

A design evaluation system for Xi'an subway stations was established based on a two-round Delphi study. The Analytic Hierarchy Process (AHP) was then used to calculate the weightings. Fifteen experts were invited to participate in the assessment. The experts were primarily faculty members from multiple Xi'an universities, as well as professionals engaged in architectural design and rail transit within the city. The composition of the expert panel ensured the representativeness and scientific rigor of the subjective weight assignments within the AHP methodology (Table 11).

Table 11. Details of the Experts (AHP Panel; Author's Compilation).

Number	Professional Title	Work Years	Expertise Area
Expert 1	Senior Engineer	10–20	Rail Transit Design
Expert 2	Associate Professor	10–20	Architectural Design
Expert 3	Professor	10–20	Urban Planning
Expert 4	Senior Engineer	10–20	Rail Transit Design
Expert 5	Associate Professor	10–20	Environmental Design
Expert 6	Senior Engineer	10–20	Architectural Design
Expert 7	Senior Engineer	20–30	Urban Planning
Expert 8	Associate Professor	10–20	Transportation Design
Expert 9	Senior Engineer	10–20	Rail Transit Design
Expert 10	Senior Engineer	10–20	Environmental Design
Expert 11	Engineer	1–10	Interior Design
Expert 12	Associate Professor	1–10	Interior Design
Expert 13	Engineer	1–10	Environmental Design
Expert 14	Professor	10–20	Urban Planning
Expert 15	Professor	10–20	Interior Design

From 1 April to 10 May 2025, this study conducted a questionnaire survey via email. Experts performed pairwise judgments on each element layer to construct a judgment matrix for each indicator level. The results were collected and aggregated in Microsoft Excel and Yaahp 2.6 to calculate indicator weights at each level, as shown in Table 12.

Following verification, all layer-level judgment matrices and the target layer have passed consistency tests, with CR values below 0.1. Of the primary indicators, Visual Expression (0.2462) has the greatest influence on the evaluation of the spatial design of Xi'an subway station, followed by B5 Cultural Identity (0.2247), B3 Auditory Elements (0.2071), B4 Psychological Experience (0.1654) and B2 Tactile Elements (0.1567). Among the secondary indicators, form has the greatest weighting, followed by cultural perception, cultural soundscape, guidance and information, and emotional comfort. The top five tertiary indicators are Spatial Theme, Cultural Scenario Creation, Urban Identity, Xi'an Regional Form and Accessible Voice Assistance.

Table 12. Hierarchical Weight Structure of the AHP Evaluation System (Author’s Compilation).

First-Level Indicator	Weight W1	Second-Level Indicator	Weight W2	Third-Level Indicator	Weight W3
B1 Visual Expression	0.2462	C1 Form	0.6613	D1 Cultural Symbols	0.1114
				D2 Xi’an Regional Form	0.34
				D3 Spatial Theme	0.5486
		C2 Color	0.1808	D4 Regional Colors	0.3684
				D5 Color and Form	0.178
				D6 Functional Color Integration	0.4536
		C3 Light and Shadow	0.1579	D7 Lighting Atmosphere	0.4144
				D8 Light–Shadow Interaction	0.1699
				D9 Theme Recognition	0.4157
B2 Tactile Elements	0.1567	C4 Texture	0.197	D10 Perceptible Texture	0.4907
				D11 Cultural Coordination	0.5093
		C5 Material and Touch	0.224	D12 Tactile Comfort	0.353
				D13 Regional Craft	0.1808
				D14 Durable and Easy Maintenance	0.4661
		C6 Usage Experience	0.579	D15 Auxiliary Facilities	0.4135
				D16 Accessibility Friendly	0.5865
B3 Auditory Elements	0.2071	C7 Cultural Sounds	0.5209	D17 Regional Cultural Sound	0.458
				D18 Cultural Scene Creation	0.542
		C8 Guidance and Information	0.4791	D19 Accessible Voice Aid	0.539
				D20 Visual Sign Clarity	0.461
B4 Psychological Experience	0.1654	C9 Spatial Identity	0.4447	D21 Cultural Identity	0.3723
				D22 Urban Spirit Expression	0.4877
				D23 Memorability and Recognition	0.1401
		C10 Emotional Comfort	0.5553	D24 Spatial Affinity	0.4635
				D25 Art–Nature Integration	0.5365
				D26 Cultural Character	0.3085
B5 Cultural Recognition	0.2247	C11 City Spirit Conveyance	0.2805	D27 Public Memory	0.3156
				D28 City Symbol Elements	0.376
				D29 Innovation of Tradition	0.2366
		C12 Tradition–Modern Integration	0.2032	D30 Material and Craft Innovation	0.4482
				D31 Digital Cultural Display	0.3152
				D32 Cultural Resonance	0.1531
		C13 Cultural Perception	0.5163	D33 Artistic Appeal	0.3697
				D34 City Recognition	0.4772

3.4. Calculate the Fuzzy Comprehensive Evaluation Score

To further optimize the plan, the FCE method was used to evaluate it. Between 22 April and 15 May 2025, this study invited 20 experts from relevant fields to participate in the Analytic Hierarchy Process (AHP). Their areas of expertise included urban planning, transportation engineering and architectural design, among others. The majority were aged 30–40, and over 50% held master’s or doctoral degrees. This ensured the credibility of the survey.

In mid-May 2025, a large-scale survey was conducted among Xi’an subway passengers. A questionnaire was distributed to 165 passengers, with 130 valid responses collected. The primary age group among these respondents was 36–45 years old (23.8%), and the most common level of education was a bachelor’s degree. Travel patterns indicated that the sample primarily engaged in functional daily commutes, predominantly for work and errands. Ultimately, 150 participants provided ratings, including 20 experts and 130 subway passengers who represented the target audience. The membership degree for each indicator was calculated as the ratio of evaluators to the total number of participants. The aggregated results are presented in the Table 13 below:

Table 13. Fuzzy Comprehensive Evaluation Results for the Indicators (Author’s Compilation).

Evaluation Indicator	Excellent	Good	Average	Below Average	Poor
D1 Cultural Symbols	0.44	0.26	0.28	0.02	0.0
D2 Xi’an Regional Form	0.54	0.34	0.06	0.06	0.0
D3 Spatial Theme	0.67	0.17	0.16	0.0	0.0
D4 Regional Colors	0.47	0.31	0.22	0.0	0.0
D5 Color and Form	0.19	0.30	0.37	0.14	0.0
D6 Functional Color Integration	0.02	0.39	0.59	0.0	0.0
D7 Lighting Atmosphere	0.67	0.23	0.10	0.0	0.0
D8 Light–Shadow Interaction	0.15	0.53	0.27	0.05	0.0
D9 Theme Recognition	0.32	0.45	0.23	0.0	0.0
D10 Perceptible Texture	0.25	0.35	0.40	0.0	0.0
D11 Cultural Coordination	0.25	0.50	0.16	0.09	0.0
D12 Tactile Comfort	0.45	0.37	0.13	0.05	0.0
D13 Regional Craft	0.37	0.23	0.23	0.12	0.05
D14 Durable and Easy Maintenance	0.56	0.23	0.17	0.04	0.0
D15 Auxiliary Facilities	0.24	0.31	0.44	0.01	0.0
D16 Accessibility Friendly	0.17	0.70	0.13	0.0	0.0
D17 Regional Cultural Sound	0.60	0.23	0.17	0.0	0.0
D18 Cultural Scene Creation	0.73	0.17	0.06	0.04	0.0
D19 Accessible Voice Aid	0.62	0.13	0.25	0.0	0.0
D20 Visual Sign Clarity	0.32	0.27	0.26	0.15	0.0
D21 Cultural Identity	0.52	0.17	0.27	0.04	0.0
D22 Urban Spirit Expression	0.51	0.27	0.20	0.02	0.0
D23 Memorability and Recognition	0.37	0.28	0.22	0.08	0.05
D24 Spatial Affinity	0.45	0.24	0.16	0.15	0.0
D25 Art–Nature Integration	0.37	0.29	0.25	0.09	0.0
D26 Cultural Character	0.19	0.28	0.42	0.11	0.0
D27 Public Memory	0.15	0.32	0.50	0.0	0.0
D28 City Symbol Elements	0.29	0.24	0.39	0.08	0.0
D29 Innovation of Tradition	0.43	0.35	0.07	0.08	0.07
D30 Material and Craft Innovation	0.31	0.39	0.30	0.0	0.0
D31 Digital Cultural Display	0.54	0.16	0.23	0.07	0.0
D32 Cultural Resonance	0.22	0.43	0.19	0.13	0.03
D33 Artistic Appeal	0.39	0.46	0.15	0.0	0.0
D34 City Recognition	0.61	0.30	0.09	0.0	0.0

This hierarchical structure functions as a multi-level indicator system and requires multi-level, comprehensive evaluation to derive the final assessment results. Fuzzy evaluation is conducted for the third-level indicators C1–C13 based on statistical outcomes. The membership degrees of C1–C13 are then calculated using their weight sets and fuzzy matrix statistics.

$$\begin{aligned}
 Z_{C1} &= W_{C1} \times F_{C1} = [0.6002 \ 0.2378 \ 0.1394 \ 0.0226 \ 0.0] \\
 Z_{C2} &= W_{C2} \times F_{C2} = [0.216 \ 0.3445 \ 0.4145 \ 0.0249 \ 0.0] \\
 Z_{C3} &= W_{C3} \times F_{C3} = [0.4362 \ 0.3724 \ 0.1829 \ 0.085 \ 0.0] \\
 Z_{C4} &= W_{C4} \times F_{C4} = \begin{bmatrix} 0.25 & 0.4264 & 0.2778 & 0.0458 & 0.0 \end{bmatrix} \\
 Z_{C5} &= W_{C5} \times F_{C5} = [0.4868 \ 0.2794 \ 0.1667 \ 0.058 \ 0.009] \\
 Z_{C6} &= W_{C6} \times F_{C6} = \begin{bmatrix} 0.1989 & 0.5387 & 0.2582 & 0.0041 & 0.0 \end{bmatrix} \\
 Z_{C7} &= W_{C7} \times F_{C7} = \begin{bmatrix} 0.6705 & 0.1975 & 0.1104 & 0.0217 & 0.0 \end{bmatrix} \\
 Z_{C8} &= W_{C8} \times F_{C8} = \begin{bmatrix} 0.4817 & 0.1945 & 0.2546 & 0.0692 & 0.0 \end{bmatrix} \\
 Z_{C9} &= W_{C9} \times F_{C9} = [0.4942 \ 0.2342 \ 0.2287 \ 0.0359 \ 0.007] \\
 Z_{C10} &= W_{C10} \times F_{C10} = \begin{bmatrix} 0.4071 & 0.2668 & 0.2083 & 0.1178 & 0.0 \end{bmatrix} \\
 Z_{C11} &= W_{C11} \times F_{C11} = [0.215 \ 0.2776 \ 0.434 \ 0.0735 \ 0.0] \\
 Z_{C12} &= W_{C12} \times F_{C12} = [0.4109 \ 0.308 \ 0.2235 \ 0.0104 \ 0.0118] \\
 Z_{C13} &= W_{C13} \times F_{C13} = [0.469 \ 0.3791 \ 0.1275 \ 0.0199 \ 0.0046]
 \end{aligned} \tag{8}$$

Based on the statistical results, a fuzzy evaluation is performed on secondary indicator B1. The weight set and fuzzy matrix of B1 are denoted W_{B1} and F_{B1} , respectively, and the membership degree of B1 is calculated.

$$\begin{aligned}
 W_{B1} &= \begin{bmatrix} 0.6613 & 0.1808 & 0.1579 \end{bmatrix} \\
 F_{B1} &= \begin{bmatrix} 0.6002 & 0.2378 & 0.1394 & 0.0226 & 0.0 \\ 0.216 & 0.3445 & 0.4145 & 0.0249 & 0.0 \\ 0.4362 & 0.3724 & 0.1829 & 0.0085 & 0.0 \end{bmatrix} \\
 Z_{B1} &= W_{B1} \times F_{B1} = [0.5048 \ 0.2783 \ 0.196 \ 0.0208 \ 0.0]
 \end{aligned} \tag{9}$$

Based on the statistical results, a fuzzy evaluation is performed on indicator B2. Its weight set and fuzzy matrix are denoted W_{B2} and F_{B2} , respectively, and the membership degree of B2 is calculated.

$$\begin{aligned}
 W_{B2} &= \begin{bmatrix} 0.197 & 0.224 & 0.579 \end{bmatrix} \\
 F_{B2} &= \begin{bmatrix} 0.250 & 0.4264 & 0.2778 & 0.0458 & 0.0 \\ 0.4868 & 0.2794 & 0.1667 & 0.058 & 0.009 \\ 0.1989 & 0.5387 & 0.2582 & 0.0041 & 0.0 \end{bmatrix} \\
 Z_{B2} &= W_{B2} \times F_{B2} = \begin{bmatrix} 0.2735 & 0.4585 & 0.2416 & 0.0244 & 0.002 \end{bmatrix}
 \end{aligned} \tag{10}$$

Based on the statistical results, a fuzzy evaluation is performed on indicator B3. Its weight set and fuzzy matrix are denoted W_{B3} and F_{B3} , respectively. The membership degree of B3 is calculated as follows:

$$\begin{aligned}
 W_{B3} &= \begin{bmatrix} 0.5209 & 0.4791 \end{bmatrix} \\
 F_{B3} &= \begin{bmatrix} 0.6705 & 0.1975 & 0.1104 & 0.0217 & 0 \\ 0.4817 & 0.1945 & 0.2546 & 0.0692 & 0 \end{bmatrix} \\
 Z_{B3} &= W_{B3} \times F_{B3} = \begin{bmatrix} 0.58 & 0.1961 & 0.1795 & 0.0445 & 0.0 \end{bmatrix}
 \end{aligned} \tag{11}$$

Based on the statistical results, a fuzzy evaluation is performed on indicator B4. Its weight is denoted as W_{B4} and its fuzzy matrix as F_{B4} . The membership degree of B4 is then calculated.

$$\begin{aligned} W_{B4} &= \begin{bmatrix} 0.4447 & 0.5553 \end{bmatrix} \\ F_{B4} &= \begin{bmatrix} 0.4942 & 0.2342 & 0.2289 & 0.0359 & 0.007 \\ 0.4071 & 0.2668 & 0.2083 & 0.1178 & 0.0 \end{bmatrix} \\ Z_{B4} &= W_{B4} \times F_{B4} = \begin{bmatrix} 0.4448 & 0.2523 & 0.2175 & 0.0814 & 0.0031 \end{bmatrix} \end{aligned} \quad (12)$$

Based on the statistical results, a fuzzy evaluation is performed for indicator B5. Its weight set and fuzzy matrix are denoted W_{B5} and F_{B5} , respectively. The membership degree of B5 is calculated as follows:

$$\begin{aligned} W_{B5} &= \begin{bmatrix} 0.2805 & 0.2032 & 0.5163 \end{bmatrix} \\ F_{B5} &= \begin{bmatrix} 0.215 & 0.277 & 0.434 & 0.0735 & 0.0 \\ 0.4109 & 0.308 & 0.2235 & 0.041 & 0.0166 \\ 0.469 & 0.3791 & 0.1275 & 0.0199 & 0.0046 \end{bmatrix} \\ Z_{B5} &= W_{B5} \times F_{B5} = \begin{bmatrix} 0.3859 & 0.3362 & 0.233 & 0.0392 & 0.0057 \end{bmatrix} \end{aligned} \quad (13)$$

Finally, a fuzzy evaluation is performed on target layer A based on the statistical results. Its weight set and fuzzy matrix are denoted W_A and F_A , respectively, and the membership degree of A is calculated.

$$\begin{aligned} W_A &= \begin{bmatrix} 0.2462 & 0.1567 & 0.2071 & 0.1654 & 0.2247 \end{bmatrix} \\ F_A &= \begin{bmatrix} 0.5048 & 0.2783 & 0.196 & 0.0208 & 0.0 \\ 0.2735 & 0.4585 & 0.2416 & 0.0244 & 0.002 \\ 0.58 & 0.1961 & 0.1795 & 0.0445 & 0.0 \\ 0.4458 & 0.2523 & 0.2175 & 0.0814 & 0.0031 \\ 0.3859 & 0.3362 & 0.233 & 0.0472 & 0.0057 \end{bmatrix} \\ Z_A &= W_A \times F_A = \begin{bmatrix} 0.4127 & 0.2983 & 0.2314 & 0.0566 & 0.0021 \end{bmatrix} \end{aligned} \quad (14)$$

This study adopts the Fuzzy Comprehensive Evaluation (FCE) method to establish a multi-dimensional quantitative assessment model. The results show that the spatial design of Xi'an metro stations is predominantly classified as the "Good" and "Excellent" grades. Specifically, the membership degree for "Good" is 0.2983, and that of "Excellent" is 0.4127. The evaluation demonstrates outstanding performance in visual expression, cultural identity, and psychological experience. Overall, the design effectively embodies the city's historical and cultural connotations. These findings provide valuable empirical references for subsequent metro design and renovation initiatives.

4. Discussion

4.1. Methodological Innovation

This study uses the Delphi method to select indicators and employs a combined approach with the AHP-FCE method for data research and analysis. This methodology offers greater systematicity and comprehensiveness in data collection and analysis, while the FCE method incorporates the passenger perspective. Analysis of the AHP-FCE research evaluation results reveals significant consensus between passengers and experts regarding the design of Xi'an subway stations. Visual expression is critical for improving the overall spatial design of subway stations, reflecting the public's focus on historical and cultural aspects of visual expression in public spaces. Results from indicators such as cultural

identity, auditory perception, psychological evaluation and tactile experience highlight the importance of multisensory design.

The methodology and empirical contributions of this study were validated using a quantitative research framework. As a renowned historical city in China, Xi'an prioritizes the preservation and promotion of its cultural heritage. Guided by the Xi'an Municipal Government's policy directives for subway station design, the project enhances cultural expression and the continuity of urban memory, all the while ensuring the safety and accessibility of service information. Based on the FCE results of Xi'an subway stations, the overall spatial design is in line with the policy directives. Visual expression and auditory elements scored highest, indicating recognition of the thematic and structural design execution of Xi'an Metro. Psychological experience and cultural recognition metrics approached excellence, demonstrating effective urban cultural communication with a clear identity. However, tactile elements showed overall weakness, and there is room for improvement in spatial color expression, light-shadow interaction, thematic continuity and the depth of spatial narrative storytelling.

In summary, all judgment matrices in the AHP study, including the objective layer, have passed consistency tests. In the FCE assessment, the Xi'an subway station spatial design achieved the highest membership degree for 'Excellent' in the overall fuzzy comprehensive evaluation. The individual scores provide empirical evidence that further establishes the methodological innovation of evaluating the spatial design of Xi'an subway station.

4.2. Application of Genius Loci in Metro Design

Based on prior literature, scholars have progressively shifted their focus from the esthetics of traditional spatial forms to the study of natural sustainability and cultural synergy. In particular, with regard to the impact of space on human emotions, these factors emphasize the importance of a human-centered approach. However, gaps remain in the quantitative assessment of the isomorphy relationship between human senses and space within design strategies focused on human-space interaction, as well as in empirical evaluations of subway station spatial design. This study addresses these issues by employing a quantitative AHP-FCE method integrated with the theory of place spirit. Using the design of Xi'an subway stations as a case study, this approach systematically quantifies passengers' sensory experiences within the space, revealing the demand for culturally resonant spaces and context-adaptive technologies. AHP-FCE analysis provides empirical evidence directly linking these dimensions to core outcomes. By integrating user-driven data, the analysis translates theoretical propositions for designing metro spaces infused with historical and cultural elements into actionable frameworks, thereby deepening public understanding of subway station design and construction.

4.3. Research Implications

Based on empirical analysis and related discussions, this study has produced several recommendations for the design of Xi'an subway stations. These recommendations are intended to help government departments and planners enhance design implementation. The design analysis is as follows:

The AHP calculation results show that Xi'an subway stations demonstrate outstanding design performance in terms of visual culture. The integration of spatial form and artistic expression creates a unique historical and cultural atmosphere. Visual expression accounts for a significant proportion, and the combined weight of the three dimensions—cultural cognition and auditory elements—exceeds 67%. This proves that visual elements dominate subway station design and that culture and auditory elements reinforce each other.

Therefore, based on the case study of Xi'an subway stations, the design of subway stations should prioritize two core aspects of visual expression: 'Design Form' and 'Design Colors'. This involves strengthening design morphology, emphasizing the thematic integration of color and lighting, and incorporating historical and cultural narratives into spatial design through traditional Chinese elements such as ancient scripts and murals. Another major indicator is that auditory elements can incorporate opera, dialects and other sounds to create soundscapes that form part of the spatial cultural narrative. Concurrently, it is crucial to address the limitations of tactile experiences. There should be an emphasis on multi-sensory interactive experiences and accessible facilities, transforming subway spaces into culturally resonant places that are perceptible, recognizable and memorable (Figure 5).

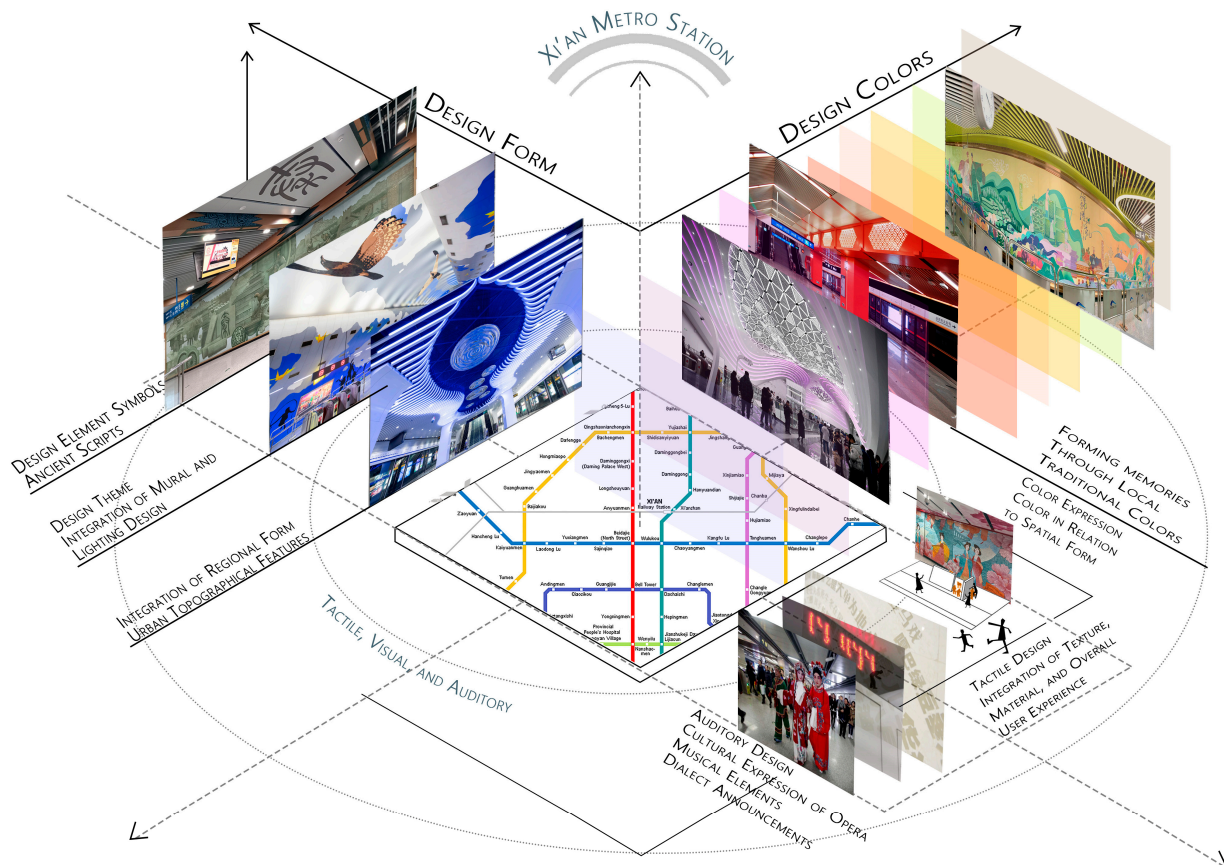


Figure 5. Conceptual Framework of Metro Station Spatial Design (Source: Authors).

AHP research identified the core indicators for the design of Xi'an subway stations, while FCE analysis revealed design shortcomings and guided further optimization. Based on the analysis of relatively weaker indicators, eight key recommendations for modifications were formulated: enhance cultural coordination and material perception, improve the integration of spatial artistry and nature, strengthen the expression of cultural characteristics, innovate traditional craftsmanship and materials, improve auxiliary facilities, optimize color and form, enhance cultural resonance, and improve the interplay of light and shadow (Figure 6).

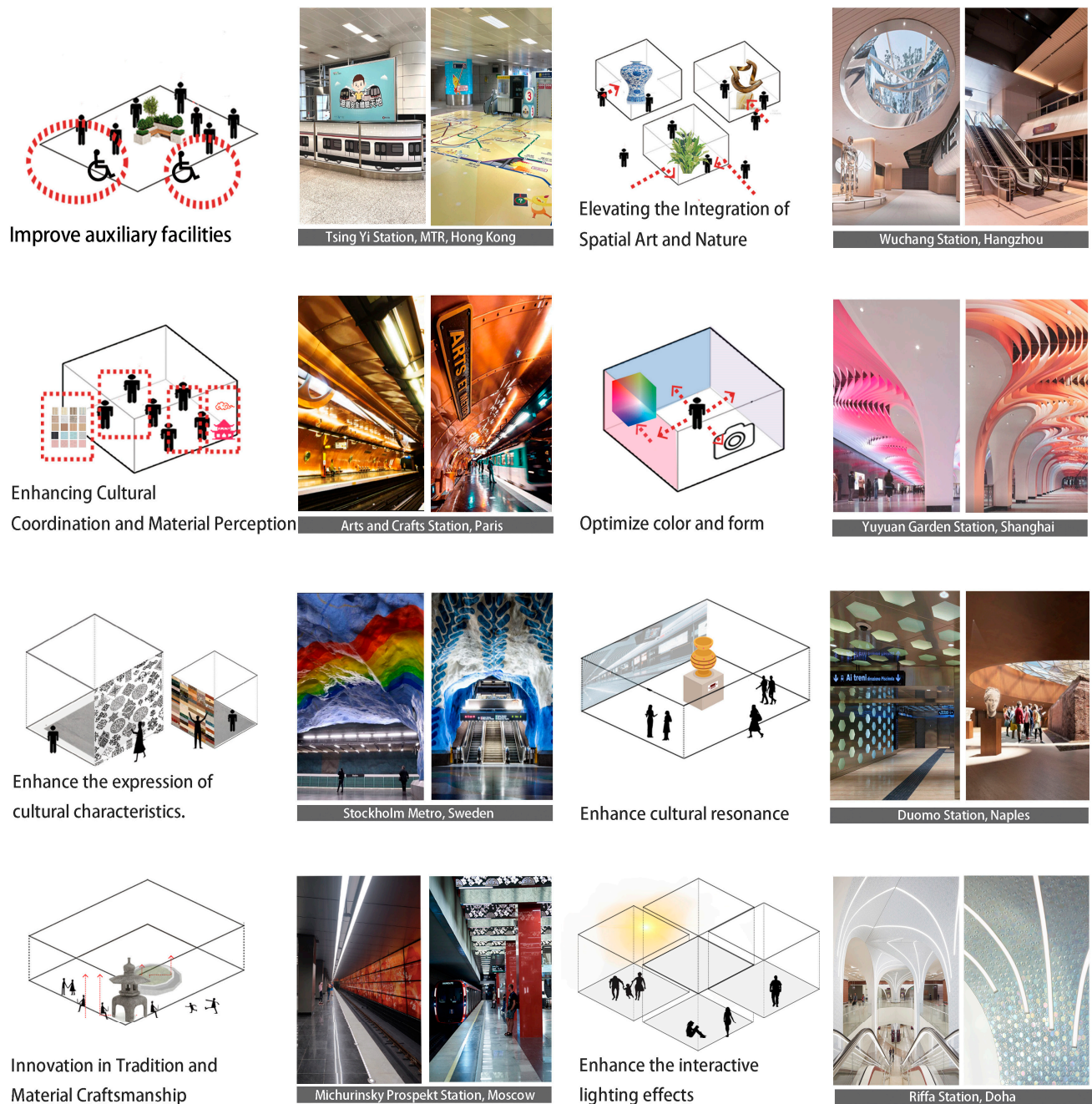


Figure 6. Metro Station Spatial Design (Source: Authors).

Based on field research at Chinese subway stations and project presentations from overseas subway operators' websites, combined with theoretical analysis, the following design recommendations are proposed: First, regarding auxiliary facilities, prioritize rational distribution and accessibility. Hong Kong MTR stations exemplify this through educational signage and enhanced barrier-free design, ensuring convenience for diverse user groups. Second, to enhance the integration of spatial artistry with nature, we strengthen the fusion of artistic and natural elements. Hangzhou Metro stations incorporate circular skylights within existing architectural structures, channeling natural light through an hourglass-shaped design to elevate passenger comfort and immersion. Regarding color and form optimization, functional color unity is emphasized. Shanghai Metro stations integrate varied color lighting into undulating wave-patterned ceilings, elevating overall esthetics and immersion. To enhance cultural harmony and material perception, cultural symbols

are aligned with spatial design. Paris Metro stations feature copper-colored riveted metal panels alongside massive gears and mechanical installations, creating a retro-futuristic atmosphere. In strengthening cultural expression, public memory points are reinforced. Sweden's metro stations integrate local culture to heighten spatial cultural identity and commemorative value. In innovating traditional materials and craftsmanship, the Moscow Metro employs design techniques that express the characteristics of traditional materials, combining traditional patterns with lighting and decorative art to enhance modernity and cultural continuity. To improve light-and-shadow interaction effects, Doha Metro stations create open, bright, and welcoming interiors through distinctive decorative elements and material combinations. Finally, to deepen cultural resonance, stations offer immersive cultural experiences. Cathedral Station features an exhibition-ready archeological space that integrates the metro station with a museum to evoke emotional and cultural connections among visitors.

Contemporary subway design must balance multiple dimensions, including barrier-free access, environmental integration, visual unity, cultural expression, material quality, and narrative depth. When these dimensions synergize, subway stations transcend mere transit spaces and evolve into genuine places that awaken the senses, create memories, and foster a sense of belonging.

5. Conclusions

With the progression of the times, the design of Chinese subway stations has evolved from merely meeting basic functional requirements to enhancing urban cultural value. Their spatial design has gradually achieved in-depth integration with the historical and cultural heritage of cities, forming organic complementarity with core transportation functions. While the development of historical and cultural design within subway stations has advanced rapidly, systematic evaluation methods for such designs remain relatively insufficient. This study takes Xi'an, an ancient city with millennia of cultural heritage, as the research case, systematically exploring the application pathway of the AHP-FCE (Analytic Hierarchy Process-Fuzzy Comprehensive Evaluation) method in subway station spatial design. It provides a novel systematic research framework for the integration of historical and cultural design elements into global subway spaces.

The purpose of subway stations is to craft tailored spaces for passengers, allowing them to immerse themselves in the cultural connotations conveyed by these spaces and elevating subway travel into a spiritual enjoyment. This study employs a theoretical framework anchored in "Genius Loci" (Spirit of Place) and grounded in multisensory design principles, aiming to examine the interplay between humans and space. It fosters emotional attachment to the place, evoking recognition of its value and significance while nurturing a strong sense of belonging. Through theoretical investigations and a systematic literature review, alongside indicator screening and model construction via the Delphi method, a research framework encompassing 5 primary indicators, 13 secondary indicators, and 34 tertiary indicators was ultimately established. This research framework offers valuable insights and a robust foundation for subsequent evaluation research on subway stations.

Through the analysis of indicators via the Analytic Hierarchy Process (AHP), this study ascertained the design elements for subway station spaces integrating history and culture, as well as their hierarchical priority levels. The findings demonstrate that visual design, auditory elements, and cultural cognition constitute the core focal points of subway station design, while passenger subway station usage experience and design aesthetics also deserve heightened attention. Subsequently, a comprehensive evaluation of the designs was conducted based on the Fuzzy Comprehensive Evaluation (FCE) method, revealing that the majority of Xi'an subway station designs fall into the "Good" and "Fairly Good" rating

levels. At the design operational level, key aspects requiring prioritization encompass: cultural coordination and material perception, spatial artistry and integration with nature, innovation in traditional materials and craftsmanship, expression of cultural characteristics, enhancement of auxiliary facilities, optimization of color and form, cultural resonance, and interactive lighting effects. The application of the AHP-FCE integrated evaluation model not only guarantees the rationality of the research structure but also minimizes subjective biases of decision-makers to the greatest extent.

This study adopts three integrated methodologies: the Delphi method, the Analytic Hierarchy Process (AHP), and Fuzzy Comprehensive Evaluation (FCE). Their combination features close interconnection, progressive logic, and complementary advantages. This integrated approach empowers designers globally to formulate and optimize subway station design schemes in a more scientific and systematic manner. Nevertheless, historical and cultural expression is overlooked in some subway station designs. Thus, the deepening and expansion of this theoretical framework are pivotal for applied research focusing on the integration of history and culture into subway station design. Based on the systematic analysis and in-depth investigation of spatial design in Xi'an Metro stations (China), this research provides actionable references for subway station designers worldwide. It encourages designers to explore their own national cultural heritage, thereby enhancing local passengers' emotional, environmental, and cultural identification with subway station spaces. Ultimately, this elevates the practical value of the methodological findings to a higher dimension.

This study still has certain limitations. First, the evaluation indicator system and comprehensive evaluation method are constrained by time and cannot be validated through extensive long-term research, and there remains a lack of systematic evaluation methodologies and research paradigms. Therefore, future studies should prioritize the long-term refinement and validation of indicators across all hierarchical levels. Subsequent studies will apply the AHP-FCE model developed in this research to subway station designs in other cities. This will facilitate in-depth exploration of subway station designs amid diverse historical and cultural contexts, examining synergistic development pathways between theoretical research and subway station spatial design. The core objective is to uncover a spatial renewal design system for subway stations, providing multiple options and references for subsequent subway station design. Such an approach seeks to transcend mere functional attributes, transforming subway stations into cultural calling cards that embody and showcase a city's historical heritage.

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