https://doi.org/10.15302/J-LAF-0-020032 Received Date | 2024-07-08 Accepted Date | 2025-01-15

Naturalized or Paved: Preference Conflicts and Resolution Strategies of Trail Spaces in Suburban Mountain Areas

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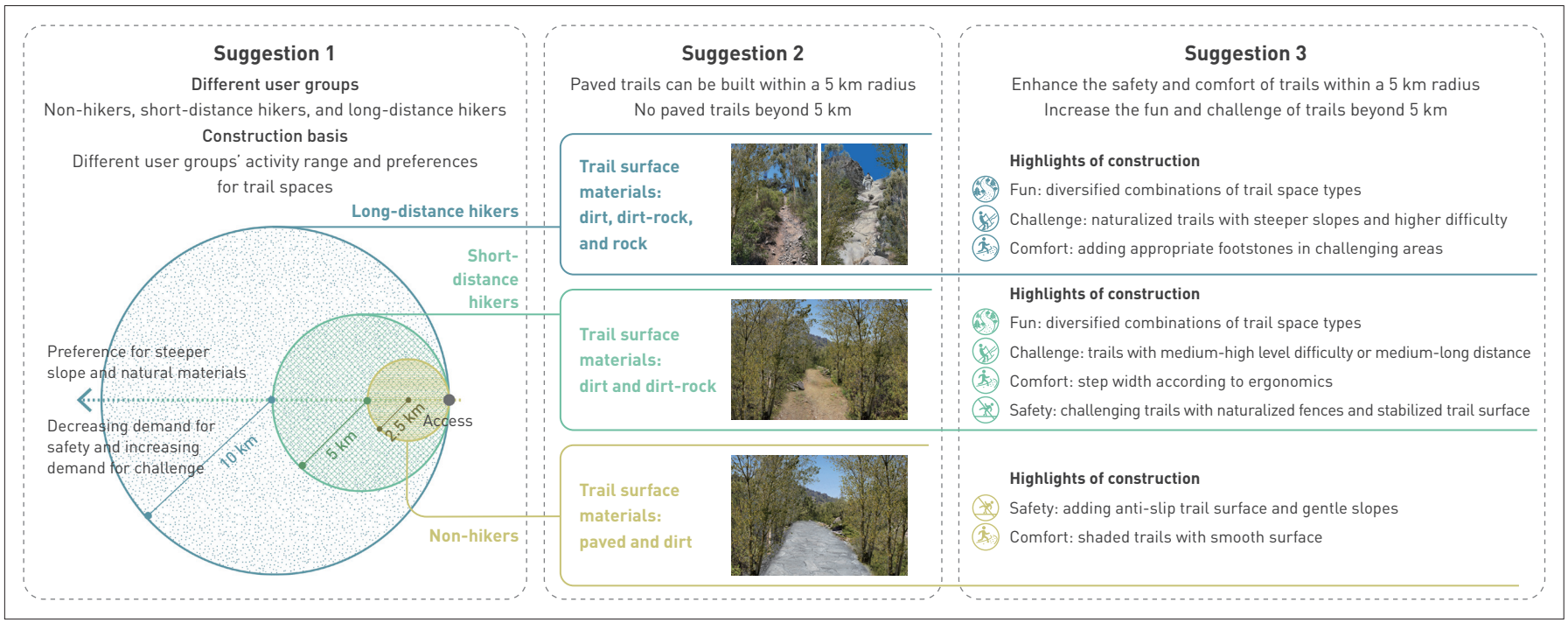
GRAPHICAL ABSTRACT



ABSTRACT

As the awareness of public health arises, hiking has grown increasingly popular. Suburban mountain areas have become important areas of activities for recreational exercisers like hikers, necessitating adaptations in the planning and construction of their trail systems to meet diverse demands. Taking Xiaoxishan in Beijing as a case study, this research classifies the spatial characteristics of the trail spaces based on data from the 2bulu website and field surveys, examines the profiles of trail users and their evaluations of various trail spaces through questionnaire surveys, and explores the preferences, the differences in preferences, and the underlying reasons for preferences among non-hikers and hikers (including short-distance and long-distance hikers). The results show a clear preference for naturalized trail spaces—including the importance level to spatial elements, the preference of trial surface materials, and the preference of specific trail space types—as the preferred hiking distance increases. Specifically, the importance of slope decreases while the preference for steeper slopes increases; the attention to trail surface materials intensifies while the preference shifting from paved trails to dirt or dirt-rock trails. In addition, concerns about safety decrease, while demands for comfort and

fun among long-distance hikers increase. Based on these varying preferences, this study proposes differentiated trail design strategies and provides practical insights to enrich the content of the National Fitness Strategy, inform the formulation of trail system policies, and facilitate related planning and design practice.

KEYWORDS

Suburban Mountain Area; Trail Space; Mountain Hiking; Preference Difference; Xiaoxishan in Beijing

HIGHLIGHTS

- Reveals diverse user profiles of suburban mountain trails
- Discovers similarities and differences in preferences for paved and naturalized trails among different user groups
- Reveals that suburban mountain trail improvements do not meet hikers' needs
- Different user groups see a demand disparity in safety and challenge and common demands for comfort and fun

RESEARCH FUND

Project of "Research on the Formation Mechanism of Recreational Service Values of Urban Green Space System Based on Multi-source Data," the National Natural Science Foundation of China (No. 42271300)

EDITED BY Tina TIAN, Moying WANG

1 Introduction

Rapid urbanization and rising living standards have made public health a critical global concern. As a cost-effective and accessible form of physical activity, hiking not only enhances physiological functions[1] but also, through exposure to nature, positively impacts cognitive capacity, emotional state, and stress level[2], while exerting overall benefits on physical and mental health[3][4]. In recent years, hiking has gradually become one of the popular tourism and leisure activities. According to the *China Hiking Tourism Development Report (2019)*, approximately 130 million people engage in outdoor sports in China, with hiking being the most popular and frequently participated activity among outdoor enthusiasts for four consecutive years[5]. Research indicates that outdoor hiking has reflected trends such as universal participation, multi-generational involvement, shorter routes, and simplified approaches[6][7].

Foreign research on hikers began relatively early, with a number of studies indicating that hikers' leisure motivations include accessing nature and exploring broader environmental elements influencing their preferences for natural settings[8]~[10]. Some studies have found that hikers tend to pay particular attention to natural elements such as trees, scenery, rocks, water, and wildlife[11], while other research utilizing semantic analysis has identified key factors influencing hikers' preferences for hiking environments, primarily including elevation, topography, trail material, trail condition, and landscape attractiveness[12]. Additionally, several studies have comprehensively analyzed the factors influencing hiking environments, encompassing ecosystems, flora and fauna, environmental diversity, and cultural perception[13]. Furthermore, researchers have carried out field emotion assessments of complex scenarios by examining factors such as the sense of enclosure, types of vegetation, geomorphological characteristics, and landscape visibility[14]. Moreover, other studies have examined the specific characteristics of environmental factors that influence the hiking experience, including hikers' preferences for enclosed vegetation[15] and vegetation density[16][17], as well as trail remoteness and path maintenance[11]. Among these studies, some consider the condition of trail surfaces as a critical component in enhancing park route systems[18]. They investigate the influence of factors such as trail incision, muddiness, roughness, width, and slope on hiking experience[19]. Additionally, related attributes, including trail vegetation cover and soil[20][21], as well as design and maintenance approaches involving trail material, slope, and stride length[18], have been discussed. However, a comprehensive understanding of the preferences of specific environmental factors that closely influence the walking experience and can be directly applied to trail design and maintenance is lacking.

Current preference research has rarely addressed the diverse perceptions and preferences regarding trail spatial environments among different hikers. Most studies focus on the analysis of landscape resource elements within tourist attractions[22] or individuals' preferences toward landscape resources[23]. Only a limited number of studies have investigated the factors influencing the trail system experience[24] and conducted post-use evaluations[25]. Furthermore, these studies typically overlook other user groups beyond tourists, thereby neglecting the differences in perception and demand related to trail spaces and associated components and

elements. It is noteworthy that, in the absence of research focusing on trail space preferences, existing studies rarely address the underlying factors influencing hiking preferences. Only a limited number of investigations have explored the correlation between hiking motivation and hiker satisfaction[26]. Other research has predominantly concentrated on the physical activity characteristics of outdoor enthusiasts[27][28] or has adopted sociological approaches to examining exercise behavior types and motivations[29]. As a result, there is a marked scarcity of studies on the relationship between outdoor activity motivations and spatial requirements.

Suburban mountain areas, as accessible natural environments, adequately satisfy the needs of short-distance hikers. However, the diverse user groups impose higher demands on the planning and management of trail spaces[30]. Currently, there is a lack of research addressing the differentiated needs of mountain trail users, leading to inadequate practical guidance for planning and design. Accordingly, this study commences by examining the user groups of mountain trail spaces. By employing perception surveys, this study compares the differences in preferences for trail spaces among various user groups, thereby providing insights for the planning and construction of mountain trails.

2 Methods

2.1 Study Area and Research Framework

The research chose the Xiaoxishan area in Beijing as the study area, which starts from Baiwang Mountain in the east, extending to Moshikou in the south, the Junzhuang–Dajue Temple in the west, and Wenquan Road in the north. It is close to the urban area with beautiful natural scenery and rich cultural landscapes. The two east–west and north–south mountain ranges of Xiaoxishan intersect in an "X" shape, forming a road network mainly based on the firebreak roads on the ridges and the paved municipal roads, together with densely meandered paths in between. Being a moderately challenging hiking site, Xiaoxishan has now become one of Beijing's top destinations for short-distance hiking, and many hiking routes of various lengths and difficulty levels have been developed.

As the *Xishan Greenway (Shijingshan Section) Construction Project* envisioned, general leisure citizens are the main user group of the Xishan suburban mountain area. However, it attracts more diverse user groups. The management authority of Xiaoxishan has coordinated the integration of various mountain trails, undertaking comprehensive improvements, connectivity enhancements, and pavement renovations to the existing trail network to promote the greenway's leisure and recreational functions. Some sections of the project have already been completed. To better understand user preferences for mountain trail spaces and to apply findings to the construction of other suburban mountain trail systems, this study seeks to answer the following questions: 1) Do users like the current improvements made to the mountain trail spaces? 2) What are the differences in preferences for mountain trail spaces among varied user groups? And 3) what are the underlying reasons for these differences in user preferences?

This study consisted of three parts: the classification of trail space types, the investigation of user preferences, and the analysis of spatial preference patterns. The study area was delineated by referring to relevant literature[31], and identified trail space information from geographic data. Using a combination of online data sources and on-site field surveys, typical trail space types in Xiaoxishan were extracted and categorized. A questionnaire survey was conducted to collect demographic and behavioral characteristics of mountain trail users, with a focus on analyzing differences in spatial preferences among different user groups and the reasons behind these differences. The study aims to construct preference profiles for different types of users, provide a theoretical basis for the rational design of suburban mountain trail spaces by demonstrating the Xiaoxishan case, and ultimately offer insights into the systematic and standardized development of mountain trail systems.

2.2 Extraction of Trail Space Types

2bulu is one of China's outdoor platforms based on location-based services (LBS), aggregating a substantial amount of data including user tracks and photographs, providing a valuable foundation for understanding the types of landscapes preferred by tourists. From November 23 to 26, 2023, researchers collected geographic information data and associated photographs within the study area from 2bulu using keywords such as "Badachu," "Xiangshan," and the names of other attractions in Xiaoxishan①. A total of 1,399 geographic trajectories and 3,788 photographs were obtained. Subsequently, these images were filtered based on whether they reflected environmental characteristics of trail spaces, resulting in a final dataset of 1,752 photographs. Based on the analysis of images, field survey results, and domestic and international trail

① The keywords used in the search for all Xiaoxishan attractions included "Badachu," "Xiangshan," "National Botanical Garden," "Heishitou," "Keleyu," "Long'en Temple," "Woniutai," "Tianshan Mausoleum," "Hujialing," "Fushouling," "Fahai Temple," "Shuangquan Temple," "Tanyu," "Dayingwa," "Biesimao," "Wangjinglou," "Dongshancun," "Xiyangtuo," "Dongyangtuo," and "Xiangyu."

construction standards[32][33], the research team identified four key spatial elements of mountain trails within the study area:

1) Trail surface material: dirt, dirt-rock, rock, or paved;

2) Vegetation enclosure: tree or shrub;

3) Trail width: narrow (0 ~ 1.2 m) or wide (over 1.2 m);

4) Slope: gentle (0 ~ 15°), moderate (15° ~ 40°), or steep (over 40°).

The relationship between the proportions of sky and vegetation in the images, along with the height of the viewpoints, served as preliminary criteria for assessing vegetation enclosure and slope. Meanwhile, the particle size of the trail graininess and the area occupied by the trail were used as criteria for determining trail surface material and trail width. In addition, the study performed differential comparisons and adjustments among mountain trails with similar geographical coordinates to reduce the impact of factors such as seasonality and viewpoint on the classification of trail types. Ultimately, 27 trail space types were identified (Fig. 1), including 5 types of dirt trails, 9 types of dirt-rock trails, 9 types of rock trails, and 4 types of paved trails. Each trail space type was coded as D for dirt surface, DR for dirt-rock surface, R for rock surface, and P for paved surface; T for tree and S for shrub; N for narrow trail and W for wide trail; G for gentle, M for moderate, and S for steep slope.

This study exacted the graphic materials of the four spatial elements from corresponding photographs as templates. It operated under the assumption that representations of identical element types were consistent and that elements across different hierarchical levels remained distinguishable, and extraneous variables—such as season, weather, and viewpoint—were normalized to mitigate bias. This approach resulted in the creation of scenario-based illustrations, which served as materials for the spatial evaluation questionnaire on mountain trails.

2.3 Questionnaire Survey and Analysis

The questionnaire consists of three main sections: user profiling, evaluation of trail pavement, and investigation of preferences for trail spatial elements. First, user profiles were created by collecting respondents' self-reported demographic information, behavioral characteristics, and preferences and reasons for specific trail spatial elements. Second, respondents were asked to evaluate two sections of mountain trails within the study area before renovation (primarily natural trails) and after renovation (primarily paved trails) by using a scale from 1 to 3 (1 means non-preferred, 2 means neutral, and 3 means preferred). Third, respondents were asked to score a set of representative trail scenario images (with the same scale above), so as to understand their preferences for different trail spaces. Referring to a synthesis of domestic and international literature on hiking motivation, the reasons of preferences were summarized into four dimensions: fun, safety, comfort, and challenge[26][34].

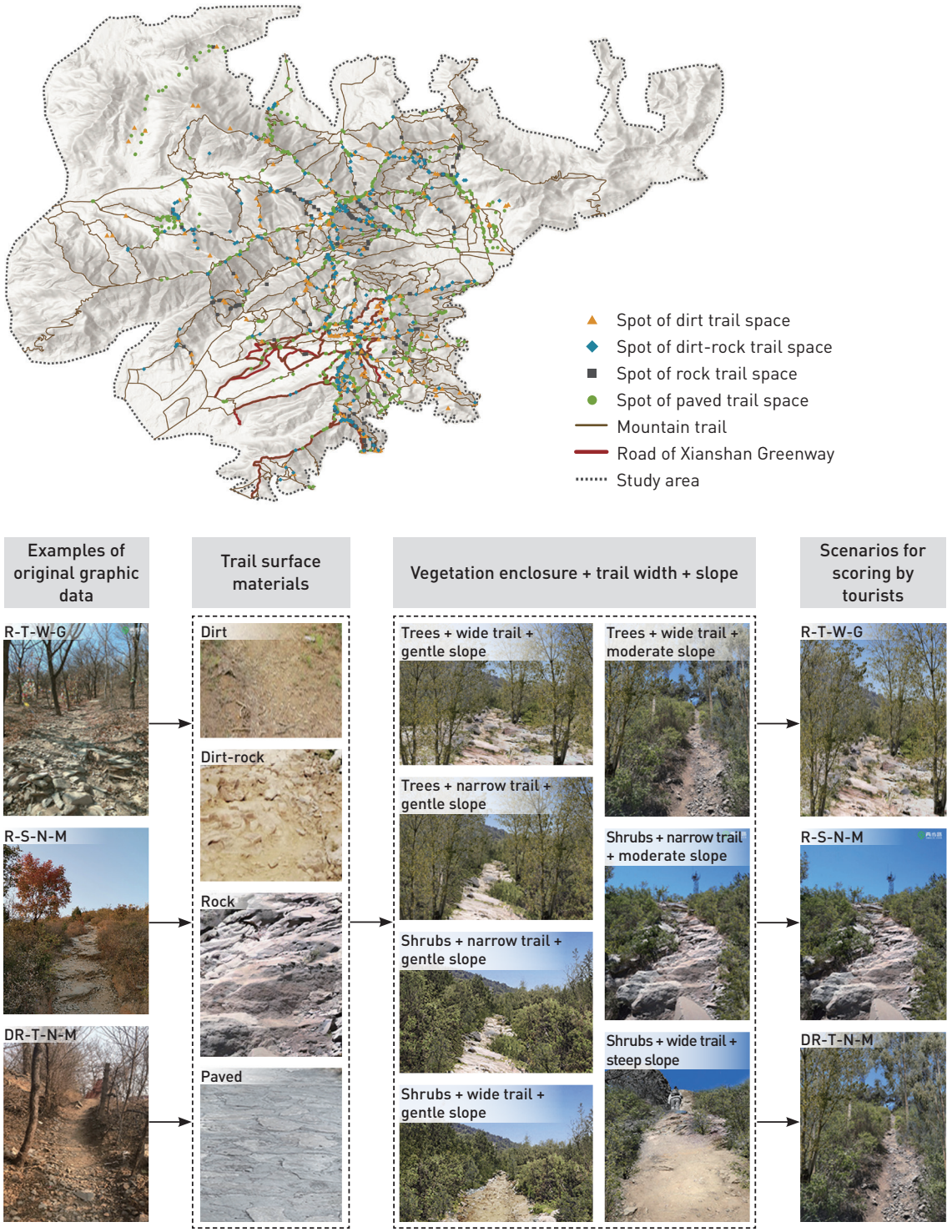
This study focused on all-age mountain trail users who participate in hiking activities. They were divided into two groups, hikers and non-hikers, according to their self-identification. The questionnaires were distributed to diverse groups such as hikers, mountaineers, fitness people, and the general public in Beijing, from October to December 2023, through WeChat, Weibo, and offline distribution. A total of 339 questionnaires were returned, and by screening uncompleted and regularly answered questionnaires, 310 valid questionnaires remained. The gender, age, and other characteristics of the respondents basically confirmed those of the Seventh Beijing Census, which covers a wide range of occupations, with a male to female ratio of 91:64. It is noteworthy that among the respondents, individuals over the age of 60 accounted for 2%, lower than Beijing's average (19.6%) reported in the census. This discrepancy may be related to the all-age participation in hiking activities, which still presents physical difficulties for elder people.

This study employed the two-step-cluster analysis of SPSS and descriptive statistics for user group segmentation and characterization. Subsequently, the Mann–Whitney U test was utilized to analyze preference differences between groups, while the Wilcoxon Match-Pairs Signed Ranks Test was applied to compare preference differences within the groups regarding varied types of trail spaces.

3 Study Results

3.1 User Profiles

In this study, respondents' feature variables were identified through a two-step-cluster analysis. Data of self-identified user group (non-hikiers or hikers), years of hiking, frequency, distance, and elevation gain were utilized to conduct a cluster analysis of hiking behavior characteristics (the size ratio of the clusters was 1.33), and eventually three user groups were identified. Furthermore, the survey results revealed that respondents with more extensive hiking experience and higher activity frequency exhibited a preference for trails with greater elevation gain and longer distances. Based on the cluster analysis results and observed differences in hiking behavior, the three groups were categorized as non-hikers, short-distance hikers, and long-distance hikers (Table 1). Interestingly, approximately half of the short-distance hikers self-reported themselves as non-hikers, highlighting a significant divergence between subjective self-identification and the objective classification determined by their behavior patterns.



Dirt trail space

D-S-N-G (narrow dirt trail with shrubs and a gentle slope)
D-S-N-M (narrow dirt trail with shrubs and a moderate slope)
D-T-N-G (narrow dirt trail with trees and a gentle slope)
D-T-W-G (wide dirt trail with trees and a gentle slope)
D-T-W-M (wide dirt trail with trees and a moderate slope)

Dirt-rock trail space

DR-S-N-G (narrow dirt-rock trail with shrubs and a gentle slope)
DR-S-W-G (wide dirt-rock trail with shrubs and a gentle slope)
DR-S-N-M (narrow dirt-rock trail with shrubs and a moderate slope)
DR-S-N-S (narrow dirt-rock trail with shrubs and a steep slope)
DR-S-W-S (wide dirt-rock trail with shrubs and a steep slope)
DR-T-N-G (narrow dirt-rock trail with trees and a gentle slope)
DR-T-W-G (wide dirt-rock trail with trees and a gentle slope)
DR-T-N-M (narrow dirt-rock trail with trees and a moderate slope)
DR-T-N-S (narrow dirt-rock trail with tress and a steep slope)

Rock trail space

R-S-N-G (narrow rock trail with shrubs and a gentle slope)
R-S-N-M (narrow rock trail with shrubs and a moderate slope)
R-S-W-M (wide rock trail with shrubs and a moderate slope)
R-S-N-S (narrow rock trail with shrubs and a steep slope)
R-T-N-G (narrow rock trail with trees and a gentle slope)
R-T-W-G (wide rock trail with trees and a gentle slope)
R-T-N-M (narrow rock trail with trees and a moderate slope)
R-T-N-S (narrow rock trail with trees and a steep slope)
R-T-W-S (wide rock trail with trees and a steep slope)

Paved trail space

P-S-N-G (narrow paved trail with shrubs and a gentle slope)
P-S-N-M (narrow paved trail with shrubs and a moderate slope)
P-T-W-G (wide paved trail with trees and a gentle slope)
P-T-W-M (wide paved trail with trees and a moderate slope)

1

1. Distribution of trail spatial elements in the study area and examples of scenarios for scoring by tourists. The spots of trail spaces were the photographing locations of the data collected from 2bulu, and the research team categorized them into different trail space types through manual audit (base map was sourced from Esri, Intermap, NASA, NGA, and USGS).

The three groups also differed in terms of gender, age, and occupation. The age distribution among non-hikers was relatively balanced across the ranges of 19 ~ 27, 28 ~ 40, and 41 ~ 60. Notably, as hiking distances increased, there was a distinct trend toward younger individuals among long-distance hikers. Among male respondents, long-distance hikers were more prevalent, whereas among female respondents, short-distance hikers were more common. The occupational composition revealed notable differences among representative groups, including students, corporate employees, and government staff. As the level of hiking

Table 1: Clustering results of respondents

Sample size and variables		User groups		
		Non-hiker	Short-distance hiker	Long-distance hiker
Sample size		113	85	112
Self-reported user group	Non-hiker	113	44	1
	Hiker	0	41	111
Years of hiking	Less than 1 year	113	67	9
	1 ~ 2 years	0	13	21
	More than 2 years	0	5	82
Hiking frequency	Once or less per month	113	32	23
	1 ~ 2 times per month	0	40	48
	2 ~ 4 times per month	0	7	21
	More than 4 times per month	0	6	20
Hiking distance	< 5 km	113	53	10
	5 ~ 10 km	0	26	39
	10 ~ 15 km	0	2	36
	15 ~ 20 km	0	4	18
	> 20 km	0	0	9
Elevation gain	< 300 m	113	53	11
	300 ~ 600 m	0	25	51
	600 ~ 1,000 m	0	6	35
	> 1,000 m	0	1	15

Table 2: Demographic statistics of respondents

Sample		Non-hiker	Short-distance hiker	Long-distance hiker
Age	19 ~ 27	35.44%	12.22%	43.55%
	28 ~ 40	37.34%	50.00%	48.39%
	41 ~ 60	25.32%	34.44%	8.06%
	> 60	1.90%	3.33%	0.00%
Gender	Male	32.28%	38.89%	67.74%
	Female	67.72%	61.11%	32.26%
Occupation	Student	27.22%	12.22%	30.65%
	Teacher	5.70%	11.11%	4.84%
	Government staff	10.13%	10.00%	4.84%
	Corporate employee	32.28%	42.22%	46.77%
	Private business owner	5.06%	6.67%	3.23%
	Freelancer	5.70%	2.22%	6.45%
	Peasantry	0.63%	0.00%	0.00%
	Retiree	5.06%	5.56%	1.61%
	Others	8.23%	10.00%	1.61%

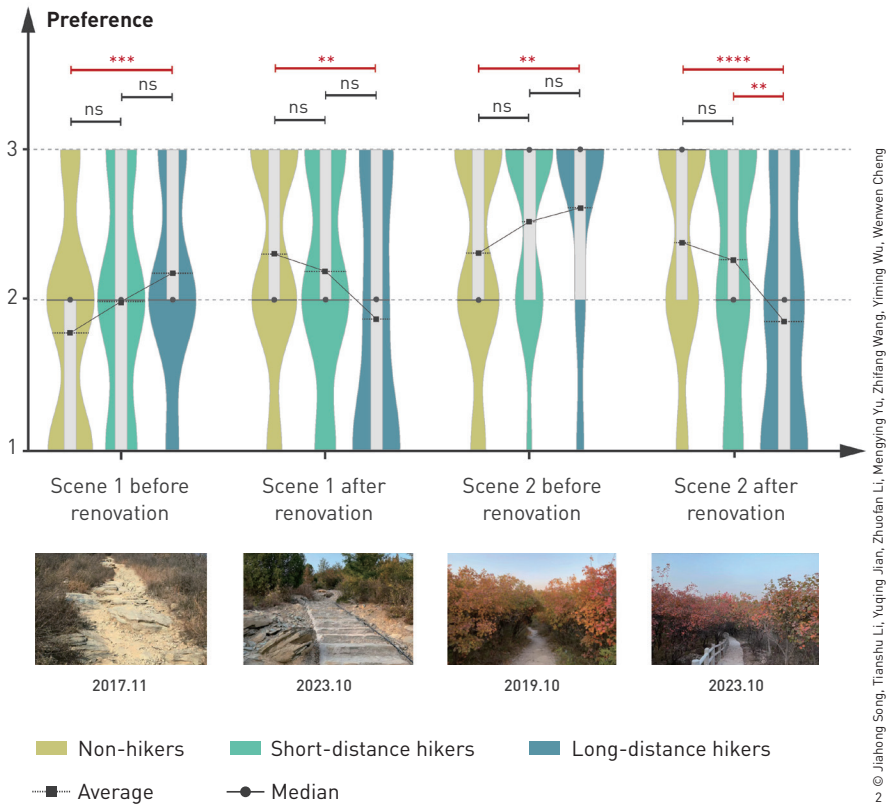
participation increased, the proportion of corporate employees also increased. Conversely, government staff were predominantly found among non-hikers and short-distance hikers, while students constituted a significant portion of both the non-hiker and long-distance hiker groups (Table 2).

3.2 Pre- and Post-Construction Evaluation of the Trail Renovation

The study found that different user groups had conflicting preferences for the two trail sections before and after renovation: positive evaluations from non-hikers consistently improved, while those from long-distance hikers consistently declined. For the same scenario, the preference levels of the three groups for the previous trails rose sequentially, and fell sequentially for the renovated trails; moreover, the ratings of non-hikers and long-distance hikers differed significantly ($p < 0.05$) (Fig. 2). This indicated that the renovated trail spaces were more preferred by non-hikers, but non-preferred by hikers.

3.3 Differences in Preferences for Trail Spatial Elements

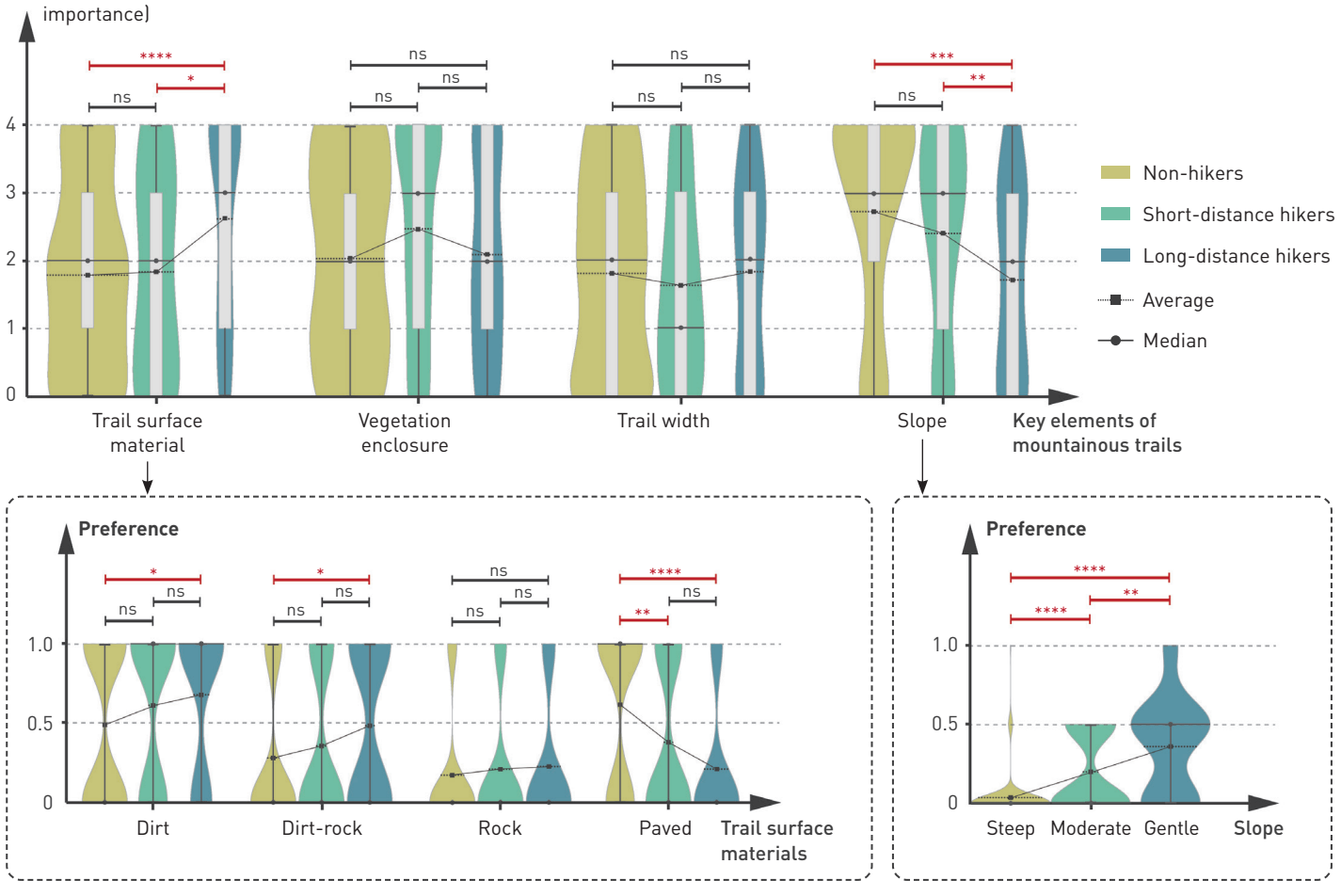
Within each user group, there were notable differences in the importance given to various spatial elements. Non-hikers prioritized slope significantly outweighing other three elements. Short-distance hikers prioritized both slope and vegetative enclosure. In contrast, long-distance hikers placed their greatest emphasis



on trail surface material. In terms of trail material, long-distance hikers valued significantly more than non-hikers and short-distance hikers, and the latter two showed an equal importance. For slope, non-hikers valued the most, and both non-hikers and short-distance hikers valued it significantly more than long-distance hikers (Fig. 3). There were no significant differences in importance for trail width and vegetation enclosure between the three groups.

Overall, in terms of specific preferences for trail material, vegetation enclosure, trail width, and slope of trail spaces, the three user groups all preferred wide trails and tall tree enclosing spaces. Further analysis of the preference differences in slope and trail surface material has implications for understanding hiking difficulty choices and element preferences among different user groups. Non-hikers and short-distance hikers exhibited a preference for gentle slopes, while long-distance hikers prefered moderate slopes. The preferred slopes of the three groups increased sequentially, and significant differences existed between each pair of groups ($p < 0.05$). In terms of preferences for trail surface material, non-hikers favored materials in the following order: paved, dirt, dirt-rock, and rock.

Level of importance
(converting rankings into levels of importance, scored from 0 to 4, with higher scores indicating higher levels of importance)



2. Analysis of the pre- and post-construction evaluation results of the trail renovation (ns means $p > 0.05$; * means $0.01 < p \leq 0.05$; ** means $0.001 < p \leq 0.01$; *** means $0.0001 < p \leq 0.001$; **** means $p \leq 0.0001$).
3. Importance analysis of various trail spatial elements across different user groups, and analyses of their preferences for trail surface materials and slope (ns means $p > 0.05$; * means $0.01 < p \leq 0.05$; ** means $0.001 < p \leq 0.01$; *** means $0.0001 < p \leq 0.001$; **** means $p \leq 0.0001$).

Short-distance hikers prefered dirt first, followed by paved, dirt-rock, and rock. Long-distance hikers prioritized dirt, followed by dirt-rock, rock, and paved. Across the three groups, the preference for paved trails decreased, while the preference for natural trails (dirt, dirt-rock, and rock) increased. Notably, long-distance hikers exhibited a significantly lower preference for paved trails compared with the other two groups ($p < 0.05$), and their preference for dirt and dirt-rock trails was significantly higher than that of non-hikers ($p < 0.05$).

Among the 27 trail space types, non-hikers preferred paved trail spaces and a few of gentle natural trail spaces. Short-distance hikers predominantly favored dirt trail spaces, while long-distance hikers preferring various dirt, dirt-rock, and rock trail spaces (Fig. 4).

In addition to long-distance hikers having significantly lower preferences for all paved types than the other two groups, the three groups also differed significantly on a small number of dirt and rock trail spaces. Non-hikers showed a significantly higher preference for D-T-W-G trail compared with short-distance hikers, while their preference for D-S-N-G trail was significantly lower than that of short-distance hikers. Furthermore, long-distance hikers exhibited a significantly higher preference for DR-T-N-M trail compared with the other two groups, and they also had a significantly higher preference for DR-T-N-G trail than short-distance hikers.

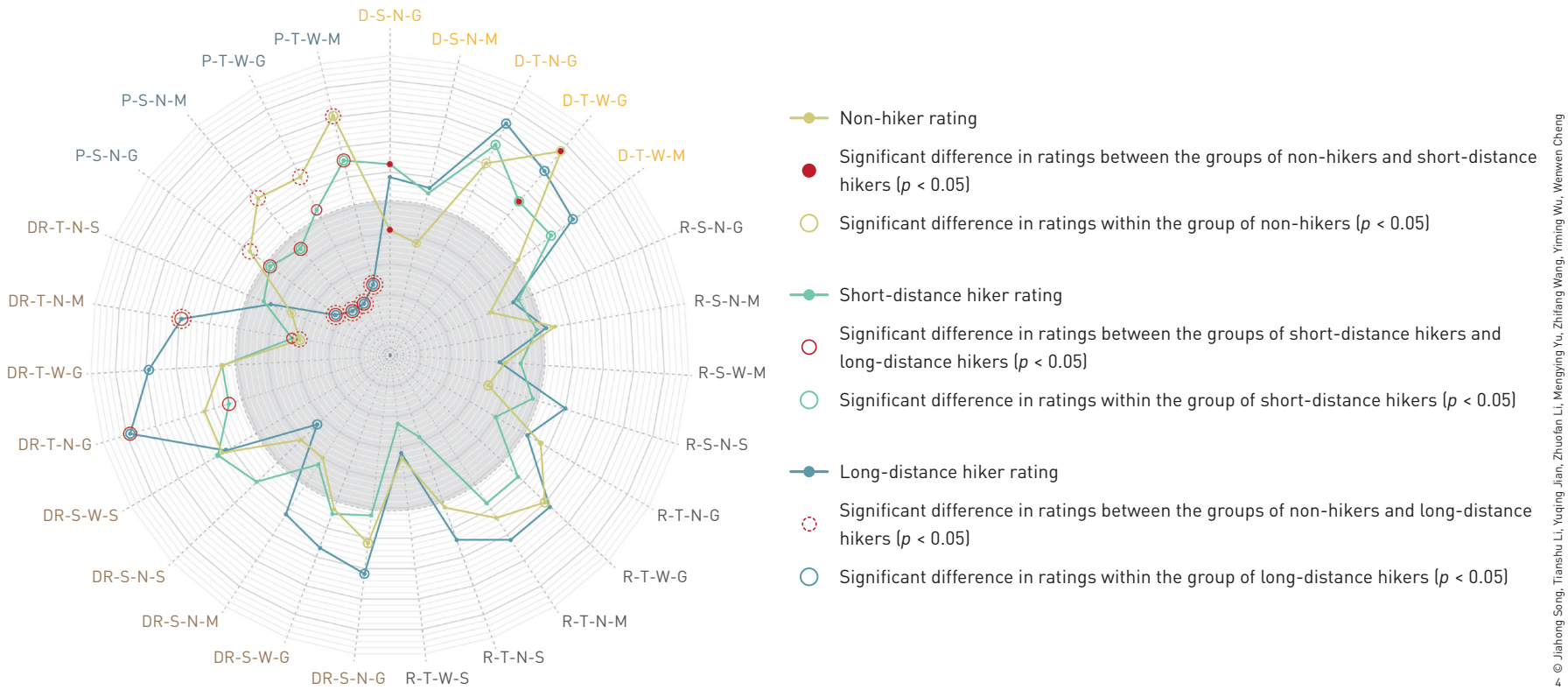
Specifically, among the 27 trail space types, non-hikers relatively preferred D-T-W-G, DR-S-N-G, R-T-W-G, P-T-W-M, and D-T-N-G, with a significant disfavor for natural trails with steeper slopes, such as DR-T-N-M, R-S-N-S, DR-T-N-S, and D-S-N-M. The preference of short-distance hikers was not significant, with a relative preference for D-T-N-G and a significant dislike for P-S-N-M or P-S-N-G. Meanwhile, long-distance hikers had a relatively greater preference for D-T-W-G, DR-T-N-G, D-T-W-M, D-T-N-G, DR-T-W-G, and DR-S-N-G, and a significant dislike for all paved trails.

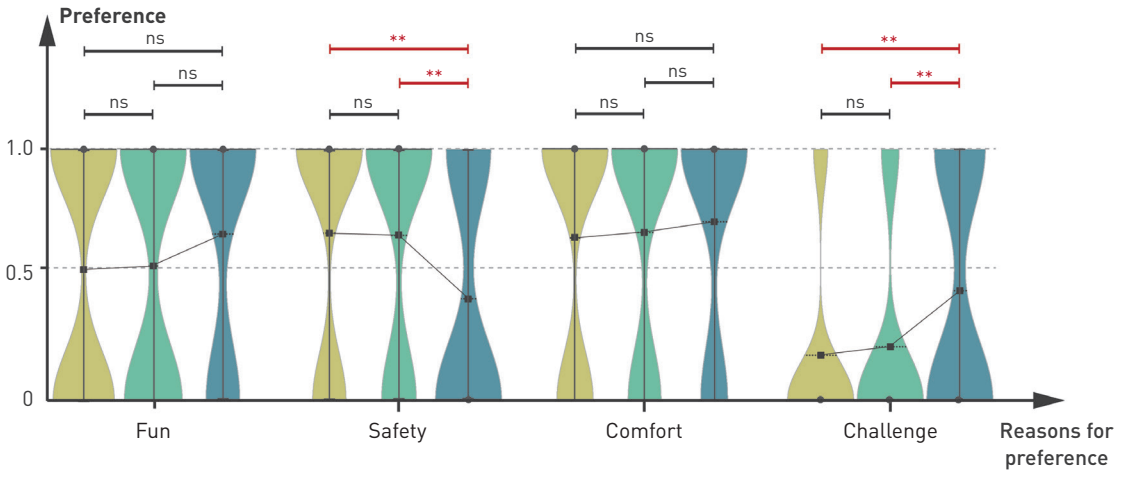
The types of trail space commonly preferred by the three groups were D-T-W-G, D-T-N-G, D-T-W-M, DR-S-W-G, DR-S-N-G, DR-T-W-G, DR-T-N-G, R-T-W-G, R-T-N-M, and DR-S-N-S.

3.4 Reasons for Preference Disparity

The primary reason for the preference differences among the three groups lied in their varying demands for safety and challenge (Fig. 5). Non-hikers and short-distance hikers had a significantly stronger demand for safety compared with long-distance hikers, whereas long-distance hikers exhibited a significantly higher demand for challenge than the other two groups. In addition, all groups highly focused on fun and comfort, showing a graded distribution among non-hikers, short-distance hikers, and long-

4. Differences in preferences for specific trail space types among the user groups.





5. Reasons for trail spatial preferences among different user groups (ns means $p > 0.05$; * means $0.01 < p \leqslant 0.05$; ** means $0.001 < p \leqslant 0.01$).

distance hikers, no statistically significant differences between the groups though. Relatively speaking, hikers had a higher requirement for the fun and comfort of trail spaces.

In addition, there were similarities and differences between the reasons for preference and the spatial elements of trails concerned by different groups. Although all three groups focused on fun and comfort, non-hikers and short-distance hikers were more concerned with the fun by slope and vegetation enclosure, and long-distance hikers were more concerned with the fun by vegetation enclosure and trail surface material; non-hikers were concerned with the comfort by slope and vegetation enclosure, and short-distance hikers and long-distance hikers were more concerned with the comfort by slope and trail surface material. Although there were significant differences among the three groups in safety and challenge, they all prioritized the experience differences brought about by slope.

4 Discussion

4.1 Conflicting Preference for Trail Spaces

This study showed that there was a correlation between participation level in hiking and the preference for naturalized trail spaces: the higher the participation level in hiking, the stronger the preference for naturalized trail spaces. The conclusions of this study align with existing research findings that differential preferences of tourists and hikers exist regarding the acceptability of natural environments[9]. Hikers prefer open, natural environment with low artificial interference, and are more attracted by spaces with natural variations in space, topography, and enclosure conditions[35], and are more concerned with the naturality of trail spaces[11].

Regarding the differences in perceptions of specific trail spaces among groups, previous research found that some groups prefer asphalt or gravel trails, while others being indifferent to the type of trail surface material. In addition, some individuals perceive mud and rock trails as obstacles to navigation[10]. This study indicates that non-hikers showed a greater preference for paved trail spaces, whereas hikers favored naturalized trail spaces, with a clear conflict between the preferences of these two user groups. A study taken in Swedish discussed the changes and differences in the characteristics and preferences of hikers over time: wider age ranges, increased demand for natural trails and challenge will be the future trends[6].

This study also found some similarities between different use groups. For example, all groups had high requirements for comfort and fun, and some dirt trails were favored by all groups. A study abroad found that both hikers and general tourists exhibit a preference for natural environmental features to some extent[36]. Hikers tend to favor undeveloped areas and natural trails, while tourists prefer paved trails that have undergone some degree of human modification. However, it has been found that naturalized spaces can serve as attractive landscapes that are acceptable to both general tourists and hikers[9]. In terms of mountain trail construction in China, it is important to respect the preferences of various user groups while fully considering the higher demand for safety of non-hikers and short-distance hikers. On the premise of ensuring the safety of natural trails, efforts should be made to transform the trails into a form that is more easily accepted by general tourists, so as to achieve the promotion of naturalized trails.

4.2 Planning and Design Recommendations for Mountain Trail Spaces

Mountain trail space is a crucial component of the mountain ecosystem. In order to meet the goals of good experience, all-age friendliness, and beautiful landscapes, trail routing should prioritize the ones with good forest resources. For the planning and design

of mountain trail spaces, it is essential to understand the needs and preferences of different user groups, and trail design should skillfully incorporate the behavioral characteristics of these groups by type, grade, form, and segmentation, to meet the diversified, differentiated, and personalized needs (Fig. 6).

1) Paved trails can be used mainly in the hiking range of general tourists (within 5 km), focusing on safety and comfort needs, and appropriately designing naturalized trail spaces preferred by non-hikers (e.g., D-T-W-G, D-T-N-G) while making the gradient of the trails as gentle as possible (no more than 15°). Additionally, anti-slip and smooth measures should be used, and tall trees can be planted along the trails to create shaded spaces.

2) For the hiking range beyond 5 km, efforts should be made to preserve the natural conditions of trails. The focus should be on maintaining dirt or dirt-rock trails and adjusting rock trails, while retaining the trails with slopes of 15° or more to enhance the interest and challenge of trail spaces. However, given that the domestic hiking groups are predominantly short-distance hikers, emphasis should be placed on enhancing the comfort of naturalized trails through measures like using stepping stones, adjusting

6. Planning suggestions for the trail spaces in Xiaoxishan.

Preferring natural trails (e.g., dirt, dirt-rock, and rock trails) and moderate or steep slopes

DR-T-N-G

DR-T-N-M

R-T-N-M

R-T-N-S

Fun: diversified combinations of trail space types
Challenge: naturalized trails with steeper slopes and higher difficulty
Comfort: adding appropriate footstones in challenging areas

Preferring natural trails (e.g., dirt, dirt-rock, and rock trails) and moderate or gentle slopes

DR-S-W-G

D-T-N-G

D-T-W-M

Fun: diversified combinations of trail space types
Challenge: trails with medium-high level difficulty or medium-long distance
Comfort: step width according to ergonomics
Safety: Challenging trails with naturalized fences and stabilized trail surface

Preferring wider paved or dirt trails with trees and gentle (moderate) slopes

P-T-W-G

P-T-W-M

D-T-W-G

P-S-N-G

Safety: adding anti-slip trail surface and gentle slopes
Comfort: shaded trails with smooth surface

Range for non-hikers
Trails in the range for non-hikers
Range for short-distance hikers
Trails in the range for short-distance hikers
Range for long-distance hikers
Trails in the range for long-distance hikers
Study area

the roughness of the trails, and designing steps according to ergonomics.

3) In areas serving for both general tourists and hikers, naturalized trails (e.g., D-T-W-G, D-T-N-G, DR-S-W-G, DR-S-N-G) preferred by various groups can be designed to balance the safety, comfort, and fun as much as possible.

4) To ensure the safety of all users, trail conditions and safety risks should be notified along naturalized routes, allowing hikers to make informed decisions. Naturalized fences are set up on difficult sections, while stabilizing the trail surface structure.

5) In order to promote "naturalization" in future suburban mountain trail planning and design, it is necessary to enhance public preference for naturalized trail spaces. Thus, in terms of fun, different forms and contents of nature education programs can be combined to increase the public's participation in hiking activities, then promoting the general preference for naturalized trail spaces.

5 Conclusions

Driven by the goals of healthy city construction, hiking has become one of the effective ways to promote public health. Trail spaces, as important sites for hiking activities, can be developed into an adaptive construction by exploring the preferences of different user groups to meet their diversified needs. This study takes Xiaoxishan in Beijing as a case to reveal the conflicting preferences among different user groups of suburban mountain trail spaces, and to explore the differences in preferences and the underlying reasons among various groups. The research develops specific user profiles of suburban mountain trail spaces and focuses on key trail spatial elements closely related to hiking experience—trail surface material, vegetation enclosure, trail width, and slope. It also examines the reasons for preference differences, including fun, safety, comfort, and challenge. The findings offer universal and practical implications for the planning and design of suburban mountain trail spaces. The study not only provides corresponding strategies for trail construction in suburban mountain areas, exemplified by Xiaoxishan, but also contributes to enriching the content of National Fitness Strategy, advancing the formulation of trail system policies and improving related planning and design practices. At the same time, it can provide a reference for the sustainable development of mountain spaces compatible with both natural conservation and activity needs.

Competing interests | The authors declare that they have no competing interests.

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https://doi.org/10.15302/J-LAF-0-020032 收稿日期 | 2024-07-08 录用日期 | 2025-01-15 中图分类号 | TU984 文献标识码 | A

自然还是硬化：城郊山地步道空间的偏好冲突及解决策略

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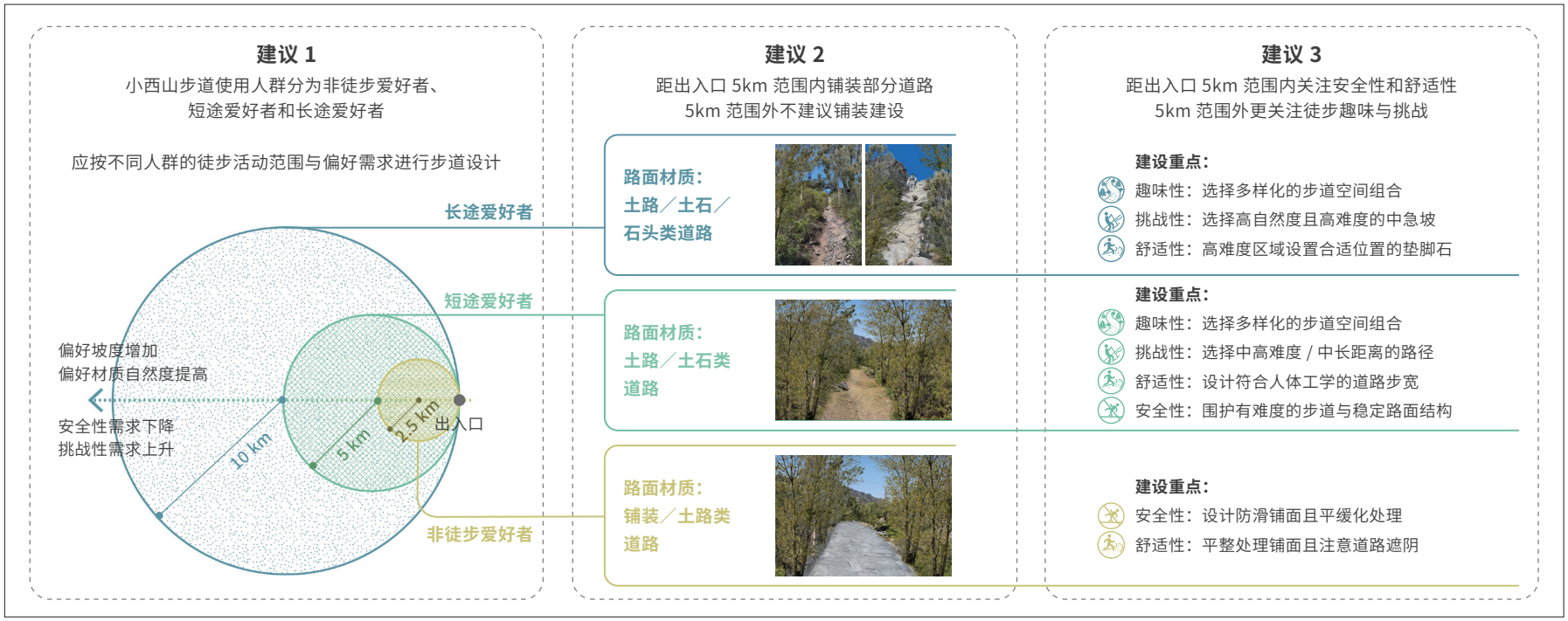
图文摘要



摘要

随着公众健康意识的提升，徒步活动日趋流行。城郊山地空间已成为徒步等休闲健身活动的重要承载空间，其步道系统的规划建设也需要适应更多样的需求。本文以北京市小西山为研究对象，通过两步路户外网图片数据与实地调研对步道空间特征进行分类提取，以问卷调研的方式获取徒步登山活动人群的特征及步道空间评价，探究非徒步者和徒步者（短途爱好者和长途爱好者）等不同人群对步道空间的偏好、偏好差异及偏好原因。研究发现，随着偏好徒步距离的增加，在人群对步道空间要素重视程度、对道路材质的偏好度、对具体步道空间的偏好类型这三个层面上，都体现出了明显的自然化倾向：对坡度的重视程度下降，对较大坡度的偏好程度上升；对道路材质的重视程度上升，对铺装类步道空间的偏好程度逐渐降低，对土路、土石类材质道路的偏好程度上升；人群对徒步环境安全性的需求降低，对长距离徒步中的舒适性、趣味性需求提高。研究以不同人群偏好的步道空间组合类型为基础，提出山地步道空间建设对应策略，从而为丰富“全民健身战略”的发展内涵、推动步道体系政策制定、提升相关规划设计实践提供积极借鉴。

关键词

城郊山地；步道空间；徒步登山活动；偏好差异；北京小西山

文章亮点

- 揭示城郊山地步道使用者的不同人群画像
- 发现不同使用人群对铺装化与自然化道路的偏好异同
- 揭示城郊山地步道改造有违徒步者的需求
- 发现不同使用人群对安全性与挑战性的偏好差异，对舒适性与趣味性的共同趋向

基金项目

国家自然科学基金“基于多源数据的城市绿地系统游憩服务价值形成机制研究”（编号：42271300）

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1 研究背景

随着城市化进程的持续推进与居民生活水平的提升，公众健康成为全球关注的重要议题。徒步作为低成本、低门槛的运动方式，在促进全民健康中优势显著：既能有效活跃机体功能[1]，沿途的自然暴露还能够对认知功能、情绪状态及压力水平产生积极影响[2]，整体上对身心健康具有正向作用[3][4]。近年来，徒步逐渐成为热门旅游休闲活动之一。《中国徒步旅游发展报告（2019）》显示，我国约1.3亿人参与户外运动，且徒步连续4年成为户外爱好者最喜欢和最常参加的活动[5]。有研究表明，户外徒步出现了全民化、全龄化、短途化、轻量化的倾向[6][7]。

国外有关徒步者的研究起步较早，较多研究指出徒步者的休闲动机包括亲近自然，并探究其在自然偏好中关注的广义环境要素[8]~[10]。有研究发现，徒步者较多关注树木、风景、岩石、水、野生动物等自然要素[11]，也有研究通过语义分析发现影响徒步者对徒步环境偏好的要素主要包括海拔、地形、道路材质、步道条件、景观吸引力等[12]。另外有研究综合分析了徒步环境的影响因素，如生态系统、动植物、环境多样性、文化感知等[13]，进而对复合要素的环境场景——围合感、植被类型、地貌特点、景观视线等——进行了实地情感评价[14]。另有研究讨论影响徒步体验环境要素的具体特征，如徒步者对围合性植物[15]、植被茂密度[16][17]等的偏好，以及小径位置偏僻与否、铺装维护[11]等对徒步体验的影响。其中，有研究将步道路面情况作为公园路线体系提升的重要组成部分[18]：探究步道断面深度、泥泞度、粗糙度、宽度、坡度等因素对徒步体验的影响[19]；对步道植被覆盖、土壤等相关属性要素[20][21]，以及步道材料、坡度、步长等设计与维护方法[18]等进行了讨论。然而，对于与步行体验密切相关、可以直接运用于步道设计与维护的具体环境要素偏好并没有形成全面研究。

现有偏好研究较少关注不同徒步参与人群对于步道空间环境的偏好与感知，而大多针对景区中的景观资源进行要素分析[22]或聚焦于个体对景观资源的偏好评价[23]，少数涉及步道体系体验的影响因素分析[24]及使用后评价[25]，也较少涉及游客之外的使用群体，忽略了步道空间及相关构成要素的感知与需求差异。值得注意的是，在步道空间环境偏好研究缺失的情况下，现有研究更是较少涉及徒步偏好产生的原因，仅有个别研究探讨徒步动机和徒步者满意度的相关性[26]，或属于关注户外人群的运动特征研究[27][28]及关于运动行为类型与动机的社会学研究[29]，较少探索户外活动动机与空间需求之间的关系。

城郊山地空间作为近郊自然环境，可满足徒步者的短途徒步需求，但复合使用人群对步道空间规划与管理提出了更高的要求[30]。而目前尚无研究关注山地登山步道使用者的差异化需求，对实际规划设计的指导价值不足。因此本研究从山地步道空间使用群体出发，通过使用者主观感知调查，对比不同使用者对步道空间的偏好差异，从而为山地步道规划建设提供参考。

2 研究方法

2.1 研究区域与研究框架

本研究选择北京市小西山地区作为研究场地。小西山东起百望山、南到模式口、西到军庄—大觉寺一线、北到温泉路，紧邻市区，自然景观优美，文化景观丰富。小西山的两条东西、南北走向的山脉交叉呈“X”形，形成以山脊防火道与市政道路为主干、自然小径密集分布的道路网络，山地徒步难度适中。小西山现已成为北京户外短途徒步者的重要目的地之一，徒步者们已开辟出多条长度与难度不尽相同的徒步线路。

《西山绿道（石景山段）建设工程项目》将一般性休闲市民作为西山近郊山地空间的使用者，而实际使用人群更加多元。小西山管理者统筹各种山地步道，并对现有道路网络进行统一修整、连通与路面铺装改造，着力实现西山绿道的休闲游憩功能，目前相关工程已有局部路段完工。为了探究不同使用者对登山步道空间的偏好，并将研究结果应用于其他城郊山地空间步道建设上，本研究尝试回应以下问题：1）使用者是否喜欢目前山地步道空间的改造效果？2）不同使用者对山地步道空间存在哪些偏好差异？3）造成使用者对山地步道空间偏好差异的原因有哪些？

本研究主要包括三方面的研究内容，即步道空间类型提取、步道空间偏好调研，以及步道空间偏好分析。本研究参考相关文献划定研究区域范围[31]，识别研究区域地理信息数据中的步道空间信息，通过网络数据与实地调研对小西山典型步道空间特征进行分类提取；以问卷调研的方式获取山地步道空间使用者的特征，并深入探究不同使用者群体的步道空间偏好差异与偏好原因。研究尝试为不同人群偏好的步道空间绘制需求画像，为以小西山为代表的城郊山地步道空间合理化设计提供理论基础，进而为山地步道的系统化和规范化建设提供参考。

2.2 步道空间类型提取

“两步路户外网”是中国基于位置定位服务（LBS）的专业户外平台之一，汇集了大量的用户轨迹、照片等数据，为了解游客偏好的景观类型提供了重要依据。本研究于2023年11月23~26日以“八大处”“香山”等小西山景点为关键词①，收集两步路户外网发布的研究区域内附带照片的地理信息数据，获取原始地理轨迹1 399条，原始图片3 788张；而后以是否体现步道空间特征为筛选依据，最终得到1 752张与步道空间相关的图片。结合图片分析和实地调研发现，以及国内外步道建设标准[32][33]，研究团队提取了4类研究区域内的山地步道要素：1）道路材质（土路、土石、石头、铺装）；2）植被围合（乔木、灌木）；3）路宽（窄路0～1.2m、宽路1.2m以上）；4）坡度（缓坡0～15°、中坡15°～40°、陡坡40°以上）。

图片中天空与植被的占比关系与可视点的高低被作为判定植被围合、坡度的初步筛选依据；道路颗粒度大小与道路所占面积为道路材质、路宽的判定依据。此外，研究对具有相近地理坐标的山地步道进行差异比对与调整，以减少季节、视角等因素对步道类型判断的干扰，最终形成27种步道类型（图1）：土路类步道5种、土石类步道9种、石头类步道9种、铺装类步道4种。

研究以对应类型照片中的要素素材为模板，在相同类型要素表现形式一致、不同类型层次间的要素具有可识别性的前提条件下，统一季节、天气、视角等无关变量，形成场景化图示作为山地步道空间评价问卷的素材。

2.3 问卷调查与分析

问卷内容包括人群画像、场地改造评价与步道空间要素偏好调查。问卷首先根据受访者的自我认定进行人群画像，包括基础身份信息、行为特征、步道空间要素偏好及原因等信息。其次，要求受访者对研究范围内的两段山地步道改造前（自然步道为主）后（铺装步道为主）的效果进行打分（分值1～3分，1分表示不喜欢，2分表示一般，3分表示喜欢）。再次，以典型类型场景化图片作为评价素材，要求受访者针对不同场景化步道空间进行打分（分值划分同上）；偏好原因根据国内外对徒步动机的总结归纳，分为趣味性、安全性、舒适性、挑战性4类[26][34]。

本研究将参与登山活动的全年龄段人群视为研究对象，并根据受访者的自我认定划分为徒步爱好者和非徒步爱好者两个群体，于2023年10～12月，通过微信、微博及线下问卷发放，向北京市的徒步爱好者、登山爱好者、健身人群、普通民众等多元群体发放问卷。共计回收问卷339份，筛选填写完整、无规律回答的问卷为有效问卷，共计310份。本次问卷的受访者样本的性别、年龄等特征与北京市第七次人口普查结果占比基本一致，涵盖各行各业，其中男女比例为91:64。需要说明的是，本次受访者样本中，60岁以上群体占2%，低于北京市人口普查结果（19.6%），这与徒步活动的全龄化但存在体力与难度门槛相关。

本研究通过SPSS的“两步聚类”与描述统计方法进行人群类型细分与特征刻画，而后采用Mann–Whitney U检验分析人群间的偏好差异，并采用Wilcoxon成对数据加符号秩检验比较人群内部对于不同步道空间类型的偏好差异。

3 研究结果

3.1 人群画像

根据两步聚类筛选有效的特征变量，并最终对问卷自我认定的身份属性（非徒步爱好者／徒步爱好者）、徒步／爬山年限、频率、里程、爬升高度进行徒步行为特征聚类（聚类大小比率为1.33），最终形成了三类人群。同时，调查结果显示，受访者徒步活动年限越长、频次越高，所偏好的爬升高度越高、里程越长。根据聚类结果和实际徒步行为差异，将三类人群命名为非徒步爱好者、短途爱好者和长途爱好者（表1）。其中，短途爱好者中有一半左右的受访者将自己定义为非徒步爱好者，说明受访者的自我认定结果主观性较强，与基于受访者行为进行的客观划分结果之间存在较大差距。

在具体人群构成上，这三类人群在性别、年龄、职业构成上也存在差异。非徒步爱好者的年龄在19～27岁、28～40岁、41～60岁三个年龄段中分布相对均衡，随着徒步距离增加，长途徒步的年轻化特征明显；男性受访者中长途爱好者居多，女性中短途爱好者居多；在职业构成上，以学生、企业员工、政府工作人员为代表的群体存在差异性变化：随着人群徒步参与程度增加，其中企业员工的占比稳定增加，政府工作人员以非徒步爱好者与短途爱好者居多，而学生以非徒步爱好者与长途爱好者居多（表2）。

① 检索使用的全部小西山景点关键词包括：“八大处”“香山”“国家植物园”“黑石头”“克勒峪”“隆恩寺”“卧牛台”“天山陵园”“胡家岭”“福寿岭”“法海寺”“双泉寺”“潭峪”“打鹰洼”“憋死猫”“望京楼”“东山村”“西杨坨”“东杨坨”“香峪”。

表 1：受访者人群聚类结果

样本量及变量		人群类型		
		非徒步爱好者	短途爱好者	长途爱好者
样本量		113	85	112
身份属性（自我认定）	非徒步爱好者	113	44	1
	徒步爱好者	0	41	111
徒步／爬山年限	一年以内	113	67	9
	一至两年	0	13	21
	两年以上	0	5	82
徒步／爬山频次	每月 0 ～ 1 次	113	32	23
	每月 1 ～ 2 次	0	40	48
	每月 2 ～ 4 次	0	7	21
	每月 4 次以上	0	6	20
徒步／爬山里程	＜ 5km	113	53	10
	5 ～ 10km	0	26	39
	10 ～ 15km	0	2	36
	15 ～ 20km	0	4	18
	＞ 20km	0	0	9
爬升高度	＜ 300m	113	53	11
	300 ～ 600m	0	25	51
	600 ～ 1 000m	0	6	35
	＞ 1 000m	0	1	15

表 2：人群特征

样本		非徒步爱好者	短途爱好者	长途爱好者
年龄	19 ～ 27 岁	35.44%	12.22%	43.55%
	28 ～ 40 岁	37.34%	50.00%	48.39%
	41 ～ 60 岁	25.32%	34.44%	8.06%
	＞ 60 岁	1.90%	3.33%	0.00%
性别	男	32.28%	38.89%	67.74%
	女	67.72%	61.11%	32.26%
职业	学生	27.22%	12.22%	30.65%
	教师	5.70%	11.11%	4.84%
	政府工作人员	10.13%	10.00%	4.84%
	企业员工	32.28%	42.22%	46.77%
	私营业主	5.06%	6.67%	3.23%
	自由职业者	5.70%	2.22%	6.45%
	农民	0.63%	0.00%	0.00%
	离退休人员	5.06%	5.56%	1.61%
	其他	8.23%	10.00%	1.61%

3.2 步道改造前后评价

研究发现不同使用人群对两处山地步道改造的反馈截然不同，存在偏好冲突：非徒步爱好者的评价均有提升，长途爱好者的评价均下降。针对同一场景，三类人群的评价均呈现梯级分布，改造前均依次上升，改造后均依次下降，且非徒步爱好者与长途爱好者的评价呈现显著差异（$p<0.05$）（图2）。这一分析结果说明，目前步道空间的改造更符合非徒步爱好者的偏好，却并不符合徒步爱好者的偏好。

3.3 步道空间要素偏好差异

每类人群内部对不同要素重视程度存在较明显的差异。非徒步爱好者以坡度为最优先考虑因素，远超其他三种要素；短途爱好者以坡度、植被围合为最优先考虑因素；长途爱好者最重视道路材质。在道路材质上，长途爱好者的重视程度显著高于非徒步爱好者和短途爱好者，后二者的重视程度相当。在道路坡度上，非徒步爱好者的重视程度最高，且非徒步爱好者和短途爱好者的重视程度都显著高于长途徒步爱好者（图3）。在路宽和植被围合两个要素上，三类人群的重视程度未见显著差异。

整体而言，在步道空间道路材质、植被围合、路宽、坡度要素的具体偏好上，三类人群集中偏向宽路与高大乔木空间。深入挖掘坡度与道路材质的偏好差异对探讨不同人群的徒步难度选择与要素偏好具有意义：非徒步爱好者与短途爱好者偏好缓坡，长途爱好者偏好中坡；三类人群偏好的坡度依次上升，且三类人群两两间对道路坡度偏好程度存在显著差异（$p<0.05$）。在道路材质偏好方面，非徒步爱好者的偏好材

质依次为铺装、土路、土石、石头，短途爱好者的偏好依次为土路、铺装、土石、石头，长途爱好者则为土路、土石、石头、铺装；在三类人群间，非徒步爱好者、短途爱好者、长途爱好者对铺装类步道的偏好依次下降、对自然道路（土路、土石路、石头路）的偏好依次上升，长途爱好者对铺装道路的偏好显著低于另两类人群（$p<0.05$），且他们对土路类与土石类步道的偏好显著高于非徒步爱好者（$p<0.05$）。

根据已有的27种具体步道空间类型，非徒步爱好者偏好铺装类型步道空间及个别平缓的自然步道空间，短途爱好者集中偏好土路步道空间，长途爱好者集中偏好大部分土路、土石和石头步道空间（图4）。

除了长途爱好者在所有铺装类型上的偏好显著低于另两类人群之外，三类人群在少部分土路类和土石类步道空间上也存在显著差异：非徒步爱好者在土路乔木宽路缓坡的偏好上显著高于短途爱好者，在土路灌木窄路缓坡偏好上显著低于短途爱好者；长途爱好者在土石乔木窄路中坡的偏好上显著高于另两类人群，且在土石乔木窄路缓坡的偏好上显著高于短途爱好者。

具体而言，在27种具体步道空间类型中，非徒步爱好者相对更偏好土路乔木宽路缓坡、土石灌木窄路缓坡、石头乔木宽路缓坡、铺装乔木宽路中坡，以及土路乔木窄路缓坡，显著不偏好坡度较大的自然道路，如土石乔木窄路中坡、石头灌木窄路急坡、土石乔木窄路急坡，以及土路灌木窄路中坡。短途爱好者偏好显著性不强，相对偏好土路乔木窄路缓坡，显著不偏好铺装灌木窄路中坡和铺装灌木窄路缓坡。长途爱好者相对更偏好土路乔木宽路缓坡、土石乔木窄路缓坡、土路乔木宽路中坡、土路乔木窄路缓坡、土石乔木宽路缓坡，以及土石灌木窄路缓坡，显著不偏好所有铺装类型道路。

三类人群共同偏好的步道空间类型有土路乔木宽路缓坡、土路乔木窄路缓坡、土路乔木宽路中坡、土石灌木宽路缓坡、土石灌木窄路缓坡、土石乔木宽路缓坡、土石乔木窄路缓坡、石头乔木宽路缓坡、石头乔木窄路中坡、土石灌木窄路急坡。

3.4 人群偏好差异原因

三类人群偏好差异的主要原因是对安全性和挑战性的需求不同（图5）：非徒步爱好者、短途爱好者对安全性的需求显著强于长途爱好者，而长途爱好者对挑战性的需求显著强于非徒步爱好者和短途爱好者。此外，所有人群都很注重趣味性和舒适性，虽在非徒步爱好者、短途爱好者、长途爱好者间呈现梯级分布，但不存在组间差异。相对而言，徒步爱好者对步道空间的趣味性和舒适性要求更高。

此外，不同人群的偏好原因与关注的步道空间要素间也存在相似性与差异性。虽然三类人群都注重趣味性与舒适性，但非徒步爱好者与短途爱好者更关注坡度与植被围合带来的趣味性，长途爱好者更关注植被围合与道路材质的趣味性；非徒步爱好者关注坡度与植被围合带来的舒适性，短途爱好者与长途爱好者更关注坡度与道路材质的舒适性。虽然三类人群对安全性和挑战性的关注存在较大差异，但都首要关注坡度要素带来的体验差异。

4 讨论

4.1 冲突的步道空间偏好

本研究表明，徒步爱好的参与度与自然化道路空间偏好存在相关性：徒步的参与度越高，对自然化步道空间的偏好越强。本研究结论与已有研究中“游客与徒步爱好者对于自然环境接受度的差异性偏好”的结论相吻合[9]，徒步爱好者更偏好人工干扰较低、开放自然的环境，认为自然变化的空间、地形、围合条件具有较强的吸引力[35]，对于步道空间自然性的关注度更高[11]。

在人群对具体步道空间的认知差异方面，已有研究发现，部分人群偏好沥青、碎石铺装道路，亦有人群不在意道路材质，另有部分人群将泥路、石头路等视为道路障碍[10]。本研究表明，非徒步爱好者更加偏好铺装化的步道空间，徒步爱好者偏好自然化的步道空间，两个使用群体间存在明显冲突。一项针对瑞典地区的研究讨论了随着时间推移徒步爱好者特征与偏好的变化与差异，全龄化、对道路自然性及挑战性的要求增加等将成为未来趋势[6]。

本研究也发现不同使用人群间存在一些相似性。例如，所有人群都对舒适度和趣味性有较高要求，部分土路类步道受到了各类人群的喜爱。国外有研究表明，徒步爱好者与普通游客在某种程度上均表现出对自然环境特征的偏好[36]，徒步爱好者表现出对未开发地区与自然化道路的偏好，游客则偏好经过一定人工改造的铺装道路，并发现自然化的空间作为有吸引力的景观，可同时被普通游客与徒步爱好者接受[9]。就中国的山地步道建设而言，应在尊重各类人群的偏好基础上，充分考虑非徒步爱好者、短途爱好者对安全性的较强需求，在保障自然化道路安全性的前提下，将之改造成更易被普通游客接受的形态，从而实现自然化道路的推广。

4.2 山地步道空间规划设计建议

山地步道空间是山体生态系统的重要组成部分，为符合体验良好、全龄友好、景观美好建设目标，步道选线应优先选择森林本底良好的线路。山地步道空间规划设计需要在理解不同使用人群需求偏好的基础上，巧妙根据不同人群的行为特征，按照分类、分级、分型、分段的方式开展山地步道设计，以满足多元化、差异化、个性化需求（图6）。

1）可在一般休闲人群的徒步范围（5km以内）主要采用铺装化道路，注重安全性和舒适性需求，并适当设计非徒步爱好者偏好的自然化步道空间类型（如土路乔木宽路缓坡、土路乔木窄路缓坡等），同时尽

量使步道坡度平缓（不高于15° ），注意路面的防滑与平整处理，且沿途种植高大乔木进行道路遮阴。

2）在徒步爱好者的徒步范围（5km以外）应尽量维持道路的自然状态，重点维护土路或土石类等道路，调整石头类道路，同时保留15° 以上具有一定难度的道路，以提升步道空间的趣味性与挑战性。但鉴于国内徒步人群以短途徒步人群为主，因此应着重通过设计垫脚石、调整道路粗糙程度、设计符合人体工学的步宽等措施提升自然化道路的舒适性。

3）在一般休闲人群和徒步爱好者交叉活动区域，可设计各类人群均偏好的自然化道路（如土路乔木宽路缓坡、土路乔木窄路缓坡、土石灌木宽路缓坡、土石灌木窄路缓坡等），尽可能兼顾安全性、舒适性与趣味性。

4）为保证使用人群的安全性，应在自然化道路路段进行道路情况告知与安全风险提示，以便徒步人群选择，并在高难度路段进行自然化围护、稳定路面结构。

5）推动“自然化”成为未来城郊山地步道空间规划设计的主要趋势，但这需要提升公众对自然化道路空间的偏好。因而在趣味性方面，可结合不同形式与内容的自然教育项目，提高公众对于徒步活动的参与积极性，从而推动公众对自然化步道空间的普遍偏好。

图 1. 研究区域内步道空间要素分布与场景化图示示例。图中各步道空间点为两步路户外网上包含地理坐标信息的徒步拍照点，研究团队通过图片信息归类该点的步道空间类型（底图来源：Esri、Intermap、NASA、NGA 和 USGS）。

图 2. 山地步道改造前后评价结果分析（ns 表示在 0.05 的水平上无显著相关性；* 表示在 0.05 的水平上显示显著相关性，** 表示在 0.01 的水平上显示显著相关性；*** 表示在 0.001 的水平上显示显著相关性；**** 表示在 0.0001 的水平上显示显著相关性）。

图 3. 三类人群对不同步道空间要素的重视程度分析，以及对道路材质和坡度的详细偏好分析（ns 表示在 0.05 的水平上无显著相关性；* 表示在 0.05 的水平上显示显著相关性，** 表示在 0.01 的水平上显示显著相关性；*** 表示在 0.001 的水平上显示显著相关性；**** 表示在 0.0001 的水平上显示显著相关性）。

图 4. 三类人群对步道空间具体类型的偏好差异

图 5. 三类人群的步道空间偏好原因（ns 表示在 0.05 的水平上无显著相关性；* 表示在 0.05 的水平上显示显著相关性，** 表示在 0.01 的水平上显示显著相关性）。

图 6. 小西山步道空间规划建议

5 结论

在健康城市建设的推动下，徒步成为促进全民健康的有效方式之一。而步道空间作为徒步活动的重要空间载体，可通过探讨不同使用人群对步道空间的偏好，形成适应性建设方法，以满足多元需求。本研究以北京市小西山为研究案例，揭示了当下城郊山地步道空间存在的不同类型使用人群间偏好冲突的问题，探讨了不同登山徒步人群对于步道空间的偏好差异与原因。研究为城郊山地步道空间的使用构建了具体的人群画像，并聚焦与徒步体验密切相关的具体步道空间要素（道路材质、植物围合、路宽、坡度），关注人群偏好差异原因（趣味性、安全性、舒适性、挑战性），为城郊山地步道空间规划设计提供了具有普适性与可实践性的研究结论。研究既可为以小西山为代表的城郊山地步道建设提出对应策略，也能够为丰富全民健身的内涵、推动步道体系政策制定、提升相关规划设计实践提供积极借鉴，同时亦可为山地空间兼容自然保护与活动需求的可持续发展未来提供参考。