Journal of Landscape Research 2025, 17(2): 65–67, 72

Evaluation and Selection of Street Tree Species for Urban Main Roads in Hefei City

YANG Zhongliu, ZHAO Zhiyan*, FENG Jingwen, LI Huanhuan

(Department of Architecture and Landscape Design, Anhui Xinhua University, Hefei, Anhui 230088, China)

Abstract Through the investigation of the species of street trees located along the main urban roads in Hefei City, a total of 22 species were selected, belonging to 16 families and 22 genera, with the Sapindaceae family being the most prevalent. In this study, the Analytic Hierarchy Process (AHP) was employed to assess the comprehensive value of 22 species of street trees applied along the main urban roads in Hefei City. Fourteen evaluation criteria were selected from four categories: morphological indices, functional indices, resistance indices, and management indices, to develop a comprehensive evaluation model. Based on a composite score derived from 22 street trees, these trees were classified into three distinct grades. Grade I ($L \geq 3.0$) exhibited a high comprehensive application value in Hefei City and included 6 tree species, such as *Platanus*. Grade II ($2.5 \leq L < 3.0$) also demonstrated a high comprehensive application value, comprising 15 tree species, including *Catalpa bungei*. In contrast, grade III ($L < 2.5$) indicated a general comprehensive application value, represented by a single species, *Cedrus deodara*. The evaluation results can offer theoretical insights for the selection of urban street trees.

Keywords Street tree, Hefei City, Analytic Hierarchy Process (AHP), Comprehensive evaluation model, Application value

DOI 10.16785/j.issn 1943-989x.2025.2.015

Street trees play a crucial role in the urban green space system. The selection of street trees reflects the local climatic characteristics and cultural significances, serving as a significant indicator of the level of civilization and development within a city[1]. Street trees contribute to the enhancement of the environment by beautifying the landscape, purifying the air, and mitigating noise pollution. Furthermore, they assist in guiding the line of sight, thereby playing a significant role in promoting driving safety[2]. Currently, the selection of street trees in Hefei City faces several challenges, including a lack of species diversity, inadequate adaptability, and suboptimal aesthetic impact. This study conducts a comprehensive evaluation of the application value of various street tree species along the main roads of Hefei City using the Analytic Hierarchy Process (AHP), aiming to offer a valuable reference for the selection of appropriate street tree species in the city.

1 Overview of the study area

Hefei City is situated in eastern China, within the central region of Anhui Province, positioned between the Yangtze River and the Huaihe River, on the northern shore of Chaohu Lake, 116°41'–117°58' E, 31°30'–32°37' N. The city is characterized by a predominantly flat terrain, with elevations ranging from 20 to 40 m, and is situated around Chaohu Lake, such as Hengbu River and Chuhe River. The region is situated within the northern subtropical humid monsoon climate zone, which is characterized by a mild climate, moderate rainfall, abundant sunshine, and the absence of prolonged frost periods. The average annual temperature ranges from 15 to 17°C, while the average annual precipitation varies between 800 and 1,100 mm[3]. The soil in Hefei City is predominantly classified as clayey yellow-brown loam, characterized by shallow layers and a sticky, heavy texture. The pH level of the soil is generally neutral, falling within the range of 6.5 to 7.5, which facilitates the growth and development of various plant species[4].

2 Methods

2.1 Tree species

This study investigated street trees located along main roads in Hefei City from 2024 to 2025. A total of 22 common street tree species were identified, belonging to 16 families and 22 genera. Among these species, 13 are native to the region, while 9 are classified as exotic species, as detailed in Table 1.

2.2 Establishment of comprehensive evaluation model

This study evaluated 22 species of street trees, taking into account their biological characteristics and functional requirements, as well as the natural ecological conditions of the specific urban environment. Based on thorough investigation and research, and in reference to the findings of Luo Guibin[5], as well as the method proposed by Li Dan et al.[6] for establishing an index system for the evaluation of man-made forest habitats, the hierarchical structure of the index system for the evaluation of street trees were developed. A recursive hierarchical evaluation model that included a goal layer (A), a constraint layer (C), a criterion layer (P), and an alternative layer (D) was established (Table 2). According to the principles for the application of street trees, a total of 14 specific evaluation indices, including tree shape, trunk, shading effect, drought tolerance, soil adaptability, and pruning tolerance, were established as the criterion layer (P). The alternative layer (D) consisted of 22 species of street trees designated for evaluation.

2.3 Construction of judgement matrix and consistency test

The evaluation indices for each hierarchical level were compared. The 4 factors of the constraint layer and the 14 factors of the criterion layer were assessed and quantified using the 1–9 scale method. Subsequently, five pairwise comparison judgment matrices were constructed based on the results obtained from the experts' scoring (Table 3). The consistency test of the judgment matrix was performed

Received: February 16, 2025 Accepted: March 20, 2025

Sponsored by Provincial-level Undergraduate Innovation Training Program of Anhui Xinhua University (S202312216043); Natural Science Key Research Program for Colleges and Universities in Anhui Province (2023AH051816); Anhui General Teaching Research Project (2022jyxm665).

* Corresponding author.

using the maximum eigenvalue (λmax) and the corresponding weight values (*W*), with the consistency index (*CI*) utilized as an indicator for evaluation. The formula for calculating the *CI* is expressed as $CI=(\lambda max-n)/(n-1)$, where *n* represents the order of the matrix. The average random consistency index (*RI*) was examined, with values of *RI* being 0.0, 0.58, 0.90, 1.12, 1.24, 1.32, 1.41, and 1.45 for sample sizes (*n*) ranging from 1 to 9. The consistency ratio (*CR*) was subsequently calculated using the formula $CR=CI/RI$. A *CR* value of less than 0.10 indicates that the consistency of the judgment matrices is deemed acceptable, namely satisfying the criteria for a one-time test. The results presented in Table 3 demonstrated that all five judgment matrices exhibited a *CR* of less than 0.10, thereby passing the consistency test.

2.4 Calculation of hierarchical overall ranking weights

The total hierarchical ranking weights represent the relative importance of all factors within the same layer in relation to the supreme goal[7]. By employing a weighting calculation, one can ascertain the relative significance of each specific evaluation index factor in relation to the goal layer, thereby deriving the total ranking weights of the hierarchy[8]. The total ranking weights of the criterion layer in relation to the goal layer were as follows: tree shape (P1) 0.082, trunk (P2) 0.054, foliage (P3) 0.025, crown diameter (P4) 0.019, shading effect (P5) 0.307, ornamental value (P6) 0.153, barren tolerance (P7) 0.032, cold tolerance (P8) 0.150, drought tolerance (P9) 0.068, disease and insect resistance (P10) 0.023, pruning tolerance (P11) 0.020, defoliation and fruit drop (P12) 0.050, seedling multiplication (P13) 0.010, and transplanting survival rate (P14) 0.009.

3 Results and analysis

3.1 Evaluation values for each species

Based on the scores assigned to each tree species across various evaluation factors, the data underwent standardization before being incorporated into the comprehensive evaluation index system. Subsequently, the composite evaluation scores for each tree species were computed, as presented in Table 4.

Based on a composite score derived from 22 street trees, these trees were classified into three distinct grades. Grade I ($L \geqslant 3.0$) exhibited a high comprehensive application value in Hefei City and included 6 tree species, such as *Platanus*. Grade II ($2.5 \leqslant L < 3.0$) also demonstrated a high comprehensive application value, comprising 15 tree species, including *C. bungei*. In contrast, grade III ($L < 2.5$) indicated a general comprehensive application value, represented by a single species, *C. deodara*.

3.2 Conclusions and discussion

The findings regarding the composite score of the application value of street tree species indicate that grade I ($L \geqslant 3.0$) include tree species that have relatively high comprehensive application value in Hefei City. This classification includes six species: *Platanus*, *V. liquidambaricolum*, *A. buergerianum*, *S. sebiferum*, *K. paniculata*, and *P. stenoptera*. All six species exhibit broad crowns and dense foliage, which contribute to an effective shading effect. From a life form perspective, these species are classified as deciduous trees and demonstrate a high degree of adaptability to the environmental conditions of Hefei City. They possess notable ornamental value and are relatively easy to manage, resulting in a favorable overall evaluation. The preliminary survey indicated a high frequency of application for *Platanus* and *K. paniculata*, whereas the application frequency of *P. stenoptera* was notably low. *P. stenoptera* is a native tree species in Hefei City, characterized by its strong adaptability, rapid growth, effective shading effect, and robust resistance to pollution. Additionally, it offers both ecological benefits and aesthetic value. Therefore, it is imperative to enhance the utilization of this tree species.

Grade II ($2.5 \leqslant L < 3.0$) encompasses tree species that possess significant comprehensive application value in Hefei City, comprising a total of 15 species. However, these tree species are not sufficiently prominent in Hefei, as indicated by factors such as resistance, shading effect, landscape effect, and management frequency, which contribute to a relatively low composite score. The leaf morphology of *L. chinense* is distinctive, and its ornamental qualities are commendable; however, the associated management costs are substantial, resulting in a low composite score. Conversely, *C. camphora* exhibits a relatively slow growth rate, particularly

Table 1 Street trees in main roads of Hefei City

No.	Tree species	Family	Source
1	*Sapium sebiferum*	Euphorbiaceae	Native
2	*Bischofia polycarpa*	Euphorbiaceae	Native
3	*Sophora japonica*	Leguminosae	Native
4	*Albizia julibrissin*	Leguminosae	Native
5	*Pterocarya stenoptera*	Juglandaceae	Native
6	*Ailanthus altissima*	Simaroubaceae	Native
7	*Camptotheca acuminata*	Nyssaceae	Exotic
8	*Magnolia grandiflora*	Magnoliaceae	Exotic
9	*Liriodendron chinense*	Magnoliaceae	Exotic
10	*Ligustrum lucidum*	Oleaceae	Exotic
11	*Acer buergerianum*	Sapindaceae	Exotic
12	*Metasequoia glyptostroboides*	Taxodiaceae	Native
13	*Cedrus deodara*	Pinaceae	Exotic
14	*Koelreuteria paniculata*	Sapindaceae	Native
15	*Sapindus mukorossi*	Sapindaceae	Native
16	*Platanus*	Platanaceae	Exotic
17	*Viscum liquidambaricolum*	Altingiaceae	Native
18	*Ginkgo biloba*	Ginkgoaceae	Exotic
19	*Celtis sinensis*	Ulmaceae	Native
20	*Zelkova serrata*	Ulmaceae	Native
21	*Cinnamomum camphora*	Lauraceae	Exotic
22	*Catalpa bungei*	Bignoniaceae	Native

Table 2 Hierarchical index system for comprehensive evaluation of the application value of street trees

Goal layer (A)	Constraint layer (C)	Criterion layer (P)	Alternative layer (D)
Comprehensive evaluation of the application value of street trees (A)	Morphological index (C1)	Tree shape (P1), trunk (P2), foliage (P3), crown diameter (P4)	22 species of street trees to be evaluated (D1, D2, D3, …, D22)
	Functional index (C2)	Shading effect (P5), ornamental value (P6)	
	Resistance index (C3)	Barren tolerance (P7), cold tolerance (P8), drought tolerance (P9), disease and insect resistance (P10)	
	Management index (C4)	Pruning tolerance (P11), defoliation and fruit drop (P12), seedling multiplication (P13), transplanting survival rate (P14)	

Table 3 judgement matrix and consistency test

Hierarchical model	Judgment matrix					Relative weight (*W*)	Consistency test
A-C		C1	C2	C3	C4		
	C1	1	1/3	1/2	3	0.180	λmax=4.087
	C2	3	1	2	4	0.460	*CI*=0.029
	C3	2	1/2	1	3	0.272	*CR*=0.033<0.1
	C4	1/3	1/4	1/3	1	0.088	
C1-P		P1	P2	P3	P4		
	P1	1	2	4	3	0.457	λmax=4.132
	P2	1/2	1	3	3	0.300	*CI*=0.044
	P3	1/4	1/3	1	2	0.138	*CR*=0.05<0.1
	P4	1/3	1/3	1/2	1	0.105	
C2-P		P5	P6				λmax=4.132
	P5	1	2			0.667	*CI*=0
	P6	1/2	1			0.333	*CR*=0<0.1
C3-P		P7	P8	P9	P10		
	P7	1	1/5	1/3	2	0.118	λmax=4.104
	P8	5	1	3	5	0.550	*CI*=0.035
	P9	3	1/3	1	3	0.249	*CR*=0.039<0.1
	P10	1/2	1/5	1/3	1	0.083	
C4-P		P11	P12	P13	P14		
	P11	1	1/3	2	3	0.230	λmax=4.034
	P12	3	1	5	5	0.563	*CI*=0.011
	P13	1/2	1/5	1	1	0.108	*CR*=0.013<0.1
	P14	1/3	1/5	1	1	0.099	

Table 4 Comprehensive evaluation scores

No.	Tree species	Evaluation score	Evaluation grade
1	*Platanus*	3.341	I
2	*Viscum liquidambaricolum*	3.341	
3	*Acer buergerianum*	3.108	
4	*Sapium sebiferum*	3.090	
5	*Koelreuteria paniculata*	3.058	
6	*Pterocarya stenoptera*	3.013	
7	*Catalpa bungei*	2.955	II
8	*Celtis sinensis*	2.937	
9	*Ginkgo biloba*	2.918	
10	*Bischofia polycarpa*	2.908	
11	*Ligustrum lucidum*	2.846	
12	*Zelkova serrata*	2.837	
13	*Albizia julibrissin*	2.771	
14	*Sapindus mukorossi*	2.746	
15	*Cinnamomum camphora*	2.687	
16	*Sophora japonica*	2.670	
17	*Camptotheca acuminata*	2.655	
18	*Liriodendron chinense*	2.644	
19	*Metasequoia glyptostroboides*	2.560	
20	*Ailanthus altissima*	2.556	
21	*Magnolia grandiflora*	2.544	
22	*Cedrus deodara*	2.444	III

during the initial stages of cultivation. The prolonged period required for the establishment of a shading effect hampers its ability to promptly fulfill the demands of urban greening initiatives. Additionally, this species demonstrates poor tolerance to low temperatures, which can be problematic during winter months in Hefei City, where occasional low-temperature events may lead to frostbite of the leaves or hinder growth. Furthermore, the necessity for *C. camphora* to be safeguarded against diseases and pests contributes to increased maintenance costs, ultimately resulting in a low composite score for this species. Street tree species classified within grade II of the comprehensive value exhibit distinct characteristics that inform the selection of planting areas. This selection is based on local conditions, taking into account the climatic characteristics of Hefei and the urban layout. Consequently, this approach not only enhances the quality of urban greening but also contributes to the ecological and aesthetic value of the landscape. For instance, *L. chinense* exhibits an upright growth form, possesses a distinctive leaf morphology, and displays vibrant green foliage during the spring and summer months, transitioning to a golden yellow in the autumn. This species is recognized for its significant ornamental value. However, *L. chinense* demonstrates limited resilience to wind, water, moisture, and low temperatures. Therefore, it is essential to consider the specific field conditions when selecting appropriate tree species for cultivation.

Grade III (L < 2.5) encompasses tree species that possess an average comprehensive application value, with *C. deodara* being the sole representative. *C. deodara* is characterized by a tower-shaped crown and can attain heights of 20–30 m during its later growth stages. This significant height has the potential to obstruct traffic signals and street lamps, thereby impacting traffic safety and illumination. Furthermore, its well-developed yet shallow root system may cause damage to pavements and underground pipelines, consequently leading to increased maintenance costs. *C. deodara* prefers cool and dry climates. In contrast, Hefei City is characterized by a northern subtropical humid monsoon climate, which features high temperatures and significant rainfall in summer, as well as wet and cold conditions in winter. These climatic conditions are not entirely conducive to the growth of *C. deodara*, potentially resulting in suboptimal growth performance. Furthermore, *C. deodara* has stringent requirements regarding soil and water quality, necessitating regular pruning and management. Without proper care, the species is susceptible to diseases, pests, and growth imbalances, which complicates urban greening maintenance and increases associated costs. Consequently, these factors contribute to the low composite score of *C. deodara*. *C. deodara* possesses a distinctive morphology and contributes significantly to the landscape, while also providing ecological benefits to the environment. Its cultivation presents certain advantages, particularly as *C. deodara* thrives in the local microclimatic conditions of Hefei City, such as areas near water bodies or those characterized by high humidity. Therefore, it is essential to select an appropriate planting site for *C. deodara* based on the specific environmental conditions.

In conclusion, the selection of street tree species should be aligned with the local context.

(To be continued in P72)

of ecological vulnerability and the pressures associated with tourism development.

The exploration of green tourism practices serves as an effective means to enhance the appeal of regional tourism while simultaneously functioning as a critical strategy for achieving a balance between ecological preservation and tourism development. By establishing cross-sectoral coordination mechanisms, improving ecological compensation policies, and innovating community participation models, and other institutional frameworks, it is possible to foster the synergistic protection of regional natural and cultural diversity. This approach promotes the development of a sustainable pattern in which humans and nature coexist harmoniously.

4 Conclusions

A systematic analysis is performed to assess the current situation of transportation and tourism integration in 20 districts and counties located along National Highway 310 (Gansu–Qinghai section), and optimization strategies are further explored. We examine the current situation of integrated transportation and tourism development in the Gansu–Qinghai region and its surrounding areas. The findings indicate that both Gansu and Qinghai provinces face an urgent need to elevate the integration of transportation and tourism. This can be achieved through the innovation of development concepts and the optimization of operational models, thereby enhancing the comprehensive benefits of both the transportation and tourism industries. We additionally develop a framework aimed at facilitating the deep integration of road transportation and tourism. This framework simulates a "fast-forward-slow-travel" system in which tourists commence their journey from the origin, traverse through core, secondary, and subsidiary tourist destinations, and ultimately reach the core, secondary, and subsidiary attractions. Furthermore, this study presents optimization recommendations for the integrated development of regional transportation and tourism along the designated route. These suggestions encompass the establishment and optimization of facilities and service points, the planning and design of tourism routes, the promotion of regional synergistic development, the construction of intelligent tourism, and the implementation of green tourism routes. This approach offers a practice approach for the comprehensive integration of regional transportation and tourism, and enhances the experience of tourists while simultaneously extending the tourism industry chain. Furthermore, it promotes the high-quality development of regional tourism and facilitates the realization of multiple benefits across transportation, tourism, economy, and culture.

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Priority should be given to native species to fulfill essential ecological requirements while simultaneously contributing to the distinctive characteristics of the local landscape.

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