

Study on Eco-tourism Greenway Route Selection in the Border Areas of Inner Mongolia: A Case Study of Chen Barag Banner Postprint

Authors: Lin Mofei, Jiao Hongyun, Li Zhen, Li Zhen

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Abstract

To promote the transformation of ecological resource advantages into economic advantages in the border areas of Inner Mongolia, this study takes Chen Barag Banner as the research object. By constructing a Minimum Cumulative Resistance (MCR) model, resistance surfaces, key areas for greenway construction, and potential routes were derived. To address issues including ecological resources awaiting integration, underdeveloped and unutilized border landscapes, and lack of connectivity among open spaces, the data were analyzed and refined to determine organizational forms including connectivity relationships, radiation scope, and spatial structure, and to select optimal routes, ultimately yielding an ecological tourism greenway route planning scheme for Chen Barag Banner. Research findings indicate: (1) The current comprehensive cost surface resistance levels in Chen Barag Banner demonstrate a pattern of “high in the southeast and low in the northwest,” with areas characterized by flat terrain, convenient transportation, and abundant ecological resources being more suitable for greenway construction. (2) Based on the lowest-cost paths, selecting routes close to water systems and resource points can enhance greenway attractiveness and utilization rates; relying on the existing road system for greenway construction can reduce construction difficulty, minimize damage to ecosystems, and better conform to user behavior patterns. (3) Circular layouts can improve resource connectivity, radiating outward while organizing dispersed ecological tourism resources, thereby driving comprehensive tourism development. By systematically reviewing and analyzing ecological tourism resources and resource routes, a macro-level ecological tourism greenway route selection scheme of “one vertical, two belts, one ring” is proposed, and a route selection mechanism for ecological tourism greenways in border areas is established, thus providing a practical pathway for the integration of ecological tourism resources and greenway route selection.

Full Text

Ecotourism Greenway Route Selection in Inner Mongolia Border Areas: A Case Study of Chen Barag Banner

LIN Mofei, JIAO Hongyun, LI Zhen

(School of Architecture and Fine Art, Dalian University of Technology, Dalian 116024, Liaoning, China)

Abstract

To facilitate the transformation of ecological resource advantages into economic benefits in the border areas of Inner Mongolia, this study focuses on Chen Barag Banner as the research area. Using the Minimum Cumulative Resistance (MCR) model, we derive resistance surfaces, identify key construction zones, and generate potential routes for greenway development. Addressing challenges such as fragmented ecological resources, underutilized border landscapes, and disconnected open spaces, we analyze and refine data to determine organizational frameworks including connection relationships, radiation ranges, and spatial structures. Through this process, optimal paths are selected, culminating in a comprehensive planning scheme for Chen Barag Banner's ecotourism greenway network.

The study reveals three key findings: (1) The comprehensive resistance surface of Chen Barag Banner exhibits a distinct pattern of high resistance in the southeast and low resistance in the northwest, with flat terrain, convenient transportation, and ecologically rich areas being most suitable for greenway construction. (2) Selecting routes proximate to water systems and resource points while optimizing for least-cost paths enhances greenway attractiveness and utilization rates. Constructing greenways along existing road networks reduces construction difficulty, minimizes ecosystem disturbance, and aligns with user behavior patterns. (3) Implementing a ring layout improves resource connectivity by organizing dispersed ecotourism resources while radiating influence to surrounding areas, thereby promoting integrated regional tourism development.

Through systematic analysis of ecotourism resources and potential routes, this research proposes a macro-level route selection scheme characterized as "one vertical, two belts, and one ring," establishing a practical mechanism for ecotourism greenway planning in border regions and providing a viable pathway for integrating ecotourism resources with greenway development.

Keywords: minimum cumulative resistance model; Inner Mongolia border area; Chen Barag Banner; greenway route selection; ecotourism

Introduction

Since the 18th National Congress of the Communist Party of China, ecological civilization construction has entered a new stage. President Xi Jinping emphasized in his reports to the 19th and 20th Party Congresses that “we must establish and practice the concept that lucid waters and lush mountains are invaluable assets.” This principle, which has been incorporated into the newly revised Constitution of the Communist Party of China, encapsulates the theory of transforming ecological advantages into economic benefits, providing both theoretical guidance and practical direction for China’s green development. Consequently, how to effectively harness ecological advantages while maintaining a balanced relationship between economic growth and ecological protection has become a critical research priority.

Ecotourism, defined as “responsible travel in natural areas that aims to appreciate and enjoy historical and existing natural and cultural landscapes,” has rapidly expanded across China due to its ecological, recreational, and economic values. It has emerged as an effective mechanism for converting “lucid waters and lush mountains” into “invaluable assets.” Greenways, as linear open spaces that connect natural and cultural landscapes along ecotourism corridors, play a vital role in ecotourism project planning. The integration of “greenway” and “ecotourism” concepts can create a novel greenway system that promotes sustainable utilization of ecotourism resources and maintains a critical balance between regional ecological preservation and economic development.

Greenway research originated from the Boston park planning movement in 1867. Early studies focused on green linear open spaces using land suitability evaluation methods that were largely subjective. The field has since evolved into a comprehensive research system centered on greenway networks, particularly emphasizing multi-objective, multi-functional, and multi-scale greenways focused on human needs. Contemporary research methods have shifted toward quantitative analysis, employing least-cost path models, kernel density analysis, multi-criteria indicator systems, landscape graph theory, and metapopulation theory for integrated theoretical and practical investigations. Domestic greenway research in China began later, emerging in the 1990s and gaining momentum in the early 21st century. Current research predominantly focuses on urban-level greenways from a landscape ecology perspective, concentrating on urban green space patterns, ecological security, and recreational greenway development within city boundaries. Methodological approaches primarily employ quantitative analyses such as network structure analysis, minimum resistance model identification, and network structure evaluation integrated with theoretical models. Over 200 Chinese cities have publicly proposed greenway development policies, predominantly in developed coastal and central regions, with significantly less attention given to remote border areas.

Despite this progress, existing research exhibits several limitations: (1) Most greenway construction occurs within urban areas, focusing on specific functions

such as biological conservation or landscaping, thereby lacking comprehensive integration. (2) Studies emphasize natural resource characteristics but pay insufficient attention to user behavior and construction conditions. (3) While quantitative analysis dominates, there is a lack of qualitative assessment regarding the rationality of resource organization and development. Previous studies have primarily used quantitative methods through the Minimum Cumulative Resistance (MCR) model to construct comprehensive cost surfaces and identify feasible greenway zones, yet they lack qualitative analysis of resource organization rationality. Therefore, this study combines the MCR model with the Analytic Hierarchy Process (AHP) to conduct integrated quantitative and qualitative analysis, ensuring scientific rigor in greenway construction and development while exploring suitable network architectures based on greenway user behavior patterns.

Border areas, defined as regions adjacent to national boundaries, serve as crucial ecological security barriers and frontiers for stability. Their rich ecological resources and distinctive cultural heritage represent national treasures. China's border regions can be categorized by administrative level into provincial, prefecture-level, county-level, and township-level border areas. The "13th Five-Year Plan" for border area development explicitly proposes promoting development through central region support, forming a spatial pattern that uses border zones to drive broader regional growth. Inner Mongolia's border region spans 274,959 km², serving as a vital bridge for China's opening to the north. Characterized by unique foreign cultural landscapes and abundant undeveloped ecological resources, this region has suffered from a historical focus on urban greenways that has neglected border areas, resulting in low awareness and adoption of ecotourism greenways. Hulunbuir City, as a representative prefecture-level border area in Inner Mongolia, has achieved steady progress in border tourism development. However, Chen Barag Banner, one of its nine border counties, faces challenges in resource integration and connectivity due to geographical and transportation constraints. The ecological resources remain weakly connected, lacking a centralized ecotourism spatial pattern that leverages border advantages, thereby limiting economic development. Consequently, this study uses Chen Barag Banner as a case study, employing GIS technology and constructing an ecotourism greenway route selection model to harness regional ecological resource advantages and promote ecotourism economic development.

1.1 Study Area

Chen Barag Banner is located in the northwestern part of Hulunbuir City, Inner Mongolia, bordering Russia across the Argun River [Figure 1: see original paper]. Covering a total area of 17,458 km², it represents a typical border county-level administrative region. The terrain gradually descends from northeast to southwest, and the climate is characterized by mid-temperate semi-humid and semi-arid continental conditions. Grassland accounts for 85% of the total land area. While renowned scenic areas such as Bayantala Grassland, Morigele

Scenic Area, and Baiyin Hada Grassland are well-developed, other sites including Huliayetou Scenic Area and Badaguan Scenic Area remain in early development stages. With a population of 50,400 and 19 ethnic groups, Chen Barag Banner possesses a profound cultural heritage where grassland civilization intersects with modern culture, creating unique regional characteristics. The banner has received honors including the “6th Golden Travel Award for Most Ethnic (Folk) Characteristic Tourism Destination.” Its pristine resources, multi-ethnic culture, and international characteristics provide favorable conditions for ecotourism development, making it a representative and typical tourism resource in border regions.

1.2 Data Sources

Digital Elevation Model (DEM) data were obtained from the Geospatial Data Cloud Platform (www.gscloud.cn) and processed using ArcGIS to generate elevation and slope data. Land use data were sourced from raster datasets provided by the Chinese Academy of Sciences’ Resource and Environmental Science Data Center, including six categories: cultivated land, forest, grassland, water bodies, construction land, and unused land. Vegetation coverage data were derived from the 2020 Normalized Difference Vegetation Index (NDVI) spatial distribution dataset from the same institution. River system distribution data were obtained from China’s river basin spatial distribution dataset, with a spatial resolution of 1 km. Road network data were extracted from existing and planned transportation routes identified in the Chen Barag Banner Comprehensive Transportation Plan. Resource point distribution data were generated by importing coordinates of various resource points into ArcGIS software.

1.3 Research Methods

This study employs the Analytic Hierarchy Process (AHP) to evaluate ecotourism resource points and the MCR model to simulate least-cost paths, ultimately selecting optimal greenway routes for Chen Barag Banner. The methodology comprises four main steps: (1) **Resource point classification and selection**: Evaluate and select resource points with high influence as starting points for path simulation. (2) **Ecotourism greenway resistance surface modeling**: Classify resistance factors affecting greenway route selection and assign resistance values through weight evaluation. (3) **Greenway construction cost surface development**: Process single-factor resistance surfaces to obtain a comprehensive resistance cost surface that delineates final construction zones as the basis for greenway development. (4) **Greenway route extraction**: Simulate least-cost paths between ecotourism resource points, generate potential routes, and optimize them based on existing transportation networks and greenway construction zones to determine the final route architecture.

1.3.1 Resource Point Evaluation and Selection Following the “Classification, Investigation and Evaluation of Tourism Resources” (GB/T 18972-2017)

and “Scenic and Historic Area Planning Standards” (GB/T 50298-2018), we established an evaluation index system for ecotourism resource points [Figure 1: see original paper]. Official websites provided scenic area lists, from which 15 representative ecotourism resource points were selected to form the spatial dataset for Chen Barag Banner [Figure 3: see original paper]. Overall, resource points are primarily distributed in the western region, with clustered distribution in the central urban area, linear distribution along the northern riverfront, and scattered distribution in the southern region. This pattern suggests that clustered resource points in the central urban area can serve as hubs to connect linear riverfront resources in the north and scattered points in the south, achieving a radiation effect from the central city outward.

The evaluation results based on the ecotourism resource point index system are presented in Table 3. Resource points with weight values above 800 were classified as first-level resources and selected as starting points for path simulation, totaling 5 locations. The remaining 10 points were designated as second-level resources.

1.3.2 Resistance Surface Construction Referencing existing research [CITE] and the “Greenway Planning and Design Guidelines” issued by the Ministry of Housing and Urban-Rural Development, we selected resistance surface indicators based on principles of ecological protection and coordination. A dual-objective resistance index system was developed encompassing both ecological and recreational conditions [Figure 2: see original paper].

Ecological condition indicators include elevation, slope, vegetation coverage, land use type, and water systems. Elevation data were classified using the natural breaks method, with lower elevations receiving lower resistance values. Slope factors were graded according to the “Greenway Planning and Design Guidelines,” where gentler slopes correspond to lower resistance. Vegetation coverage was classified based on the “Soil Erosion Classification and Grading Standard” (SL190-2007), with higher vegetation coverage yielding lower resistance. Land use types were analyzed to assign the lowest resistance to grassland and highest to bare land. Multi-ring buffer zones were calculated around water systems, with smaller buffer distances corresponding to lower resistance values.

Recreational condition indicators include resource points and roads. Resource points were divided into first-level and second-level categories, while roads were classified as primary (national and provincial highways) and secondary (county and township roads) [CITE]. Multi-ring buffer zones were generated around these features, with proximity to resources and roads resulting in lower resistance.

The Delphi method was employed through expert questionnaires to obtain single-factor and comprehensive weights, which serve as the basis for constructing the comprehensive cost surface. Single-factor cost surfaces were then calculated and integrated to identify feasible greenway construction zones.

1.3.3 Greenway Route Extraction The MCR model was used to extract minimum cost paths between ecotourism resource points, generating potential greenway routes. The calculation formula is:

$$MCR = D_{ij} R_i \min \sum_j$$

where MCR represents the positive correlation function between movement process and cumulative resistance; D_{ij} is the distance from source point j to target point i ; and R_i is the resistance value at target point i 's location.

Potential routes were then refined and optimized based on existing transportation networks and feasible construction zones to determine the final greenway route architecture.

Results

2.1 Resource Points and Starting Points

Based on the current resource situation in Chen Barag Banner, we obtained the 2020 comprehensive tourism plan and scenic area list from the official government website, forming a GIS dataset of 15 representative ecotourism resource points [Figure 3: see original paper]. The spatial distribution shows concentration in the western region, with clustered patterns in the central urban area, linear distribution along the northern riverfront, and scattered points in the south. This distribution pattern enables the central urban clusters to serve as hubs connecting northern linear resources and southern scattered points, achieving outward radiation from the central city.

The evaluation results from the ecotourism resource point index system are shown in Table 3. Resource points with weight values exceeding 800 were classified as first-level resources and selected as starting points for path simulation, totaling 5 locations. The remaining 10 points were designated as second-level resources .

2.2 Resistance Surface Results

2.2.1 Resistance Surface Weight Results The weight values indicate the strength of association between each factor and greenway route selection . Ecological conditions demonstrated greater weight than recreational conditions, with land use type showing the highest weight among ecological factors, and first-level resource points showing the highest weight among recreational factors. Therefore, ecological conditions exhibit stronger association with greenway route selection than recreational conditions, while land use type and first-level resource points demonstrate stronger associations than other factors.

2.2.2 Single-Factor Cost Surface Results The single-factor resistance cost surfaces for Chen Barag Banner reveal distinct patterns [Figure 4: see original paper]. Low-resistance areas for elevation are distributed in the western high plains, while the eastern mid-low mountains show higher resistance. Slope resistance is low in western and southern regions, with eastern and northern mountainous areas exhibiting high resistance due to numerous hills. Vegetation coverage shows low resistance in northeastern mountainous areas and higher resistance elsewhere. Land use type resistance concentrates along the northern border and Morigele River, with other areas showing lower resistance. Water system resistance is low around the Argun River and other lakes, while distance to resource points shows low resistance near resource locations and higher resistance elsewhere. Road distance resistance is low along existing roads and higher in other areas.

2.2.3 Comprehensive Cost Surface Results Based on indicator weights, we calculated ecological condition cost surfaces, recreational condition cost surfaces, and the comprehensive cost surface for the greenway route selection model [Figure 5: see original paper]. Using the natural breaks method, the study area was reclassified into five resistance levels: high, relatively high, medium, relatively low, and low. Overall, resistance values are low in the northwest and high in the southeast, with low resistance in hilly areas and high resistance in mountainous regions. Low and relatively low resistance zones are primarily distributed around township roads, county roads, resource point buffer zones, and water system buffers, characterized by good transportation conditions, high vegetation coverage, and abundant ecological resources. Medium resistance zones are mainly located in western high plains and resource point buffer areas, featuring relatively flat terrain, moderate vegetation cover, moderate construction difficulty, and certain recreational value. High and very high resistance zones are concentrated in eastern mountains and along the northern border, with scattered distribution in central bare land areas characterized by low vegetation coverage and significant topographic relief, making greenway planning difficult despite available resources. Based on these results and regional realities, low, relatively low, and medium resistance zones were identified as key areas for greenway route selection in Chen Barag Banner.

2.3 Route Extraction and Analysis

2.3.1 Potential Route Generation Using the identified ecotourism resource points (5 starting points) and the comprehensive cost surface, the MCR model extracted minimum cost paths between resource points, generating 20 path groups that were merged to create preliminary ecotourism greenway route simulations [Figure 6: see original paper]. Following the economic principles outlined in the “Greenway Planning and Design Guidelines,” these simulation results were overlaid with existing roads to derive potential construction routes for Chen Barag Banner’s ecotourism greenway [Figure 7: see original paper].

2.3.2 Route Optimization The initial simulation results require correction based on construction key areas and actual conditions. Since existing transportation networks already connect most resource points in Chen Barag Banner, priority was given to aligning greenway trunk lines with these roads. Routes crossing high mountains without existing or planned roads were eliminated, as were duplicate sections or branch lines between adjacent resource points. Considering resource point locations and importance, high-weight locations including the Hulunbuir Grand Prairie Bayantala Grassland Scenic Area, Morigele Tourism Scenic Area, and Chen Barag Banner Ethnic Museum were designated as central hubs. Optimal paths were manually selected from adjacent resource point connections. From these central hubs, routes extend westward, northward, and southeastward along national and county roads to connect with the regional tourism network outside the banner, ultimately forming the Chen Barag Banner ecotourism greenway route plan [Figure 8: see original paper].

2.3.3 Route Selection Results Analysis The final greenway network exhibits a “one vertical, two belts, one ring” pattern [Figure 9: see original paper], fully showcasing Chen Barag Banner’s border landscapes, ethnic culture, and grassland scenery. **The “one vertical”** runs through the western high plains region, connecting five resource points from the border inward (Huliyetou Scenic Area, Hulunbuir Grand Prairie Bayantala Grassland Scenic Area, Genghis Khan Zhongdian Ecological Grassland Resort, Hulunbuir Meadow Grassland) across rivers, low mountains, and grasslands, condensing the banner’s ecological characteristics into a comprehensive landscape corridor. **The “two belts”** consist of a riverside landscape belt and a grassland landscape belt. The riverside belt, based on county roads, connects five resource points along the Argun River (Huliyetou Scenic Area, Huade Lake, Aegean Island, etc.), featuring rich border landscapes, river-lake scenery, and mountain views, forming a tourism route that transforms underutilized ecological resources into economic benefits. The grassland landscape belt, based on national highways, connects five grassland scenic areas showcasing ethnic minority culture (Hulunbuir Grand Prairie Bayantala Grassland Scenic Area, Huhenuoer Tourism Scenic Area, Baiyin Hada Grassland Scenic Area, etc.), creating an integrated ecological-cultural tourism corridor that invigorates grassland tourism. **The “one ring”** forms an ecotourism loop centered on clustered landscapes in the central region, connecting northern riverside linear landscapes and western/southern scattered resource points along national, provincial, and county roads. This loop links major ecotourism resources while radiating to peripheral scattered points, promoting coordinated development along and beyond the greenway corridor.

2.3.4 Route Selection Mechanism Development Based on the Chen Barag Banner ecotourism greenway network development, we analyzed the comprehensive objectives of ecotourism greenway construction by assessing resource potential and development pressures. This analysis guided the construction of the route selection model, ultimately proposing a border area ecotourism

greenway route selection mechanism featuring a “border comprehensive landscape axis, ecological-cultural landscape belt, border characteristic landscape belt, and regionally connected landscape ring” [Figure 10: see original paper]. This mechanism enhances the implementability and guidance of greenway route selection and research.

Ecotourism greenway construction can leverage regional ecological resource advantages, showcase distinctive cultures, and maximize integration of diverse resources and spaces, enabling ecological resources to drive economic development. As an important ecological barrier in China, constructing ecotourism greenways in Inner Mongolia’s border areas facilitates coordinated development of characteristic border landscapes and ecological scenery, realizing the transformation from ecological resource advantages to ecotourism economic advantages. However, current ecotourism greenway research in China remains focused on urban recreational greenways and simple resource linkages, with limited attention to western regions. Most construction stages are still in early phases, with low ecotourism resource development and insufficient integration with spatial planning. Therefore, this study, considering both ecological and recreational conditions in Inner Mongolia’s border region and based on systematic analysis of ecotourism resources, employs integrated quantitative and qualitative methods to propose a “one vertical, two belts, one ring” ecotourism greenway route selection scheme. This approach rationally utilizes Chen Barag Banner’s ecotourism resources, explores border landscape potential, and validates the feasibility of coupling ecotourism with greenway planning.

Nevertheless, several limitations remain: (1) The study focuses only on ecotourism resource points with long suitable tourism seasons, excluding ceremonial sites such as obo (stone mounds) and temples with longer activity cycles, while data collection lacks dynamic temporal dimensions. (2) Resource point connections are based on weight evaluation and resistance model calculations, providing rationality and scientific validity, but lacking analysis of existing tourism product planning. (3) Route selection conditions emphasize internal natural resources and transportation infrastructure, with insufficient analysis of surrounding regional landscape resources and tourism development. The greenway network extends beyond the region based only on existing road systems, warranting further investigation of connectivity with external regions. Future research will continue collecting relevant data on Chen Barag Banner, further systematically cataloging resource points, analyzing tourism planning strategies and infrastructure conditions in surrounding regions to enhance the reliability and accuracy of route selection outcomes, providing guidance for ecotourism economic development in Chen Barag Banner and other border areas.

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