Research on the Integrated Development of Comprehensive Transportation and Tourism Industries: A Case Study of Yunnan Province

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Abstract. This paper uses Yunnan Province as a case study. It examines the integration mechanisms and coordinated development of comprehensive transportation and tourism. The paper builds a "mechanism-evaluation" framework and analyses the interactive feedback mechanisms within these two sectors, as well as external driving factors such as policy, the economy, society, and technology. An integrated evaluation system is also set up. This system covers transportation service capacity and tourism development levels. The study employs the Entropy Weighted TOPSIS method and the Coupling Coordination Model. An empirical analysis is conducted on the integration level of transportation and tourism from 2014 to 2023. The results show that Yunnan's transportation-tourism coupling degree remains high throughout this period, and its coordination level improves gradually. The system is highly resilient. It evolves from "interactive symbiosis" to "high-efficiency synergy". Key barriers to integration vary at different stages. In the early stage, transportation challenges mainly lie in railway supply and demand imbalances, as well as insufficient network coverage. Later on, problems focus on aviation capacity, route layout, and supply and demand matching. This study provides theoretical and practical support for the integration of transport and tourism in multi-ethnic border regions. Future research should expand the range of comparative cases, delve deeper into mechanism analysis, extend the study period, and explore avenues such as "transportation + smart tourism".

Keywords: Integrated Transportation; Tourism Industry; Coupling and Coordination

1 Introduction

Integrated transport is a multimodal network comprising road, rail, and air transport. The principle is to achieve seamless coordination and linkage between different modes

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of transport, enabling the efficient movement of people and goods across spaces [1]. The tourism industry utilises an abundance of resources to offer visitors sightseeing, leisure, entertainment, and related services, spanning multiple sectors such as scenic area management, accommodation, catering, and tourism services [2]. The integrated development of comprehensive transport and tourism breaks down the traditional boundaries between the two sectors through technological convergence, product innovation, and market interaction, ultimately forming a new industrial model characterised by mutual dependence and coordinated development.

Current academic research indicates that the integration of transportation and tourism is a significant issue, attracting considerable attention in academic circles and in practical applications. In the early stages of related studies, scholars primarily focused on the one-way impact of transport on tourism. Bao Jigang et al. (2021), for example, conducted an in-depth analysis of the "time-space compression" effect brought about by high-speed transportation, exploring how this effect drives the complex redistribution of tourist flows [3]. Werner et al. (2017) highlighted the significance of transportation policies and the driving role of factors such as marketing, transparency, and demand-side attitude preferences [4]. As research progressed, the focus gradually shifted towards the bidirectional interaction between transportation and tourism. Guo Xiangyang et al. (2020), for example, used Yunnan Province as a case study to empirically verify the synergistic relationship between transportation service functions and tourism intensity, revealing the spatiotemporal characteristics of their coupled coordination state [5]. Albalate et al. (2017) found that tourism intensity can drive growth in urban public transportation demand [6]. However, existing research in this field has certain limitations. Border regions in ethnic areas typically possess abundant and unique tourism resources, yet their transportation infrastructure often lags behind. The integration mechanisms between transportation and tourism in these areas exhibit distinct characteristics that warrant further in-depth study. The pivotal role of aviation networks in the transportation–tourism integration process has yet to be fully incorporated into systematic research frameworks.

Therefore, this paper focuses on the integrated development of the tourism industry and comprehensive transportation. By analysing the intrinsic feedback mechanisms and external driving factors between the two sectors, a more comprehensive evaluation indicator system has been constructed. The study also aims to reveal the characteristics of the stages and the coordination patterns of the coupling process during integration. Using Yunnan Province as a case study, an empirical analysis is conducted to inform theoretical research and the practical advancement of transport-tourism integration in frontier regions.

2 Establishing Mechanisms and Evaluation Systems for Integrated Development

The aim of this chapter is to construct a comprehensive "mechanism-evaluation" analytical framework. It explores the intrinsic drivers, external forces, and operational

pathways of the integration of the tourism industry and comprehensive transportation, revealing the logic behind their interaction.

3 Analysis of the Integrated Development Mechanism

3.1 Internal Motivation

The development of integrated transport systems creates a "time-space compression" effect. The internal elements of these systems are closely interconnected and mutually reinforcing, collectively driving their own advancement. Key factors such as the size of transport modes, network structure, accessibility, and ease of transfer influence the level of development of the transport system itself, profoundly altering tourist behaviour and the landscape of the tourism industry. They affect tourists' decision-making by adjusting travel costs and willingness to travel, thereby governing the spatial distribution of passenger flows and dynamic changes to the spatial structure of the industry. From a developmental perspective, upgrading the integrated transport system increases its capacity, expands its coverage, and strengthens its supporting capabilities, ultimately reshaping the spatial pattern of tourism. The growth of tourism and the transformation of its spatial structure generate new transport demands, compelling the transport system to optimise and upgrade, and driving the network to evolve in response to these changes. This bidirectional interaction creates an intrinsic feedback loop: the integrated transport system drives tourism development, and tourism in turn reinforces the transport system. The two are interdependent and advance together.

The role of integrated transportation systems in boosting tourism is analysed as follows. Integrated transportation systems can drive tourism growth, expand the tourism market, and attract visitors to new destinations. Diverse transportation options and dense route networks reduce travel costs, making medium-to-long-distance and remote attractions more accessible. Transportation advancements enhance the travel experience. Airlines expand routes and optimize services; high-speed rail offers travel convenience; and highway networks evolve toward higher quality and greater customization. Integrated transportation hubs streamline transfers, collectively enhancing travel comfort. Transportation development drives tourism structural adjustments. It attracts investment, spurs new tourism formats, and enriches tourism products. Improved transportation conditions extend and integrate supply chains, forming tourism service clusters that drive related industries. This shifts tourism toward a comprehensive profit model. Enhanced transportation also accelerates tourism resource development, reduces resource utilization costs, and improves development efficiency. It attracts capital and technology for high-quality scenic area construction, connects scattered attractions, and promotes resource integration. This fosters the formation of scaled tourism routes and distinctive tourism regions, enhancing the appeal and competitiveness of tourism products.

The feedback effect of tourism development influences integrated transportation systems. While tourism development benefits from integrated transportation systems, it also exerts a powerful counterforce that drives continuous innovation within these systems. The two interact dynamically. Tourism creates new demand and guides resource

allocation, sustaining momentum for the optimisation and upgrading of integrated transport systems. This feedback effect is primarily manifested in the expansion of transportation demand driven by tourism development and the resulting structural adjustments. Tourism prosperity increases passenger volumes, directly driving the expansion of transport capacity. Seasonal fluctuations in demand compel operators to optimise scheduling and enhance efficiency. New travel modes, such as self-driving tours, encourage the development and improvement of highway networks. Transportation hubs gradually evolve into integrated service centres that cater to a variety of needs, thereby promoting the upgrading and optimisation of transport infrastructure. In order to meet tourism demands, certain facilities undergo improvements in terms of convenience, comfort, and aesthetics. The agglomeration effect of tourism will elevate construction standards for hubs. Hubs will integrate tourism services, balancing transportation and service functions, and will become showcases for urban tourism, driving improvements in transportation service quality and innovation. The high service standards of tourism will compel the transportation industry to optimise its products and services. For instance, airlines have introduced "in-flight tourism" services, railways have introduced cultural carriages, and motorways offer star-rated services. Innovative models such as "transportation + tourism" combined tickets simplify the purchasing process, guide the optimisation of transportation networks, and promote coordinated development. Tourism spatial patterns influence the planning of transportation networks, directing infrastructure towards areas rich in tourism resources. Regional coordination demands interconnectivity between interprovincial and intercity transport systems. Strengthening coordination between multiple transportation modes will facilitate seamless transfers. Tourism can explore new multimodal transport models to create efficient, convenient, integrated transport services.

3.2 External Factors

This paper employs the PEST analysis method to examine the macro-level external environment for the integration of the transportation and tourism industries.

In terms of policy promotion, the government's role is to formulate and implement a series of targeted policies to provide guidance. These policies provide crucial guidance and impetus for the integrated development of transportation and tourism. In 2017, the Ministry of Transport collaborated with five other relevant departments to jointly issue the "Several Opinions on Promoting the Integrated Development of Transportation and Tourism". This document explicitly states that the integration of transportation and tourism (hereafter referred to as "transportation-tourism integration") has become a new trend in upgrading and transforming the tourism industry. In 2019, the Central Committee of the Communist Party of China and the State Council jointly released the Outline for Building a Strong Transportation Nation. This document further clarified the new direction and pathways for the integrated development of transportation and tourism in the new era from a macro-strategic perspective. In 2022, the State Council formally issued the 14th Five-Year Plan for Tourism Development. The plan explicitly calls for the functionality of transportation networks to be strengthened to facilitate "fast access, slow exploration" and for connectivity to be enhanced between major

transportation corridors and key tourist destinations. This demonstrates the critical role of transportation in tourism development. At the same time, it powerfully confirms that continuous and steady advancement in the integration of transportation and tourism is the inevitable choice for achieving rapid growth in the tourism industry in the new era. This emphasises the pivotal role of transport in tourism development and validates the idea that sustained and steady promotion of transport-tourism integration is the key to achieving high-speed, high-quality growth in the tourism industry in the new era. This is highly significant for promoting the coordinated development of the tourism industry and its related sectors.

Meanwhile, provinces, autonomous regions, and municipalities have introduced multi-tiered policies at regional, provincial, and municipal levels, based on their own specific development characteristics and strengths. These policies have driven the integrated development of comprehensive transport and tourism networks. Yunnan Province, for example, is a transportation hub that extends to South and Southeast Asia. The province has received top-level design support for its transportation infrastructure under the national "Transportation Power" strategy and the Belt and Road Initiative. The Yunnan Provincial Government's "Yunnan Province Comprehensive Transportation Development 14th Five-Year Plan" (2022) incorporates transport and tourism integration into its "Five Vertical, Five Horizontal, One Border, Two Ring" expressway backbone network. The plan outlines six integration pathways, including "railway + tourism" and "expressway + cultural tourism". The 2025 "Several Policy Measures to Promote Comprehensive Expressway Development" document provides further details on the implementation of "Expressways + Cultural Tourism". This document requires service areas and toll stations to be connected to scenic spots and encourages the creation of new roadside attractions. Furthermore, the Five-Year Action Plan for Accelerating the Construction of a Transportation Powerhouse in Yunnan Province (2023–2027) sets out the explicit goal of establishing the "1233 Tourism Circle" by 2027, thereby strengthening the supportive role of transportation for the tourism industry.

Against the backdrop of sustained economic growth, residents' disposable income has increased steadily. This has significantly increased demand for travel and boosted residents' willingness to travel. It has also created vast market opportunities for the integrated development of comprehensive transport and tourism infrastructure. Currently, residents have ample funds for tourism. At the same time, they are increasingly opting for convenient and comfortable transport options to reach their destinations. For example, over the past decade, Yunnan Province's regional GDP has grown continuously. In 2023, Yunnan's GDP reached 3,002.112 billion yuan, with the tertiary sector accounting for 51.8%. Over this period, the tertiary sector's share of regional GDP has steadily increased, rising from 47.4% in 2014 to 51.8% in 2023. Taking into account factors such as Yunnan's stage of economic development, resource conditions, geographical advantages, and policy direction, the province has developed a distinctive industrial structure characterised by service-sector dominance, an emphasis on industrial upgrading, and agriculture-driven development. Since 2016, the service sector has consistently accounted for over 50% of Yunnan's GDP, becoming a focal point for economic growth. In line with Yunnan's strategic positioning as a "major tourism province" and "hub for South and Southeast Asia", the service sector continues to play a central role

in development. The province is committed to gradually establishing an industrial structure in which the service sector leads with a 55–60% share, high-end secondary industries account for 30–35%, and distinctive primary industries represent 10–12%. Transportation and tourism are core components of the service sector and hold significant developmental importance. As market demands evolve, tourist consumption patterns are changing. Visitors are moving away from prioritising "destination accessibility" and towards valuing "the quality of travel experiences". The rapid growth of self-driving tours and customised travel packages further highlights the need for integration between the transport and tourism sectors.

The sustained, rapid development of the socio-economy has transformed public consumption patterns and demand levels. With material needs now fully satisfied, spiritual and cultural consumption has emerged as a fundamental requirement in its own right. The tourism industry, a vital vehicle for delivering spiritual experiences, has entered a golden age of explosive growth. The upgrade in consumption in the tourism market has given rise to emerging sectors such as self-driving tours, health tourism, and cross-border travel. The growth of self-driving tours has increased demand for flexible and accessible transportation networks, accelerating the densification of highway networks and the advancement of interregional connectivity projects. Relevant departments are also developing supporting facilities such as RV campgrounds and self-driving service stations. The growth of wellness tourism has prompted scenic regions to upgrade their routes to create high-quality highways that prioritise driving safety and blend in with the surrounding landscape. The continuous expansion of cross-border tourism has accelerated the upgrading of border transportation hubs. Relevant departments are continuously improving international transport corridors and customs clearance facilities. These emerging tourism formats generate new demands that directly drive the transformation of the integrated transportation system.

Innovations in transportation technology have broken through the constraints of time and space, supporting the expansion of tourist destinations and enhancing travel experiences. The ongoing development of high-speed rail, including Fuxing series trains, has made it possible to travel a thousand miles in a single day. This has reduced journey times, revitalised the short-distance tourism market, and facilitated the integration of cross-regional tourism resources. In aviation, large passenger aircraft and wide-body jets have made long-haul flights more comfortable. Meanwhile, regional and general aviation have opened up aerial routes to remote scenic areas, bringing lesser-known destinations to the fore. New energy and green transportation technologies are pioneering new pathways for sustainable tourism development. The increased use of new energy vehicles has reduced carbon emissions during travel, while electrified railways have created clean, efficient long-distance transport networks. Energy-efficient facilities on smart highways reinforce these principles further. Big data and artificial intelligence are unlocking new avenues for precision tourism marketing. By integrating transport data and analysing passenger behaviour and consumption habits, businesses can target customer segments precisely, create personalised travel products, and achieve precise matching between transport and tourism resources. This enhances the efficiency of aligning supply and demand. It also propels the tourism industry towards more intelligent and refined development.

In summary, the current environmental conditions in China's political, economic, social, and technological spheres have created a robust external framework for the coordinated development of tourism and integrated transportation. Together, these key elements drive the orderly advancement of this integration process.

4 Construction of an Evaluation Indicator System Based on an Integration Mechanism

In order to translate the aforementioned theoretical mechanisms into quantifiable and comparable assessment tools, this chapter sets out to construct a comprehensive evaluation index system for the synergistic development of the transport and tourism industries. Based on the key pathways of internal feedback mechanisms and the core manifestations of external drivers, the system aims to accurately capture and quantify the actual performance levels of the various "effects" and "driving forces" within the mechanisms.

4.1 Construction of a Comprehensive Transportation Evaluation Indicator System

This paper draws on the research findings of Vanessa et al. [7], Nassereddine et al. [8], Guo Xiangyang et al. [5] and Karjalainen et al. [9]. The comprehensive transportation indicator system encompasses three core dimensions: road network density, accessibility, and locational advantage. While adopting the framework established by these studies, this research builds upon it and introduces innovations. It addresses the existing gap in the application of aviation network data within current research. Most existing literature focuses on ground transportation networks, overlooking the profound impact of air transport on regional tourism development. Yunnan Province, a typical tourism destination located in a mountainous border region, has benefited significantly from aviation network development. This has greatly enhanced tourism accessibility and played a crucial role in the development of tourism resources and the optimisation of tourism spatial structures. However, existing studies often overlook factors affecting the measurement of transportation service functionality, such as station distribution within the network, transfer convenience, and the relationship between the supply and demand of tourism resources. This paper incorporates these factors into an analytical framework to provide a more comprehensive and accurate evaluation of the role of transportation networks in supporting tourism development. The comprehensive transport indicator system established in this paper comprises three criterion layers: road transport services, rail transport services, and air transport services. Each criterion layer includes five indicators: road network density; traffic volume; transfer convenience; traffic capacity and supply–demand relationship; and route density. Detailed content is presented in Table 1.

Road network density is defined as the total length of transportation routes per unit area. It is a key indicator used to measure the coverage and accessibility of a region's transport infrastructure. Higher road network density usually means stronger spatial

connectivity within the area. Road network density is calculated by summing the weighted distances of highways and railways of different grades. The formula for road network density is as follows: $D = w_i \times (l_i \div A_i)$. Here, l_i represents the operational mileage of highways and railways of different grades, A_i denotes the land area of each region, and w_i signifies the weighting factor. In road transportation, the weights correspond to three categories: expressways (assigned a value of 0.5), non-expressway-grade highways (assigned a value of 0.3), and substandard roads (assigned a value of 0.1). In rail transport, weights correspond to two categories: high-speed rail (bullet trains) and conventional rail, with values of 0.5 and 0.3, respectively.

Traffic volume reflects the level of overall traffic flow within a transport network. It indicates the system's carrying capacity and operational intensity, and serves as a key indicator of its service capability and attractiveness. For highways and railways, traffic volume is calculated by multiplying passenger numbers by weighted coefficients for different road grades. For air transport, it is calculated based on passenger throughput at civil airports and airport grades. The traffic volume formula is: $T = w_i \times \ln(z_i)$. Here, w_i represents the weighting coefficient for different highway and rail transport grades. The weighting coefficient for air transport is determined based on airport passenger throughput. The specific standards are as follows: When passenger throughput is ≤ 2.5 million (inclusive), the weighting coefficient is 0.1. When passenger throughput is between 2.5 and 5 million (inclusive), the weighting coefficient is 0.3. When passenger throughput is between 5 and 10 million (inclusive), the weighting coefficient is 0.5. When passenger throughput exceeds 10 million, the weighting coefficient is 0.7. z_i represents the passenger volume, and i represents the passenger throughput corresponding to airport i.

Transfer convenience refers to how easy it is to switch between different modes of transport. It encompasses factors such as transfer distance, time, cost, and information connectivity. Transfer convenience is a key factor in determining the efficiency of combined transport and the overall travel experience. It is calculated based on the average commuting time between interchange junctions on provincial expressways, and between passenger transport stations, railway stations, and civil airports. This paper references the expressway speed design standards specified in the "Technical Standards for Highway Engineering of the People's Republic of China (JTGB01-2003)", establishing speed limits for different road types based on actual conditions in Yunnan Province. The specific speed standards are as follows: Expressways: 100 km/h; National highways: 80 km/h; Provincial highways: 60 km/h; County roads: 30 km/h. Scoring rules are as follows: If the commute time is less than 1 hour, award 2 points. If the commute time is between 1 and 2 hours (including 1 hour but not 2 hours), award 1.5 points. If the commute time is between 2 and 3 hours (including 2 hours but not 3 hours), award 0.5 points. If the commute time is greater than or equal to 3 hours, award 0 points.

Throughput capacity is the ability of a transport system to carry passengers over a given period of time. It is measured by average travel speed, which reflects the quality and efficiency of transportation operations. Throughput capacity is calculated by dividing passenger flow intensity by operational mileage. The formula for calculating the throughput capacity of road and rail transportation is as follows: $E_i = w_i \times \ln(k_i \div l_i)$. Here,

k_i represents the passenger volume of the i category of road or rail; l_i denotes the operational mileage of each category; and w_i indicates the weighting coefficient. The formula for calculating the throughput capacity of air transport is: $C = w_i \times (t_i \div l_i)$. Here, t_i represents an airport's passenger throughput, l_i denotes the number of aircraft take-offs and landings, and w_i indicates the weighting coefficient for different airport tiers.

Supply-demand relationship refers to the degree of alignment between the supply of transportation services and the demand for travel for tourism purposes. Viewed primarily from the traveller's perspective, it assesses the rationality of the allocation of transport resources and their capacity to support tourism activities. This relationship is a key factor in improving service quality and user experience. Its value is derived through a weighted calculation based on passenger throughput at highways, railways, and airports of different grades. The formula for calculating the supply-demand relationship is as follows: $X = w_i \times (l_i \div p_i)$. Here, l_i represents the operational mileage of highways and railways of grade i, as well as the number of aircraft take-offs and landings at airports of grade i, while p_i denotes the year-end resident population of each region, and w_i indicates the weighting coefficients for highways, railways, and airports of different grades.

The number of Routes is a core indicator used to measure the coverage and accessibility efficiency of an aviation network within a region. Higher route density typically indicates stronger passenger aggregation capabilities among the region's airports. Route density is calculated by assigning weights to each airport based on its passenger throughput, and then determining the overall route density. The formula for route density is as follows: $D = w_i \times (l_i \div A_i)$. Here, l_i represents the number of routes for airport i, A_i denotes the land area of the region, and w_i signifies the weight assigned to airport i.

Table 1. Comprehensive Transportation Evaluation Index System

Target Layer	Guideline Layer	Indicator Layer	Weight
A: Integrated Transportation Development Status	A_1: Road Transportation Services	A_{11}: Road Network Density /(km/km²)	0.1
		A_{12}: Traffic Volume /Point	0.07
		A_{13}: Transfer Convenience/Point	0.05
		A_{14}: Throughput Capacity /trips/km	0.09
		A_{15}: Supply-Demand Relationship/Point	0.12
	A_2: Railway Transportation Services	A_{21}: Road Network Density /km/km²	0.07
		A_{22}: Traffic Volume /Point	0.01
		A_{23}: Transfer Convenience/Point	0.05
		A_{24}: Throughput Capacity /trips/km	0.06
		A_{25}: Supply and Demand Relationship/Point	0.08
	A_3: Air Transport Services	A_{31}: Number of Routes /routes	0.04
		A_{32}: Traffic Volume /Point	0.07
		A_{33}: Transfer Convenience/Point	0.05
		A_{34}: Throughput Capacity /Point	0.08
		A_{35}: Supply and Demand Relationship/Point	0.05

4.2 Construction of an Evaluation Indicator System for the Tourism Industry

This paper aims to quantify the level of development of the tourism industry itself, as well as its potential and actual impact on transportation "feedback effects". Building upon existing research [10], this paper adopts a "supply-demand" framework for tourism activities as its analytical perspective in order to construct an evaluation indicator system for the tourism industry. This system encompasses five stages: industrial factor supply; tourist flow aggregation; the consumption process; benefit generation; and effect release. The system covers five dimensions — industrial factor supply, tourism scale, tourism consumption, tourism benefits, and tourism effects — comprising a total of 12 specific indicators (details as shown in Table 2).

Table 2. Tourism Industry Evaluation Indicator System

Target Layer	Guideline Layer	Indicator Layer	Indicator Definitions	Weight
B: Development of the Tourism Industry	B_1: Supply System	Supply of Industrial Factors	B_{11}: Number of 3A-rated and above tourist attractions and national scenic spots	0.17
			B_{12}: Number of star-rated hotels	0.03
			B_{13}: Number of travel agencies	0.12
	B_2: Demand System	Tourism Scale	B_{14}: Domestic tourist arrivals	0.05
			B_{15}: Inbound tourist arrivals	0.03
			B_{16}: Total number of tourist visits	0.05
		Tourism Spending	B_{21}: Per capita expenditure of domestic tourists	0.08
			B_{22}: Per capita expenditure of inbound tourists	0.11
		Tourism Benefits	B_{23}: Tourism revenue	0.06
			B_{24}: Tourism foreign exchange earnings	0.10
			B_{25}: Total tourism revenue	0.17
		Tourism Effect	B_{26}: Tourism output value as a percentage of GDP	0.02

5 Empirical Analysis

5.1 Research Area Overview

Yunnan Province is located in southwestern China, bordering Guizhou Province and the Guangxi Zhuang Autonomous Region to the east, Sichuan Province to the north, and the Tibet Autonomous Region to the northwest. To the west, it shares a border with Myanmar, and to the south, it connects with Laos and Vietnam. As of the end of 2023, the province covered a total area of 394,100 square kilometres and had a population of 46.73 million. The province comprises 16 prefecture-level cities and regions and is classified as an economically underdeveloped area of China with relatively low com-

prehensive economic competitiveness nationwide. Yunnan features a subtropical plateau monsoon climate. Its unique geography yields diverse natural landscapes, and the province is divided into eastern and western regions by the valley of the Yuanjiang River east of the Yunling Mountains. The eastern part comprises the Yunnan Plateau, while the western section encompasses the Hengduan Mountains. Yunnan is a multi-ethnic region where 25 minority groups have coexisted for generations, creating a rich cultural tapestry. This distinctive ethnic diversity provides a profound cultural foundation for Yunnan's tourism industry. Strategically positioned on China's tourism map, Yunnan boasts a variety of attractions, including the ancient town of Lijiang, Erhai Lake in Dali, and the tropical rainforests of Xishuangbanna, which together form an appealing cluster of tourist destinations.

5.2 Research Methods and Data Sources

In academia, there are numerous methods for determining indicator weights. The Entropy Weight TOPSIS method is unique in that it combines objective weighting with a comprehensive evaluation process. It objectively assigns weights based on the dispersion of indicator data, thereby avoiding subjective bias and accurately capturing data characteristics in complex scenarios. It also preserves the integrity of the original information [11, 12]. Consequently, this study employs the Entropy Weight TOPSIS method to calculate weight values for the transportation tourism industry's comprehensive indicator system.

The coupling coordination model is used to measure the interactions between different systems and reveal synergistic and mutually reinforcing relationships between them. A clear synergy exists between the integrated transport system and the tourism industry, where the two promote each other's development. By applying this model to calculate evaluation values, the quality of development of these two systems can be analysed [13]. The calculation process requires three indicator values: the coupling degree (C value), the coordination degree (T value), and the coupling coordination degree (D value). The specific calculation formulas are as follows:

$$C = 2 \times \sqrt{\frac{U_1 \times U_2}{(U_1 + U_2)^2}} \tag{1}$$

$$T = \alpha U_1 + \beta U_2 \tag{2}$$

$$D = \sqrt{C \times T} \tag{3}$$

This study references relevant literature and adopts widely accepted classification criteria. Using 0.4 and 0.7 as threshold points, the numerical range is divided into three categories as follows: 0 to 0.4 (excluding 0.4) is classified as the disordered decline phase; 0.4 to 0.7 (excluding 0.7) is classified as the transitional phase; and 0.7 to 1 (including both endpoints) is classified as the coordinated development phase. Each phase is then subdivided into ten levels, ranging from extreme disorder to high-quality coordination. The interval between levels is 0.1 [14]

Due to data delays, the study covers the period from 2014 to 2023. The raw data for the comprehensive transportation indicator system originates from the Yunnan Provincial Statistical Yearbooks and Prefecture-Level City Statistical Yearbooks (2015–2024) and the Yunnan Provincial Statistical Bulletins (2014–2023). Other data sources include the official websites of various government bodies, including the Yunnan Provincial Department of Transport (https://jtyst.yn.gov.cn/) and the flight schedule website (https://oag.cn/). Furthermore, data were obtained from the National Civil Transport Airport Production Statistical Bulletin (2014–2023) and the open-source mapping platform OpenStreetMap (www.openstreetmap.org). Raw data for the tourism indicator system were obtained from official websites of Yunnan Province and municipal governments, the Yunnan Statistical Yearbook (2015–2024), and the Ministry of Culture and Tourism's official website (https://www.mct.gov.cn/). Where data were missing, linear extrapolation and interpolation methods were employed to supplement the information. When transportation road data were missing or required processing, ArcGIS spatial analysis techniques were used.

5.3 Results Analysis

This study evaluated the degree of coupling coordination between the development of integrated transportation and the tourism industry after collecting data and conducting a comprehensive assessment of their respective statuses. The results of the assessment are presented in Table 3. The coupling coordination data indicate that the level of coupling between the two sectors has remained consistently high in the long term. This demonstrates that integrated transportation and the tourism industry have a strong interactive foundation in terms of resource allocation and factor mobility. It also reflects the deep interdependence between these two sectors. The development of transportation infrastructure has facilitated tourist mobility effectively, while the growth of the tourism industry has driven the optimization and upgrading of transportation facilities. The level of coordination has steadily increased, and this increase accelerated in the later stages. This trend suggests that Yunnan Province has continuously refined the development process of its integrated transport and tourism sectors, from initial design to practical implementation. The initial relatively low level of coordination was primarily due to differences in the speed of development and spatial layout between the two sectors. Later, however, policy guidance and resource integration gradually formed a mutually supportive, dynamic relationship between the two sectors. Measures such as establishing dedicated tourism corridors and optimising scenic area transportation networks have strengthened this coordination. The upward trend in coupling coordination vividly illustrates the evolution of these two industries from "interactive symbiosis" to "high-efficiency synergy". From 2020 to 2021, the coupling coordination index fluctuated slightly, primarily due to external shocks such as the pandemic. Transportation restrictions and tourism control measures temporarily disrupted the coordinated development process. However, the industry subsequently recovered quickly and resumed its upward trajectory. This demonstrates the robust resilience and significant development potential of Yunnan's integrated transport and tourism sector. When faced with

external challenges, the industry can quickly adapt and resume coordinated development.

Table 3. Coupling Degree, Coordination Degree, and Coupling Coordination Degree

Year	Coupling Degree (C Value)	Coordination Degree (T Value)	Coupling Coordination Degree (D Value)
2014	0.81	0.19	0.40
2015	0.99	0.28	0.52
2016	1.00	0.38	0.61
2017	0.99	0.44	0.66
2018	0.99	0.51	0.71
2019	0.97	0.59	0.76
2020	0.97	0.44	0.65
2021	0.97	0.42	0.64
2022	1.00	0.47	0.69
2023	0.99	0.78	0.88

Following a thorough evaluation, this study uses the obstacle degree to identify the main obstacles preventing the two systems from being coupled together effectively. This methodology provides a basis for diagnosing related issues [15]. The formula is as follows:

$$M(j) = \frac{W_j \times (1 - O_j)}{\sum_{i=1}^{n} [W_i \times (1 - O_i)]} \times 100\% \tag{4}$$

Analysis of development barriers in Yunnan Province's tourism industry and integrated transportation system reveals that, from 2014 to 2016, the main obstacles were related to "Tourism Benefits", "Total tourism revenue", and "Domestic tourist arrivals" (details as shown in Table 4). This suggests that during this period, the tourism industry experienced development bottlenecks in terms of market size and profitability, characterised by insufficient market vitality and limited revenue generation capacity. Starting in 2017, "Number of star-rated hotels" gradually emerged as a significant obstacle, becoming one of the primary barriers during the 2021–2023 period. This shift suggests that, once tourism reaches a certain stage of development, the level of supply of supporting facilities, such as accommodation, becomes a key constraint on industry growth. Other factors such as "Inbound tourist arrivals", "Tourism foreign exchange earnings", and "Per capita expenditure of domestic tourists" also gained prominence. This reflects the challenges of developing inbound tourism, while also highlighting the importance of expanding international markets and increasing foreign exchange income. From 2014 to 2019 and throughout 2020, "Number of 3A-rated and above tourist attractions and national scenic spots" remained a key constraint. This suggests that the quantity and scale of high-quality tourism resources have long limited industry growth.

As the main attraction for tourists, the shortage of premium resources limits market expansion and visitor numbers, thereby impacting overall industry growth. From 2014 to 2020, "Number of travel agencies" also served as a significant constraint. As intermediaries in tourism services, travel agencies are responsible for organising tourism products and attracting customers. Insufficient numbers of travel agencies constrain the supply capacity of tourism services and operational efficiency in the market, thereby hindering the industry's progress towards market-oriented development. These constraints collectively impact tourism development, encompassing tourism resource supply, tourism service intermediaries, supporting service facilities, market scale, and revenue (including the inbound market). Scarcity of high-quality resources weakened the foundation for industrial development, while insufficient numbers of travel agencies hindered service circulation. The lack of supporting facilities, such as star-rated hotels, limited service quality. Deficiencies in market scale and international market indicators exposed weaknesses in the industry's scaling and internationalisation processes. These multifaceted factors collectively form systemic barriers that constrain tourism development.

Table 4. Barriers to the Development of Different Industries

	First	Second	Third	Forth	Fifth
Barriers to Tourism Industry (System B) Development					
2014	B_{11}	B_{13}	B_{23}	B_{25}	B_{14}
2015	B_{11}	B_{13}	B_{23}	B_{25}	B_{14}
2016	B_{11}	B_{13}	B_{23}	B_{25}	B_{14}
2017	B_{11}	B_{13}	B_{12}	B_{21}	B_{23}
2018	B_{11}	B_{13}	B_{12}	B_{21}	B_{23}
2019	B_{11}	B_{13}	B_{12}	B_{21}	B_{23}
2020	B_{11}	B_{13}	B_{12}	B_{14}	B_{24}
2021	B_{12}	B_{11}	B_{13}	B_{13}	B_{24}
2022	B_{12}	B_{11}	B_{13}	B_{13}	B_{24}
2023	B_{12}	B_{14}	B_{21}	B_{24}	B_{22}
Barriers to Integrated Transportation (System A) Development					
2014	A_{25}	A_{21}	A_{32}	A_{22}	A_{32}
2015	A_{25}	A_{21}	A_{22}	A_{23}	A_{24}
2016	A_{25}	A_{21}	A_{22}	A_{23}	A_{22}
2017	A_{25}	A_{21}	A_{22}	A_{23}	A_{22}
2018	A_{25}	A_{21}	A_{23}	A_{22}	A_{35}
2019	A_{25}	A_{21}	A_{35}	A_{23}	A_{22}
2020	A_{24}	A_{22}	A_{32}	A_{25}	A_{21}
2021	A_{32}	A_{24}	A_{32}	A_{35}	A_{22}
2022	A_{24}	A_{32}	A_{32}	A_{35}	A_{22}
2023	A_{31}	A_{35}	A_{32}	A_{32}	A_{14}

From the perspective of the integrated transport system, "Rail Supply-demand relationship" was the main obstacle from 2014 to 2019. "Rail Road network density" consistently ranked second, becoming the second-largest constraint. This suggests that the imbalance between rail supply and demand, coupled with insufficient rail network coverage, has long hindered the development of the integrated transport system. Rail is a high-capacity, long-distance transport mode. Imbalances in supply and demand lead to operational inefficiencies. These imbalances can manifest as an inability to meet transportation needs, causing passenger and freight backlogs, or as excess capacity, resulting in wasted resources. Insufficient rail network density limits coverage, hinders effective connections between regions, and reduces the overall efficiency of the transport network. Furthermore, factors such as "Rail Traffic volume", "Rail Transfer convenience", and "Rail Throughput capacity" have repeatedly appeared among the assessed constraints over the years. This indicates that deficiencies in transport scale, transfer convenience, and operational efficiency hinder the development of integrated transport. After 2020, aviation-related constraints became increasingly prominent. In 2021, "Aviation Traffic volume" emerged as the primary constraint. By 2022, both "Aviation Traffic volume" and "Aviation Supply-demand relationship" had become significant constraints. By 2023, constraints such as "Number of Routes", "Aviation Supply-demand relationship", and "Aviation Traffic volume" had emerged. This reflects the growing importance of aviation within the integrated transport system, where capacity, route network coverage, and supply and demand alignment have become critical issues that constrain its development. The advantage of air transport is its ability to provide rapid long-distance transportation. Insufficient capacity limits the expansion of the scale of air transport, while limited route networks reduce service coverage. Imbalances between supply and demand also affect the efficiency and quality of air transport services, ultimately hindering the optimisation of the integrated transport system. In 2023, "Road Traffic volume" became the fifth major constraint. This indicates that, during certain periods, issues with road transport efficiency can also hinder the development of integrated transport. However, compared to rail and civil aviation, the impact of such issues on road transport is both transient and less pronounced. Overall, obstacles to the development of integrated transport are primarily rail-related in the early stages, while in later phases they are jointly dominated by challenges related to rail and civil aviation. This reflects the continuous evolution of development bottlenecks and constraints faced by various transport modes across different phases of development. In the early stages of integrated transport development, rail-related obstacles highlighted fundamental shortcomings of rail as the backbone mode. At the same time, as the system pursued greater efficiency and broader coverage, including long-distance rapid transport, air-related constraints revealed the challenges facing this emerging mode. These diverse types of obstacles collectively hindered the coordinated development of the integrated transport system, impeding overall efficiency gains.

From the perspective of constraints on the integrated development of the tourism industry and comprehensive transportation (as shown in Table 5), certain key factors consistently stood out, despite specific constraints varying across different years. For example, "Number of 3A-rated and above tourist attractions and national scenic spots" was a significant constraint in 2014, 2015, 2016, 2017, 2018, and 2020. This suggests

that the quantity and quality of tourism resources have a long-term constraining effect on the integrated development of the transportation and tourism industries. These premium tourism resources are the core attraction of the tourism industry. Insufficient numbers or an irrational distribution of such resources weaken the foundation of demand for integrated transportation and tourism. This also hinders the effective coordination of transportation infrastructure development and tourism industry growth. "Number of travel agencies" was also identified as a constraint in multiple years, including from 2014 to 2017 and in 2020. Travel agencies are vital intermediaries in tourism services, and their number directly affects market vitality and the ability to promote tourism products. Insufficient travel agencies limit the size of group tours, thereby affecting the integrated development of transport and tourism. For example, insufficient tourist numbers make it challenging to optimise and adjust transport routes to meet tourism demand. "Rail Supply-demand relationship" remained a constraint throughout 2014–2017. As a vital component of integrated transport, imbalances in the supply and demand for railways create two problems. On the one hand, insufficient capacity can cause inconvenience to passengers, while on the other, excess capacity can lead to the waste of resources. Both scenarios hinder the progress of integrated transport and tourism development. Key obstacles to the integrated development of comprehensive transportation and tourism include tourism resources, tourism service intermediaries, and transportation supply-demand dynamics. Subsequent efforts must address these factors by increasing the supply of high-quality tourism resources, promoting the development of travel agencies, and optimising the supply and demand for railways and other modes of transport. By taking these measures, the barriers to integrated development can be overcome.

Table 5. Barriers to the Integrated Development of Comprehensive Transportation and Tourism Industries

	First	Second	Third	Forth	Fifth
2014	B_{11}	B_{13}	A_{32}	A_{22}	A_{34}
2015	B_{11}	B_{13}	A_{22}	A_{21}	A_{22}
2016	B_{11}	B_{13}	A_{22}	A_{21}	A_{22}
2017	B_{11}	B_{13}	A_{22}	A_{21}	A_{22}
2018	B_{11}	B_{13}	A_{23}	B_{12}	A_{22}
2019	A_{32}	A_{34}	B_{24}	A_{31}	B_{15}
2020	B_{11}	B_{13}	B_{12}	A_{24}	A_{22}
2021	B_{12}	B_{11}	B_{13}	A_{32}	A_{23}
2022	B_{12}	A_{24}	A_{32}	A_{33}	A_{35}
2023	B_{12}	B_{15}	A_{31}	B_{21}	B_{24}

6 Conclusions

1) The transportation and tourism industries are integrated through an inherent feedback mechanism. The transportation sector expands the tourism market and improves the

travel experience, thereby promoting the growth of the tourism industry. Conversely, tourism stimulates demand for transport, promotes infrastructure upgrades, and consequently fuels the expansion of the transport industry. The convergence of these two sectors is driven by four external factors: political, economic, social, and technological.

2) An empirical analysis of Yunnan Province shows that the level of coupling between the transport and tourism industries has remained consistently high from 2014 to 2023. This has laid a solid foundation for their interactive development. The coordination level between the two sectors has steadily improved, with synergistic effects being continuously optimised. The coupling coordination index shows an upward trend, reflecting a shift in development from "simple interaction" to "high-efficiency coordination", and demonstrating strong resilience against risks. Even during the pandemic, both sectors achieved a rapid recovery. Next, we analyse the constraining factors. Tourism development is limited in several areas, including the quantity of high-quality tourism resources, the size of travel agencies, supporting facilities, and inbound tourism indicators. During the early stages of integrated transport development, bottlenecks primarily centred on the supply and demand relationship and the coverage of railway networks. Later, both railways and civil aviation became key factors that constrained the development of integrated transportation. The main obstacles to the integrated development of these two industries are threefold: a shortage of high-quality tourism resources; an insufficient number of travel agencies; and an imbalance between railway supply and demand.

This study has several limitations. Firstly, it uses Yunnan Province as a single case study, lacking a cross-regional comparative analysis, which reduces the generalisability of its findings. The analysis of the intrinsic logic of the mutual feedback mechanism between transportation and tourism is superficial. Furthermore, the study fails to explore the quantitative relationship between transport modes and the spatial distribution of tourism, nor does it examine the interactions among external driving factors. The empirical research covers the relatively short time period from 2014 to 2023, which makes it difficult to reflect long-term development trends or analyse the persistent impact of hindering factors. Future research should adopt a broader case scope to incorporate cross-regional comparative analysis. Micro-level methodologies should be adopted to gain a deeper understanding of the operational mechanisms of both sectors. Missing indicators should be supplemented, and the indicator system refined by integrating subjective and objective weights. Extending the timeframe of the empirical study would facilitate dynamic forecasting. Furthermore, it is crucial to explore integration pathways under new technologies and models, such as the "transportation + smart tourism" model.

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