

Article

Investigating the Accessibility between Civil Airports and Tourist Locations in Tourist Cities in Yunnan Province, China

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Abstract: Coordinated development between landside transport at civil airports and aviation networks is key for determining the attractiveness and competition of tourist cities. However, only a few studies have focused on the accessibility of tourist locations around civil airports in tourist cities in China. This paper calculates the service coverage of civil airports for tourist locations in Yunnan in selected years, consisting of 2000, 2005, 2010, and 2015, by using an accessibility calculation method with the shortest path and a spatial analysis method in ArcGIS software. The results are compared with the structural characteristics of the aviation network in corresponding years. Additionally, some suggestions are given regarding transportation development and sustainable environmental development in tourist cities. The findings show that the service coverage of civil airports in Yunnan has gradually improved over time. Specifically, 83.41% of tourist locations can be reached within 1.5 h of driving from an airport, and all tourist destinations could be reached within 3 h in 2015. Among all civil airports, the airports in the hub city of Kunming and at world-renowned tourist destinations such as Dali and Lijiang displayed the highest airport service capabilities for tourist locations. Meanwhile, the aviation network of Yunnan Province is constantly improving with an increased number of airports and airlines, and it shows the centralization trend toward KMG. However, the mismatch is observed not only in tourist cities with hub airports, such as Kunming, but also in some cities located in remote areas (i.e., far from the central city). This finding reveals that in these tourist cities in Yunnan, the development of airport transport has not considered coordination between the airline network and the service coverage of civil airports for tourist locations. For the sustainable development of tourist cities, the equal importance of airport landside transport and the airline network in the planning and management of air transport should be emphasized.

Keywords: service coverage; civil airport; landside transport; tourist city

1. Introduction

Air transport, the fastest way for transporting tourists to their destination cities, plays an extremely important role in tourist travel activities [1]. In recent years, with the booming global tourism industry, airports have become strategic assets for supporting sustainable tourism strategies and generated increasingly important implications for local tourism development [2–7]. In particular, air travel is the

only way for tourists to access cities in relatively remote locations due to the difficulty in constructing transport infrastructures such as high-speed rail networks and expressway networks.

Given the importance of airports in travel, previous studies mostly focused on improving the service quality of airport transport from the perspective of an airline network or airport management. Specifically, these studies identified the airline network structure [8,9], evaluated the aviation operating efficiency [1,10], and assessed and improved the business management performance of airports [11,12]. Moreover, some efforts, such as opening new airline routes [13], optimizing flight schedules [14], and applying advanced technology in biometric e-gate security systems [15], have been made to improve the service quality of airline networks and airports. The benefits of these endeavors include increasing the linkage and connectivity between the origin market and destinations, which occurs in the first stage of the travel chain. The travel chain concept in terms of tourists refers to travel activity origins in the tourist source market and tourist destinations. A complete travel activity includes two stages related to transport. First, the origin market is linked with the tourist destination; second, access and mobility must be provided within the destination area (e.g., a city) [16].

In recent years, with the importance of transport services in the second stage of the tourist travel chain, landside transport to and from airports has become an increasingly popular topic in the field of tourism and transportation. Notably, the above factors have led to increases in the demand for air travel and the number of airport passengers, and thus it is urgent to provide optimal landside transportation services to handle the increased passenger flows at airports with regard to airport operation management [17]. Additionally, in terms of the individual travel activities of tourists, a convenient and sound landside transport network of airports is needed to improve the overall tourism experience.

Despite the significant roles of airline networks in providing connectivity among airports and landside transport to and from airports in the travel chain, little attention has been given to coordination among travel types, which could improve the attractiveness and competitiveness of air transport in tourism travel. Currently, in China, the success of sustainable tourism development has been promoted through the construction of rapid transport networks [18]. Due to the importance of airports in tourism, a large amount of money has been allocated for airport construction and aviation infrastructure upgrades across the country. A good example of this approach is Yunnan, which is considered one of China's most attractive international tourist destinations. Since there are many mountainous areas and few plains areas in Yunnan, the construction of rapid land transport networks has faced difficulties and challenges, and the aviation industry is dominant in supporting tourism development. According to the *Development Plan of the Yunnan Aviation Industry (2018–2030)*, the total airport passenger throughput of Yunnan will increase to 150 million by 2030, and the output of the provincial aviation industry is estimated to reach 100 billion yuan by 2030. However, high-speed rail, as a rapid form of land transportation that can compete with air transport, is also developing rapidly in Yunnan. Empirical studies have examined the negative impact of the introduction of high-speed rail on air passenger flows, especially the reductions in short- and medium-distance trips [19]. In this context, there is an urgent need to enhance the attractiveness and competitiveness of airports and emphasize the equal importance of airline networks and airport landside transport in tourism. In particular, we should focus on the coordinated development between airline networks and airport landside transport.

Therefore, the objective of this study is to explore the coordination between service coverage of civil airports for tourist locations and the airline network structure through a case study of Yunnan, a representative (recognized) tourism province in China, thereby enabling airports to provide more attractive and satisfactory services to tourists with appropriate policy and management decisions. To achieve this goal, an empirical analysis was conducted of the service coverage of civil airports combined with a shortest-path method based on GIS spatial analysis in four different years (2000, 2005, 2010, and 2015), and we compared the results with the characteristics of the airline network structure in the corresponding years.

2. Related Literature

2.1. Airport Transport

Empirical studies indicated that airport transport plays an important role in tourist activities and is a determining factor in long-distance trips [6,16]. According to the International Air Transport Association (IATA), more than 70% of international tourists reach their destinations by air [20]. Although the importance of air transport in tourism development has been widely recognized, few studies have examined the influences of airport transport from a tourism perspective. Most of the existing studies focused on air transport networks, such as the complex structure characteristics of networks and the corresponding determinants, as well as the impacts of structure on industry or economic development. For example, several studies by Wang et al. [21] and Dai et al. [22] explored the evolving structure of air transport networks by using a complex network method, and they demonstrated that the economy is a factor that influences the spatial characteristics of networks. Silva et al. [10] analyzed the selection of the optimal airline network structure in the presence of congestion externalities. Berechman and Shy [23] considered the effects of network structure on the scheduling and fare choices of a monopoly airline and assumed that passengers gain an extra benefit when flying in private plane because of the short time.

Recently, the competition between high-speed rail (HSR) and air transport has attracted increased attention. Zhang et al. [24] found that HSR can decrease the connectivity of air transport networks. Rothengatter [25] indicated that airlines and HSR are fiercely competitive for trips in the range of 400–800 km. Su et al. [26] focused on passenger preferences and examined the effects of access time, income, sex, and travel purpose on the mode choice of HSR or air transport; specifically, they found that a travel companion is also a determining factor. Passengers traveling with someone else have a greater preference for HSR, whereas those traveling alone are more inclined to use air transport.

Recent works have focused on the environmental and financial sustainability of air transport. An empirical study by Tang et al. [27] examined the contribution of transport to the tourism industry in China, and they concluded that airport transport is the second largest contributor after road transport. Adler et al. [28] and Lee et al. [12] indicated that enhancing the business performance of airports can provide an effective survival environment with appropriate financial support policies. According to Jin et al. [9] and Miyoshi et al. [29], modifying an airline network, such as optimizing the layout of airline routes and improving network efficiency, is good for the sustainable development of airline networks. Other authors have insisted that high network connectivity among airports is a crucial element in airport choice [24,30], which can improve the competitiveness of airports by attracting tourism and inward investment. However, the availability of low-cost carriers at airports had a negative effect on network connectivity [31].

From the perspective of the travel chain, the above discussion is mainly associated with the first stage of the travel chain and involves intercity transport services linking the origin cities with the destination cities. However, in terms of the tourist travel chain, the second stage of transport service, which provides landside transport to and from airports and mobility within a destination area, is equally important for air travel [32,33]. Little attention has been given to coordination among these factors, and they have not been integrated into a unified framework for tourism and air transport.

2.2. Landside Transport of Airports

Landside transport of airports refers to the cost of travel and the quality/quantity of available opportunities of arriving at the destinations by land transport (e.g., road transport and urban public transport) from airports. Convenient and sound landside transport networks at airports will greatly reduce the travel time in tourist cities and increase the benefits of tourism development. Currently, many countries have realized the importance of landside transport of airports in tourism development and increased competitiveness by providing appropriate travel services, such as urban public transport and road transport [34]. In Europe, there are often connections to long-distance railway networks, and

in Asia, the majority of airports are connected to urban rail systems [35]. Budd et al. [36] indicated that for most of the major airports in the UK, road transport is heavily used by travelers accessing airports. The importance of landside transport of airports is the same in China. For several famous tourist destinations such as Beijing, Hainan, and Taiwan, there has been increased focus on promoting improvements in the connection services from airports to tourist attractions. Among the various modes of land transport that connect to airports, car travel is the most often used [37].

However, most previous studies did not specifically focus on tourists. Kazda and Caves [38] stressed that different airport users vary with regard to their landside transport access requirements and characteristics. Pels et al. [39] observed that business travelers value time more than leisure travelers, and access time is of considerable importance in the competition among airports in a region. Therefore, the landside transport of airports must be urgently assessed from a tourism perspective.

In terms of airport landside transport, the service coverage to tourist locations is an essential issue for tourists that influences the overall travel experience. Although little attention has been given to tourist travel, several studies have measured the service coverage in the surrounding areas of airports. The results showed that airport service coverage in different regions varies. In China, a 1.5-h driving time is recognized by the Civil Aviation Administration of China (CAAC), and the area within the associated distance from an airport can enjoy effective air transport services. The European Commission affirmed that a 10-km distance or 1-h driving time is the minimum service area in which effective air transport services can be obtained, and the Civil Aviation Administration of Britain claimed that the service coverage of airports is larger than a 2-h driving distance. Lieshout et al. [40] indicated that in terms of large airports, the service coverage ranges from 2-h to 3-h driving distances.

There are two types of analytical methods used to evaluate the service coverage. First, in models such as the Huff model and non-aggregation model, the service coverage divisions are based on administrative borders. The second type includes distance-based and time-based accessibility methods, which are the most widely adopted in the existing literature. Wang et al. [41] explored the spatial patterns within 50 km and 100 km of Chinese airports by using a distance-based accessibility method. Pan and Cong [42] applied a distance-based accessibility method to calculate the service coverage of Chinese airports from 1991 to 2012 and identified the evolving characteristics of airport land transport accessibility from a spatial perspective. By using a time-based accessibility method, Zhou et al. [43] investigated the impact of the airport catchment area on the air travel demand.

Therefore, this paper, based on the perspective of the tourist travel chain, focused on the equal importance of airline networks and airport landside transport in tourism. In investigating the airport landside transport, the service coverage of civil airports for tourist locations was calculated. Then, the coordination between it and airline networks was explored by using the comparison analysis between the service coverage of airports for tourist locations and airline network structure. The coordination analytical results help to provide some insights for promoting the sustainable development of airport transport, especially for airports sustainability from a tourism perspective.

3. Materials and Methods

3.1. Study Area

Located in southwestern China, Yunnan Province covers an area of 390,000 square kilometers. It consists of 16 cities, and Kunming is the provincial capital city (as shown in Figure 1). The subtropical plateau monsoon climate throughout the year makes Yunnan a pleasant place, and it enjoys the reputation of being one of the top tourist destinations in China. Since the province proposed the concept of “Building Yunnan to a Tourist Mecca” in 2013, the tourism industry in Yunnan has developed rapidly. The tourism income and tourist arrivals have surged, with average annual growth rates of 56.97% and 33.00%, respectively. In 2017, Yunnan Province ranked seventh in China in terms of tourist arrivals and gross tourism revenue, with 580.64 million visits and 569.222 billion yuan, respectively [44]. Ninety-four percent of the 390,000 square kilometers of the province are mountainous areas, which

contributes to the scattered distribution of tourism resources in Yunnan. Thus, air transportation has become a major transport mode for tourists visiting cities such as Lijiang, Dali, Shangri-La, Tengchong, and Xishuangbanna. The data indicate that tourism revenue and airport throughput are positively correlated and that the relation is statistically significant. The fitting curves of the two datasets are shown in Figure 2. Based on this relation, the development of the air transport industry in Yunnan Province is closely and positively related to the development of tourism; thus, the case of Yunnan Province is feasible and representative.

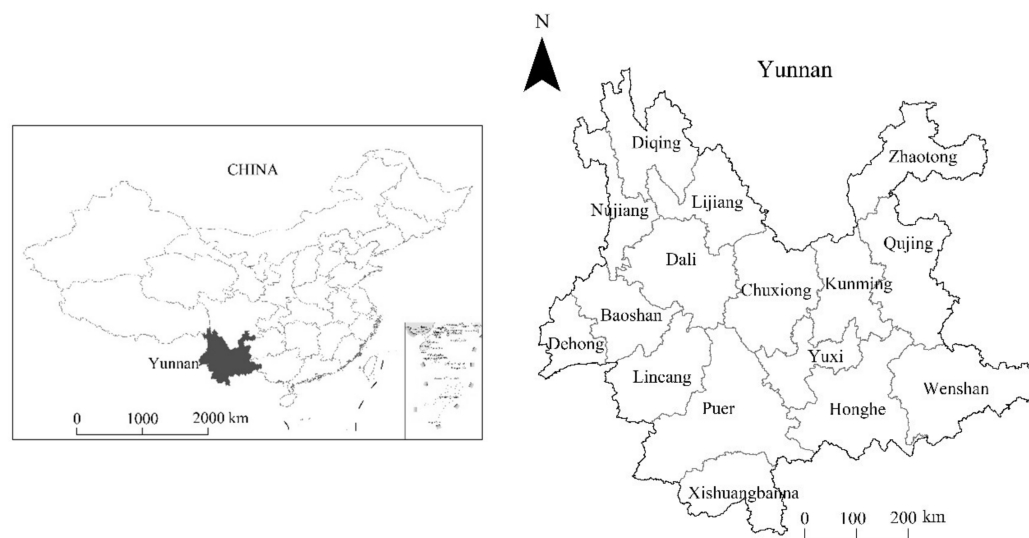


Figure 1. Location of Yunnan in China.

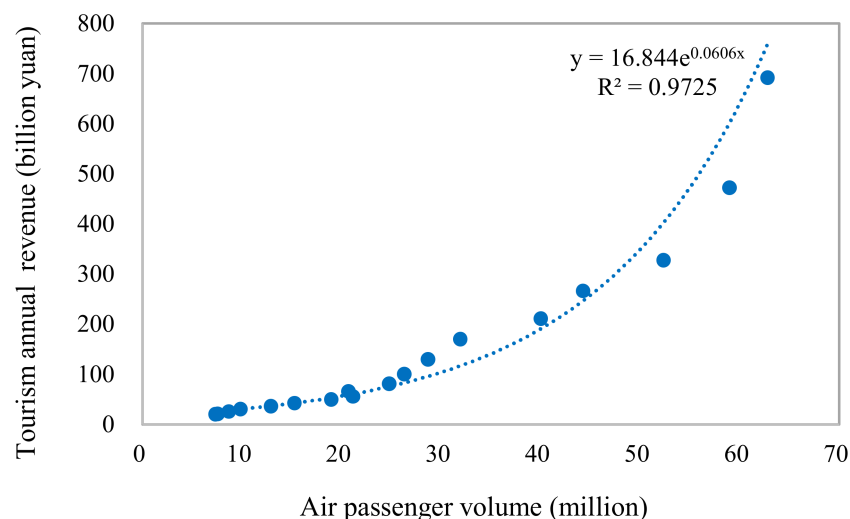


Figure 2. Fitting curves of the relationship between tourism annual revenue and the air passenger volume of civil airports in Yunnan Province from 2000 to 2017.

Currently, there are 15 civil airports in Yunnan Province. The total passenger throughput ranks first in Southwest China with 62.78 million visits. Among the 15 airports, Kunming Changshui International Airport boasts the largest passenger throughput with 44.73 million passengers, ranking first in the province and sixth in the country. According to the *Implementation Plan of Tourism in Yunnan Province*, the number of civil airports in Yunnan Province will increase to 20 by 2020, and more routes will be opened. By then, an aviation network covering the main destinations and passenger distribution centers in Yunnan Province will be established. In terms of landside transport at airports,

road networks are heavily used by tourists to reach nearby attractions. Only Kunming Changshui International Airport has a connected metro system.

3.2. Data Sources

The related data come from different sources and include graphical, transportation, and economic data. Table 1 presents the data sources in this study. Four time nodes, including 2000, 2005, 2010, and 2015, are selected to analyze the accessibility of civil airports, service scope, and traffic radiation coverage of tourist locations above the A grade.

3.2.1. Graphical Data

ArcGIS Desktop 10.2 is used in this study. Vector data of spatial administrative boundaries are derived from the basic geographic information data from a 1:4 million map provided by the National Basic Geographic Information Center. Attribute information, such as the names and types of airports and A-level tourist locations, were collated from relevant statistical yearbooks, and the corresponding geographic coordinates were obtained through Google Earth. The vector data of road traffic networks are basic geographic data from a 1:4 million map provided by the Yunnan Transportation Department.

3.2.2. Transportation and Economic Data

Air transport data were collected from the websites of the China Civil Aviation Administration and Statistical Data on Civil Aviation in China. This data includes attribute information for flight segments, such as the place of departure and destination, as well as the passenger traffic volume.

Table 1. Data sources in this study.

Data Categories	Description	Source
Graphical Data	Spatial administrative boundaries, road traffic data, geographical coordinates of airports, and scenic spots	National Basic Geographic Information Center, Yunnan Provincial Transportation Department, Statistical Data on Civil Aviation of China, Tourism Statistics Yearbook of China
Transportation and Economic Data	Flight segment attributable information, air passenger volume	Statistical Data on Civil Aviation of China, Civil Aviation Administration of China (CAAC)

3.3. Measurement of the Service Coverage of Civil Airports for Tourist Locations

Service coverage of civil airports for tourist locations is related to an effective coverage area at airports, and it can be measured by the shortest driving time distance from civil airports to tourist locations. The following two steps are designed to evaluate the service coverage of Yunnan Civil Airport for tourist locations.

In the first step, the accessibility of civil aviation airports is measured. Accessibility assessment methods have been studied in the literature [45–48], including space separation, cumulative opportunity, spatiotemporal, gravity and topological methods. The shortest-path method is adopted in this study, with a calculation formula as follows [49]:

$$A_i = \min(M_j, T_{ij}) \quad (1)$$

where A_i represents the accessibility of any point i in the study area, T_{ij} is the minimum travel time between point i and airport j in the road traffic network, and M_j expresses the weight of airport j . Generally, the weight measures the relative importance of destination airport in terms of the regional air traffic network. In this step, the objective is to obtain accessibility from any point i to airport j , and the influences of airport weight differences on accessibility are not considered. Thus, according to the literature [49], the M_j is assigned to 1. The lower the A_i , the better accessibility of the point i .

In this study, ArcGIS Desktop 10.2 is used to automatically perform calculations with Equation (1). Generally, there are two ways to implement ArcGIS computations—namely, network accessibility methods based on the ArcGIS network analyst module and raster accessibility methods based on the ArcGIS spatial analyst module. The ArcGIS network analyst module and ArcGIS spatial analyst module are two important toolboxes in the ArcGIS desktop software. The former approach is useful for calculating the accessibility of nodes that belong to the network, and the accessibility of non-network nodes cannot be obtained. However, the raster accessibility methods can overcome this shortage caused by network accessibility methods and is more accurate in accessibility estimation. Thus, raster accessibility methods based on the ArcGIS spatial analyst module are adopted in this study.

The basic principle of raster accessibility methods is to divide a specific region into many square cells (i.e., grids) first and then search for the shortest travel time to arrive at the airports from any square cell. The raster accessibility is obtained by the following steps using the ArcGIS spatial analyst module [49]. (1) The entire area of Yunnan Province is divided into 342,798 effective grids of 1000 square meters each, which is very small compared to the total area of Yunnan Province (394,100 km²); thus, there is no difference in the accessibility of each grid. (2) In line with the Highway Engineering Technical Standard of the People's Republic of China (JTGB-2003), given the designed speed and actual running speed of road traffic in different periods, the speed limits of different grades of roads are determined, and the average travel time of 1 km is calculated (Table 2). As a result, a time–cost grid based on the road traffic network is generated. (3) Taking an airport as the target, the shortest time cost from any grid to the airport in the study area is calculated by using the cost distance command in ArcGIS 10.2.

Table 2. Speed and time–cost settings for different grades of roads.

Year	Index	Expressway	National Road	Provincial Road	County Road	Countryside Road	Default Value
2000	Speed (km/h)	90	60	40	30	20	15
	Time Cost (min)	0.67	1.00	1.50	2.00	3.00	4.00
2005	Speed (km/h)	100	70	50	40	20	15
	Time Cost (min)	0.60	0.86	1.20	1.50	3.00	4.00
2010	Speed (km/h)	100	75	50	40	20	15
	Time Cost (min)	0.60	0.80	1.20	1.50	3.00	4.00
2015	Speed (km/h)	100	80	60	40	20	15
	Time Cost (min)	0.60	0.75	1.00	1.50	3.00	4.00

In the second step, the service coverage of an airport as it relates to tourist destinations is calculated. The airport service coverage is measured based on two dimensions: the number and average accessibility of A-grade tourist locations covered by the effective service area of the airport. The steps in the analysis are as follows: (1) building on the results of the first step, we use the cost allocation command in the ArcGIS spatial analysis function module to obtain the effective service scope of each airport, and (2) using the extraction and analysis commands in ArcGIS, the airport accessibility of tourist locations and the aggregation of the number of A-grade tourist locations within the effective service range of each airport are calculated.

4. Results and Discussions

4.1. Evolution Features of Civil Airport Accessibility in Yunnan

The software ArcGIS Desktop 10.2 is used to draw the accessibility map of Yunnan airports at different time nodes (Figure 3) based on the Yunnan Highway Traffic Network. The results indicate that the accessibility of civil airports in Yunnan Province reflects an attenuation trend based on distance from the center outward. Additionally, the spatial distribution has a circle structure with the airport or airport agglomeration area as the center and gradually spreads to the peripheral areas; thus, the

peripheral areas require higher travel time costs than closer areas, which correspond to the findings in previous studies, such as [32,50].

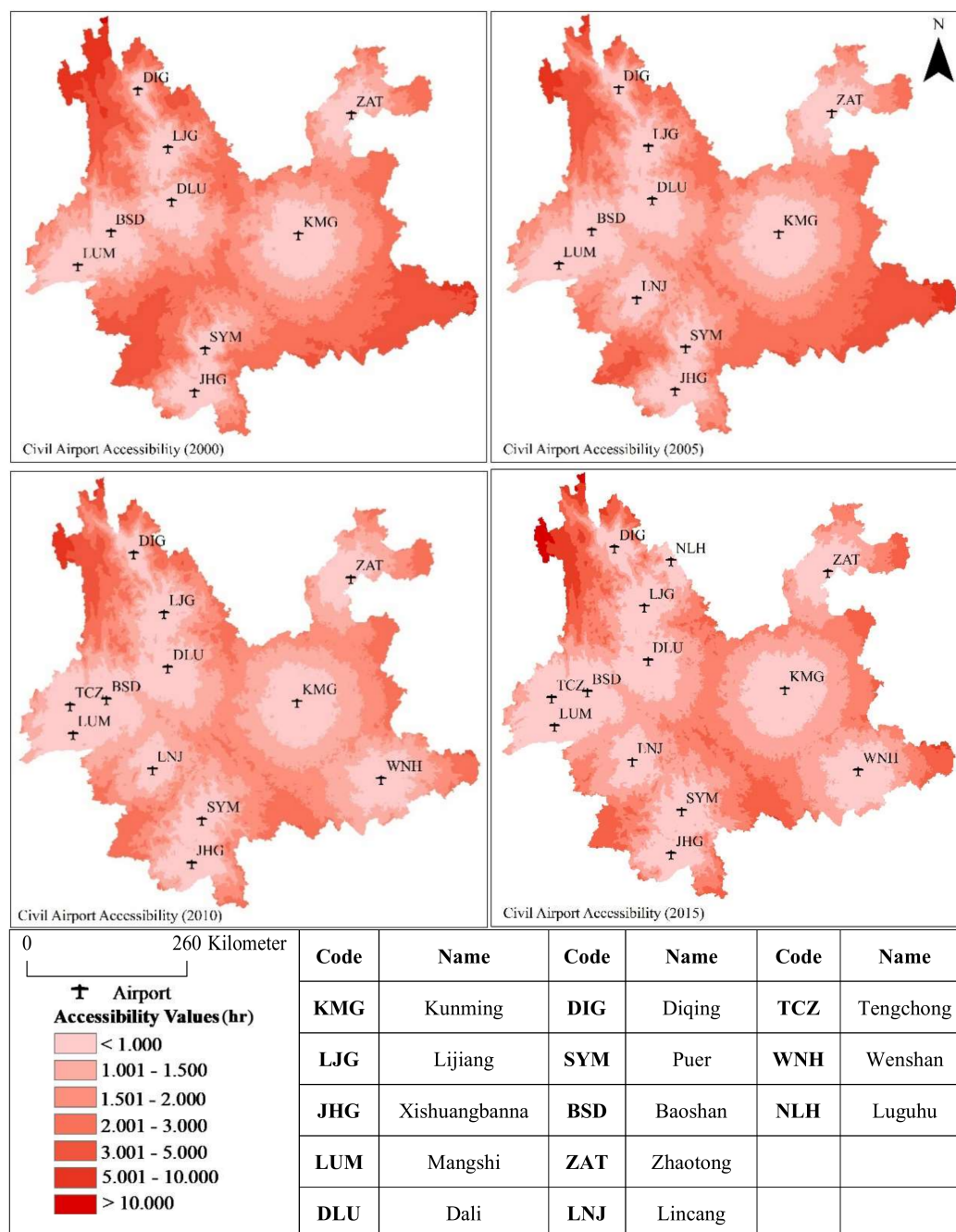


Figure 3. Airport accessibility in selected years.

The accessibility of civil airports in Yunnan Province has improved over time, which is reflected in the trend of the highest accessibility value. For instance, the time cost value of the grids with the highest accessibility in 2000 is 11.326 h, which gradually decreased to 9.150 h in 2005, 8.837 h in 2010, and 8.234 h in 2015. Moreover, the proportion of the grid area in each accessibility interval (Table 3) indicates that the area scale of the grid accessibility value gradually increased in the intervals of less than 1.0 h and 1.0–1.5 h and decreased in the intervals of 2–3 h, 3–5 h, 5–10 h and more than 10 h; additionally, there was a small fluctuation in the interval of 1.5–2 h. The China Civil Aviation Administration stipulates that the effective service scope of an airport should be covered by a travel

time of 1.5 h. In this context, it is obvious that the grid area of less than 1.5 h increased at the fastest rate, from 39.82% in 2000 to 65.77% in 2015. These results suggest that the accessibility of civil airports in Yunnan Province has gradually improved. However, these changes can be considered subtle from the perspective of the spatial distribution, which is in accordance with the airport traffic accessibility in each year in Figure 3. If the impact of new airports is not considered, the change is almost negligible.

Table 3. Coverage proportion of different accessibility values in selected years in the province.

Airport Accessibility (h)	Coverage Proportion			
	2000	2005	2010	2015
0–1	20.28%	24.40%	30.82%	35.23%
1–1.5	19.54%	23.47%	29.44%	30.54%
1.5–2	21.68%	22.06%	24.04%	22.17%
2–3	22.87%	19.66%	12.69%	9.54%
3–5	12.97%	8.90%	2.34%	1.93%
5–10	2.61%	1.51%	0.67%	0.59%
>10	0.05%	—	—	—

Furthermore, the results of the coverage of A-grade and above tourist locations in each area are expressed in Figure 4, which shows that the airport accessibility values of tourist locations in the province are within 10 h initially and then within 3 h in 2010 and 2015. Additionally, the coverage in the 1.5=h travel time area corresponding to each time node in 2000, 2005, 2010, and 2015 was 68.94%, 71.49%, 80.00%, and 83.41%, respectively. All of these findings indicate that the airport accessibility of tourist locations in the province has increased over time, implying that the road conditions from the airport to these locations have generally improved. Moreover, the evolution characteristics of tourist area coverage at different airport accessibility levels are consistent with the evolution characteristics of the airport accessibility values. The coverage increased gradually in the area less than 1.0 h; decreased in areas of 2–3 h, 3–5 h, and 5–10 h; and fluctuated slightly in the areas of 1.0–1.5 h and 1.5–2 h.

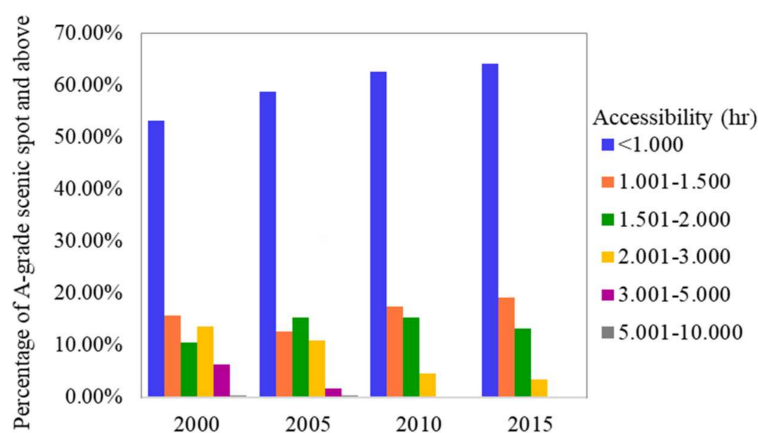


Figure 4. Tourist area coverage in selected years at different accessibility levels.

4.2. Evolution Features of the Service Coverage of Civil Airport for Tourist Locations in Yunnan

In accordance with the shortest-time cost map of accessibility from any grid to an airport and the longitude and latitude of A-grade tourist locations in Yunnan Province, a visualization and accessibility analysis of the tourist locations within the effective service scopes of civil airports at four time nodes is conducted using ArcGIS software (Figure 5). If the time required to travel from any point in the region to an airport is less than that for any other airport, the point is within the effective service scope of the airport. Additionally, the coverage rates of the tourist locations within the effective service scope are calculated (Table 4).

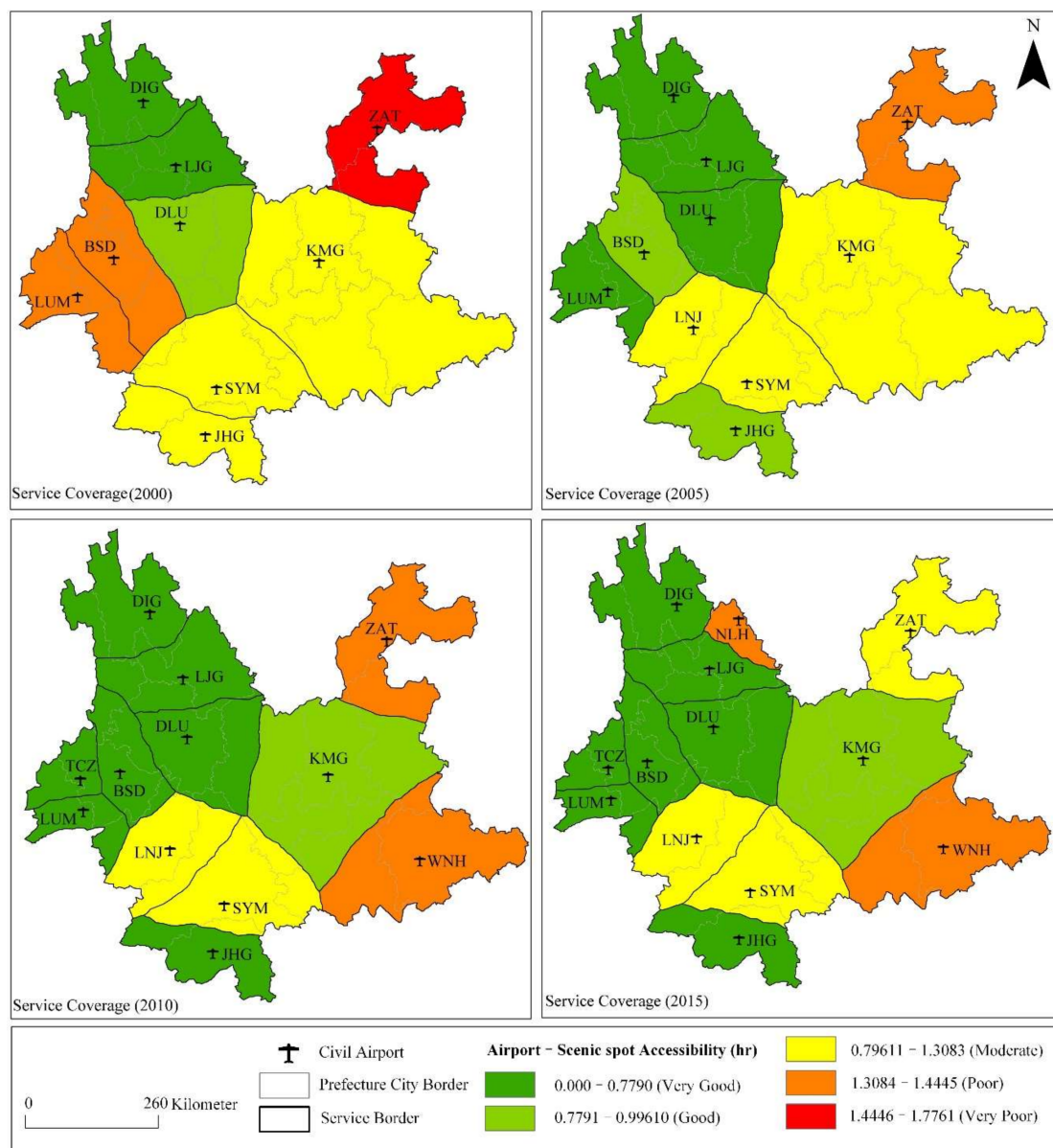


Figure 5. Airport service coverage in selected years.

In order to compare and analyze the spatial variances of service coverage in Yunnan civil airports at four time nodes, the method of natural breaks in ArcGIS is used to classify the airport accessibility of tourist locations in 2000. The basic idea of natural breaks method is the clustering algorithm, the termination condition of the algorithm is that the inter-group variance is the largest and the intra-group variance is the smallest. This method is useful to distinguish the variances between each category to a large extent. As a result, the calculation results of airport service coverage are divided into five grades as follows: less than 0.7790 h, 0.7791–0.9610 h, 0.9610–1.3083 h, 1.3084–1.4445 h, and 1.4446–1.7761 h, denoting excellent, good, average, poor, and terrible, respectively. Figure 5 shows the visualization results of the service coverage of Yunnan civil airports in selected years, including the service scope and accessibility.

Table 4. The effective service area of Yunnan civil airports and the coverage proportions of A-grade tourist locations in selected years.

City Name	Airport Code	2000		2005		2010		2015	
		Service Area (km ²)	Percentage of Tourist Locations (%)	Service Area (km ²)	Percentage of Tourist Locations (%)	Service Area (km ²)	Percentage of Tourist Locations (%)	Service Area (km ²)	Percentage of Tourist Locations (%)
Kunming	KMG	110093	37.02	112087	37.0%	66049	27.66	66076	28.09
Lijiang	LJG	27349	10.64	27996	10.64	27790	10.64	21239	9.36
	NLH	0	0	0	0	0	0	6644	1.28
Xishuangbanna	JHG	22656	8.09	20573	7.23	18999	5.53	19107	6.38
Dehong	LUM	22239	8.94	17815	6.38	11029	4.68	11277	4.68
Dali	DLU	33536	12.34	29747	11.49	30078	13.19	31494	11.91
Diqing	DIG	26930	7.66	26182	7.66	26390	7.66	26223	7.66
Puer	SYM	39902	5.53	28724	5.96	32777	6.81	32522	5.96
Baoshan	BSD	29293	8.09	21736	5.11	18922	3.83	18707	3.83
	TCZ	0	0	0	0	10220	2.98	9682	2.98
Zhaotong	ZAT	30800	1.70	30525	1.70	30407	1.70	28327	1.28
Lincang	LNJ	0	0	27413	6.81	25626	6.38	27055	7.23
Wenshan	WNH	0	0	0	0	44511	8.94	44445	9.36

The findings are as follows.

- (1). The boundaries of the effective service scope of each airport are not consistent with the administrative boundaries of the tourism cities. The KMG airport has remained at a leading position in terms of the service area and the number of tourism cities served. In 2000 and 2005, the total service area was 110,093 km² and 112,087 km², respectively, covering all of Kunming and Wenshan and parts of Qujing, Chuxiong, Honghe, and Yuxi. In 2010 and 2015, this area was reduced to 66,049 km² and 66,076 km² due to the opening of the WNH airport. Additionally, the percentage of attractions in the effective service area of KMG has always been high at greater than 20%. Dali and Lijiang, as well-known international tourism cities, displayed little difference in airport service area and ranked second and third in terms of the proportion of tourist locations in the effective service area of their airports, remaining above 10%. The proportions for other airports were relatively low at no more than 10%. Overall, the proportion of tourist locations covered by the effective service scope of each airport varies greatly, and KMG differs significantly from the other civil airports (Figure 6). In terms of the influencing factors, transport access to the surrounding area from airports is the key factor influencing the effective service coverage of civil airports for tourist locations. Convenient and sound landside transport networks at airports enable tourists to arrive at the destinations conveniently, efficiently, and at a low cost, thus causing a high value of service coverage of airports for tourist locations. In Yunnan province, Kunming has always been the city with the best transport conditions. The construction of road infrastructure and the development of road network both have been ranked the top in Yunnan, and far better than other cities. By the end of 2015, Kunming had 622 km of traffic mileage of expressways, accounting for 15.53% of the province's total highway mileage. The traffic mileage of expressways of Honghe and Qujing within the effective service area of KMG accounted for 13.93% and 12.07% of the province's total highway mileage, respectively. However, other cities such as Lijiang, Dali, and Wenshan accounted for 1.57%, 9.40%, and 8.43% respectively. Lincang, Nujiang, and Diqing had no expressway. In addition, Kunming, as Yunnan's provincial capital city, is the political and economic center of the province, which is another important reason why KMG airport is significantly higher than other airports.
- (2). Not taking the new airports that influence the effective service area into account, the spatial change in the selected years is subtle. The coverage of tourist locations within the effective service areas of airports is affected by changes in each service area, with a fluctuating trend. However, the spatial changes in airport-attraction accessibility values suggest that accessibility has increased over time; thus, the driving time from an airport to tourist destinations within the scope of the

corresponding effective service area has decreased. In 2015, only NLH and WNH were at the poor level. The service area and coverage of NLH encompassed 1.94% (6644 km²) and 1.28% of the province, respectively, and those values for WNH were 12.97% (4,444,445 km²) and 9.36%.

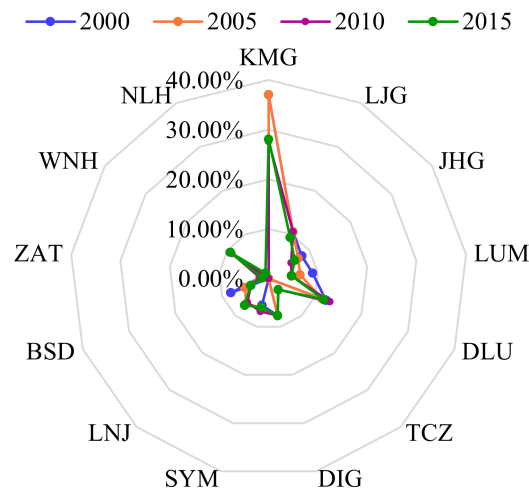


Figure 6. Scenic area coverage in selected years within the effective service coverage of Yunnan civil airports.

4.3. Coordination Analysis between the Service Coverage of Civil Airports for Tourist Locations and the Airline Network Structure

Airline networks are an important part of airport transport, and the structural characteristics of networks can effectively reveal the development level of air transport and be used to estimate the trend of the aviation network system [9,51]. In practice, the airline network structure is commonly optimized in the operation management of airports and the sustainable development of airport transport. In this section, considering the equal importance of airline networks and the landside transport of airports in tourism, a coordination analysis between the service coverage of civil airports for tourist locations and the airline network structure of civil airports is conducted. First, the airline network structure in Yunnan Province from 2000 to 2015 is determined and analyzed by using the complex network indicators and the airside accessibility index; then, the trend of the service coverage of civil airports for tourist locations in the corresponding years is compared to the structure trend. By doing so, some suggestions will be obtained regarding transportation development and sustainable environmental development in tourist cities.

4.3.1. Measurement of the Airline Network Structure of Civil Airports

We follow the methodology proposed by Wang et al. [21,52] to construct the Yunnan aviation network in selected years. In this network, cities with airports are the nodes of the network, and the routes between cities are the edges of the network. Those cities with two or more airports are treated as one node. Here, the construction scope of our network includes not only the nodes in Yunnan Province but also the domestic airport city nodes with direct flights to Yunnan Province, with the objective of investigating the development of the aviation network in Yunnan Province and the external transport links. As a result, the Yunnan aviation network is defined as an undirected graph $G = (V, E)$, where $V = \{v_i : i = 1, 2, \dots, n\}$, n is the total number of nodes (i.e., airport cities), and $E = \{e_i : i = 1, 2, \dots, m\}$, m is the number of actual edges (i.e., air routes). Air route data is from the Statistical Data on Civil Aviation in China database. Due to the limitations of data availability, the data from 2015 are used as the benchmark, and only routes with over 2000 flights are considered when constructing the network. On this basis, the density index and the network centralization index are introduced to evaluate the

overall structure of the Yunnan aviation network. Furthermore, because the accessibility of Yunnan airports reflects the difficulty of arriving at the destination by highway from an airport considering the ground (highway) traffic accessibility based on Equation (1), we calculate the airside accessibility of airports.

The network density D is an index describing the closeness between nodes in the network and is defined as the ratio of actual to maximal number of circuits in a fully connected network, written as:

$$D = 2 \frac{\sum_{i=1}^n e_i}{n(n-1)} \quad (2)$$

where e_i is the number of actual edges (air routes) between the neighbors of node i . The value of network density ranges from 0 to 1. The greater the network density is, the better the connectivity of the network. If the network density is 1, then the network is complete, and all the nodes in the network are directly connected.

The network centralization index C_x is often used to analyze the relative centralization of the most central node in the entire network compared with every other node [52]. A greater C_x indicates a more centralized network. The index reaches the minimum value 0 in a network with equal centrality for all nodes, and a maximum value 1 in a network dominated by one node, written as:

$$C_x = \frac{\sum_{i=1}^n (C_{\max} - C_i)}{\max \left[\sum_{i=1}^n (C_{\max} - C_i) \right]} \quad (3)$$

where C_i represents the centrality index of node i ; $C_{\max}$ refers to the most central node in the network and it has the highest value of centrality index, i.e., $C_{\max} = \max\{C_i\}$. In complex network theory, the centrality index consists of degree centrality (C_i^D), closeness centrality (C_i^C), and betweenness centrality (C_i^B). Using them to represent the centrality of node i ; thus, three network centralization indices are obtained correspondingly based on Equation (3): degree centralization (C_D), closeness centralization (C_C), and betweenness centralization (C_B).

Regarding aviation networks, degree centralization (C_D) is often applied to describe the overall centrality for the entire network, and the higher the value of C_D , the more significant the centralization trend of the aviation network toward the most central node (i.e., hub airport city). Closeness centralization (C_C) is used to analyze how to access the most central node (i.e., airport city with the shortest average distance) in the network is in comparison to every other node. A greater C_C indicates the better accessibility from the most central node to others. Betweenness centralization (C_B) is used to reflect the connectivity from the most central node (i.e., transshipment hub airport city) to the other nodes within the network. A greater C_B indicates that more air routes are depending on the most central node to access other destinations. The calculation formulas of them are as follows.

$$C_D = \frac{\sum_{i=1}^n (C_{\max}^D - C_i^D)}{(n-1)(n-2)} \quad (4)$$

$$C_C = \frac{\sum_{i=1}^n (C_{\max}^C - C_i^C)}{(n^2 - 3n + 2)/(2n - 3)} \quad (5)$$

$$C_B = \frac{\sum_{i=1}^n (C_{\max}^B - C_i^B)}{n^3 - 4n^2 + 5n - 2} \quad (6)$$

where $C_{\max}^D = \max\{C_i^D\}$; C_i^D refers to the degree centrality of node i and is the number of edges that a node share with others, i.e.,

$$C_i^D = \sum_{j=1}^n a_{ij} \quad (7)$$

where $a_{ij} = 1$ when a flight link exists between node i and node j and $a_{ij} = 0$ otherwise. $C_{\max}^C = \max\{C_i^C\}$; here, C_i^C is the closeness centrality and refers to the inverse of the average shortest distance from node i to all others, i.e.,

$$C_i^C = \frac{1}{\sum_{j \in V, i \neq j} d_{ij} / (n-1)} \quad (8)$$

where d_{ij} is the number of edges for the shortest path from node i to node j ; $C_{\max}^B = \max\{C_i^B\}$. Here, C_i^B is the betweenness centrality of node i and can be written as:

$$C_i^B = \sum_j^n \sum_k^n \frac{g_{jk}(i)}{g_{jk}} \dots (i \neq j \neq k, j < k) \quad (9)$$

where g_{jk} is the sum of all shortest paths between nodes j ; k and $g_{jk}(i)$ are the number of shortest paths that pass through node i .

Airport airside accessibility (A_i) refers to the travel cost and the quality/quantity of available opportunities of traveling from one airport to another in an airline network system, and it can be used to describe the importance of network nodes and external contacts. Time, space, and economic distance are commonly used in accessibility measurement. However, considering the particularity of air transportation, the flight time, flight distance, and flight cost from one airport to another do not change in a short time for technical reasons; therefore, the paper refers to the number of seats available between airports to calculate the airside accessibility based on reference [53] after comparative analysis. The calculation formula A_i is as follows.

$$A_i = \sum_{j=1}^n AS_{ij} \times W_j \quad (10)$$

$$W_j = \frac{n - (r_j - 1)}{n} \quad (11)$$

where AS_{ij} is the seating capacity of all flights between airport city i and airport city j ; W_j is the weight of the j th airport city; r_j is the rank of the j th airport city according to the airport passenger throughput. Equation (11) shows that the higher the airport city ranking, the greater its weight.

In detail, the airside accessibility of node i is divided by the average airside accessibility of all airport cities in the network, and the index of airside accessibility of coefficient AI_i is obtained, which is written as:

$$AI_i = A_i / \frac{1}{n} \sum_{i=1}^n A_i \quad (12)$$

If $AI_i \geq 1$, then the accessibility of airport city i is higher than or equal to the average accessibility of all airport cities in the aviation network, and if $AI_i < 1$, then the accessibility is less than the average accessibility of all airport cities in the aviation network.

4.3.2. Coordination Analysis

Table 5 shows the measurement results of the Yunnan aviation network structure in each selected year. Table 6 lists the airside accessibility of all nodes in the Yunnan aviation network in selected years and the nodes with airside accessibility values greater than 1 outside the province.

Table 5. Complex network indices of the air transport network of Yunnan in selected years.

Index		Year			
		2000	2005	2010	2015
No. of nodes		10	16	27	30
No. of air routes	Airlines within Yunnan	3	5	6	6
	Airlines outside Yunnan	6	10	21	27
Network density		0.2000	0.1250	0.0798	0.0788
Network centralization	Degree centralization	100%	100%	99.38%	98.94%
	Closeness centralization	100%	100%	99.68%	99.44%
	Betweenness centralization	100%	100%	99.22%	98.12%

Table 6. Airside accessibility of the air transport network of Yunnan in selected years.

Year	Airside Accessibility Coefficient	
	Yunnan	Outside Yunnan ($AI_i \geq 1$)
2000	Kunming (8.20), Xishuangbanna (1.55), Lijiang (0.89), Dali (0.54)	Chengdu (1.61), Guangzhou (1.43), Beijing (1.36)
2005	Kunming (14.10), Xishuangbanna (1.77), Lijiang (1.48), Mangshi (0.53), Dali (0.50), Diqing (0.34)	Beijing (2.21), Chongqing (1.59), Chengdu (1.44), Guangzhou (1.41), Shanghai (1.39)
2010	Kunming (23.09), Lijiang (3.19), Xishuangbanna (2.95), Mangshi (0.91), Tenchong (0.79), Diqing (0.52), Simao (0.47)	Beijing (3.22), Chengdu (2.45), Chongqing (2.33), Guangzhou (2.04), Shanghai (2.04), Changsha (1.55), Shenzhen (1.39), Xi'an (1.09)
2015	Kunming (25.52), Lijiang (3.40), Xishuangbanna (3.59), Dehong (1.43), Dali (0.64)	Beijing (2.99), Shanghai (2.45), Chongqing (2.28), Chengdu (2.24), Guangzhou (2.13), Shenzhen (1.75), Xi'an (1.75), Wuhan (1.48), Zhengzhou (1.46), Changsha (1.34), Nanjing (1.16), Hangzhou (1.13)

Note: The airlines here do not include airlines with less than 2000 annual flights; the values in () represent the average airside accessibility of the nodes.

In Table 5, the number of nodes in the Yunnan aviation network is increasing. Meanwhile, the number of airlines with more than 2000 flights increased annually, both within and outside the province. These results show that the Yunnan aviation network is constantly improving. However, the network density displays a downward trend, and the value of it is generally small; specifically, the values in 2000, 2005, 2010, and 2015 are 0.2000, 0.1250, 0.0798, and 0.0788, respectively. This result reveals that the overall connectivity of the aviation network is decreasing over time. However, this does not mean that the development of the Yunnan aviation network has not been improved. From the perspective of a complex network, although the number of nodes and links (both airlines within and outside Yunnan) of the Yunnan aviation network is constantly increasing, the increase of lines is far less than the theoretical value required by the increase of node size. As a result, the network density still shows a downward trend. Therefore, to be more precise, these findings indicate that there are still a large number of tourist city pairs lacking direct connections in each stage of the network, and there is still much room for improvement in the Yunnan aviation network.

Regarding the changes in network centralization, the degree centralization, closeness centralization, and betweenness centralization values also show a downward trend; however, these three indicators in each year are close to 1, which demonstrates an obvious trend toward the centralization of the aviation network in Yunnan Province. In terms of each node in the network, Kunming has been the highest values of degree centralization and betweenness centralization. This reveals that KMG is the hub airport, and more destination cities are connected to KMG preferentially than other airports of the network. Besides, JHG, DLU, and LJG also show a centralization trend and can be viewed as sub-hub airports of Yunnan.

In fact, many efforts have been conducted to promote the development of Yunnan air transport: the number of airports, air routes, and flights has been increasing. However, many newly opened air routes are connected to the hub airport (i.e., KMG), while connections among feeder airports are limited. From 2000 to 2015, there were only two connections among feeder airports. They were the connection between DLU and JHG, and the connection between LJG and JHG. No changes or increases had occurred in connections between other feeder airports.

In addition, nodes with accessibility values greater than 1 on the airside of the network indicate that the numbers of nodes in both the province and external links are increasing, suggesting that the scale of the aviation network is expanding and that the close links between cities and Yunnan aviation network nodes are increasing in abundance. The change in the accessibility value of the airside of these nodes implies an increasing trend each year; thus, the nodes in the aviation network are becoming increasingly critical. The convenience of flying is obviously improved, especially for some cities with abundant tourism resources and high tourism popularity, such as Kunming, Lijiang, and Xishuangbanna.

Overall, the expansion of the scale of the Yunnan aviation network, together with the improvements in the network and centralized trend of the network system, suggests that the aviation network is generally improving, and it is becoming increasingly convenient for tourists to fly to cities in the province. However, the airline network system still has room for optimization considering the network density value, which displays a downward trend. Comparing the evolution trend of the Yunnan aviation network with the service coverage of airports for tourist destinations in Section 4.2, it is found that the evolution trend of the service coverage of Yunnan airports for tourist destinations is consistent with that for the aviation network. In other words, the trend has improved over time. This result can be obtained by comparing the characteristics of scenic area coverage (Figure 4) at different airport accessibility levels with the trends of several indicators of the aviation network (such as the numbers of nodes and airlines) (Table 5) and the value of airside accessibility (Table 6) for key tourism cities.

To further understand the relationship between the development of the aviation network in different tourism cities and the evolution of the airport service coverage, three indicators, namely, the airport passenger throughput, airside accessibility coefficient, and average accessibility of tourist locations within the effective coverage area of an airport are used for comprehensive comparative analysis. The descriptive statistical results of each indicator are shown in Table 7 and can be interpreted as follows.

Airports with high passenger throughputs and high airside accessibility but low accessibility to tourist locations exist (here, tourist locations refer to those within the effective service scope of an airport). For example, the passenger throughput of KMG has always been highest in the province and is increasing each year, and the airside accessibility value of KMG has considerably increased over time, indicating that Kunming has a large demand for air travel traffic and that the convenience of air travel from other airports to KMG has increased significantly. However, the average accessibility of tourist locations within the effective service range of KMG ranks relatively low, with ranks of 6, 9, 8, and 8 in 2000, 2005, 2010, and 2015, respectively. In contrast, some airports with low passenger throughputs and low airside accessibility have relatively high accessibility to tourist locations. For example, in 2000, 2005, 2010, and 2015, DIG ranked 7th, 6th, 6th, and 7th, respectively, in terms of passenger throughput, and the airside accessibility value of the airport was less than 1, yet the corresponding average ranking of the accessibility of tourist locations within the effective service scope was 2, 1, 1, 1, and 1, respectively. These results imply that airport passenger flows and the convenience of air transport to some tourist cities are not necessarily related to the convenience of traveling from airports to tourist locations, whether in a city with a hub airport such as Kunming or a remote city such as Diqing (i.e., far from the central city). This mismatch can also be seen in JHG in 2005 and 2015, BSD in 2010 and 2015, and WNH in 2015. From the perspective of sustainability, this relation reveals that in these tourism cities of Yunnan, the development of airport transport has not considered the coordination between the airline network and landside transport to tourist locations near airports.

Table 7. Descriptive statistics of service coverage assessment indicators for aviation networks and tourist locations.

2000						2005				
Airports Code	Passenger Throughput (10,000 Visits)	Ranking of Passenger Throughput	Airside Accessibility Coefficient	Average Accessibility of Airports to Tourist Locations (h)	Ranking of the Average Accessibility of Airports to Tourist Locations	Passenger Throughput (10,000 Visits)	Ranking of Passenger Throughput	Airside Accessibility Coefficient	Average Accessibility of Airports to Tourist Locations (h)	Ranking of the Average Accessibility of Airports to Tourist Locations
KMG	560	1	8.2	1.31	6	1182	1	14.1	1.30	9
JHG	85	2	1.55	1.15	4	122	2	1.77	0.94	6
LJG	26	3	0.89	0.75	1	111	3	1.48	0.72	2
DLU	21	4	0.54	0.96	3	32	4	0.5	0.74	3
LUM	16	5	—	1.42	7	30	5	0.53	0.77	4
SYM	7	6	—	1.22	5	5	9	—	1.26	8
DIG	6	7	—	0.78	2	22	6	0.34	0.40	1
BSD	6	8	—	1.44	8	9	7	—	0.85	5
ZAT	5	9	—	1.78	9	4	10	—	1.36	10
LNJ	—	—	—	—	—	8	8	—	1.23	7
TCZ	—	—	—	—	—	—	—	—	—	—
WNH	—	—	—	—	—	—	—	—	—	—
NLH	—	—	—	—	—	—	—	—	—	—

2010						2015				
Airports Code	Passenger Throughput (10,000 Visits)	Ranking of Passenger Throughput	Airside Accessibility Coefficient	Average Accessibility of Airports to Tourist Locations (h)	Ranking of the Average Accessibility of Airports to Tourist Locations	Passenger Throughput (10,000 Visits)	Ranking of Passenger Throughput	Airside Accessibility Coefficient	Average Accessibility of Airports to Tourist Locations (h)	Ranking of the Average Accessibility of Airports to Tourist Locations
KMG	2019	1	23.09	0.87	8	3752	1	25.52	0.90	8
JHG	189	3	2.59	0.51	3	415	3	3.59	0.64	6
LJG	222	2	3.19	0.65	5	563	2	3.4	0.44	3
DLU	23	7	—	0.73	7	33	8	0.64	0.73	7
LUM	44	5	0.91	0.71	6	126	5	1.43	0.63	5
SYM	22	8	0.47	1.20	10	31	10	—	1.06	9
DIG	26	6	0.52	0.38	1	50	7	—	0.32	1
BSD	15	9	—	0.64	4	21	11	—	0.61	4
ZAT	4	12	—	1.41	11	11	12	—	1.22	11
LNJ	13	10	—	1.10	9	32	9	—	1.11	10
TCZ	47	4	0.79	0.46	2	132	4	—	0.42	2
WNH	6	11	—	1.41	12	66	6	—	1.38	13
NLH	—	—	—	—	—	1	13	—	1.31	12

In Section 4.2, we discussed how new airports influence the effective service areas of existing airports in the adjacent area. By comparing the average accessibility of tourist locations between a new airport and the adjacent airports based on passenger throughput and the effective service scope, we found that the new airport has little influence on the rankings of the adjacent regional airports. Additionally, when LNG, WNH, and LJG were joined for the first time, the two indicator values ranked below those of the entire airport system. However, TCZ displayed a different result. The average rankings of passenger throughput and the accessibility of tourist locations within the effective service range were relatively high initially; in 2010, the rankings of TCZ among 12 airports in the province were 4 and 2, and the same rankings were observed in 2015 among 13 airports.

5. Conclusions

Increasing the accessibility of tourist locations from airports can improve the travel efficiency of tourists and reduce the travel time, thus enhancing the attractiveness and competitiveness of tourist locations and cities to promote the efficient and sustainable development of urban transportation and tourism. However, previous academic research and scientific practice has mainly focused on airline network. Few studies have focused on the accessibility of tourist locations around airports in tourist cities. Meanwhile, with the booming global tourism industry in recent years, airports have become strategic assets for supporting sustainable tourism strategies and generated increasingly important implications for local tourism development. The equal importance of airline networks and the landside transport of airports in tourism is gradually increasing. However, limited empirical studies have been conducted. Therefore, this study focuses on the equal importance of airline networks and the landside transport of airports in tourism, and it attempt to discuss the trends of and coordination between the airline network structure and service coverage of civil airports for tourist locations by taking Yunnan Province as a case study. Firstly, this paper investigates the landside accessibility of civil airports near tourist locations using the measurement of service coverage in selected years, including 2000, 2005, 2010, and 2015. Secondly, the features of the aviation network structure are extracted and further compared with the landside accessibility of civil airports in corresponding years. The major findings of this study are as follows.

- (1). Highway traffic accessibility around the airports in cities in Yunnan is improving, although the spatial changes are inconspicuous. The time required to travel from airports to tourist locations has gradually decreased over time, and in 2015, 83.41% of tourist locations could be reached within 1.5 h of driving from an airport; additionally, all tourist destinations could be reached within 3 h of driving.
- (2). The accessibility of airports and the effective service scope have changed, and large spatial differences can be observed. Among all airports, Kunming, the capital of Yunnan Province, boasts an international hub airport KMG, and the effective service area of KMG covers more tourist destinations than any other airport service area. Thus, KMG ranks first in terms of the effective service area and the proportion of coverage of tourist locations. Dali and Lijiang are world-renowned tourist cities, with more than 10% of tourist destinations in their effective service areas and ranking second and third in regard to tourist location coverage among airports in the province. This result indicates that the attractiveness of destination cities may influence the development of the landside transport from airports to tourist locations.
- (3). The aviation network system of Yunnan Province is constantly improving with an increased number of airports and airline, and it shows the centralization trend toward KMG. The convenience of accessing the tourist cities in Yunnan Province has been gradually improved, especially for Kunming. However, considering changes in the airline network system and increases in airport passenger throughputs, some tourist cities have experienced a trend of less convenient travel from a destination airport to a tourist location than from an origin airport to a destination airport. This issue is particularly evident in Kunming, which is a tourist city with a hub airport, as well as in Diqing, a tourist city located in a remote area (i.e., far from the central city). These

findings indicate that the development of airport transport in these cities has not considered the coordination of the airline network and landside transport from airports to tourist locations.

- (4). A new airport will influence the effective service scope of adjacent airports. However, new airports had little influence on the passenger throughput rankings of adjacent airports and the proportions of tourist locations within the effective service scope in Yunnan.

Through the above research, three major findings and suggestions for the sustainable development of tourist cities can be established.

First, in the traffic planning and management of tourist cities, the accessibility between airports and tourist locations should be of the same importance as improving and developing airports and air traffic systems. Notably, different trends were observed for ground traffic accessibility from airports to tourist locations and aviation system development for both hub and remote airports. This kind of mismatch may restrict the efficient and sustainable development of the tourism industry in tourist cities because time costs are very important to tourist decision making, including the choice of tourist destinations and the willingness to revisit a certain location [54].

Second, to meet the goal of sustainable development, it is necessary to measure and analyze the service coverage of airports in tourist cities. Many studies have confirmed the contributions of air and highway transportation to carbon emissions and energy consumption in the tourism industry, and improving the transportation efficiency is conducive to energy conservation and emission reductions [27,55]. However, under cost limitations, there is no effective way to determine the priority for optimizing the road transport network and improving the transport efficiency, and such development is hindered by regional differences [37]. In this research, we measure the service coverage of airports in tourism cities and obtain the accessibility of A-grade tourist locations within the effective service scopes of airports. More factors, such as visitor flows at tourist locations and passenger flow rates for different forms of transportation, could be considered to provide effective information for the formulation of traffic plans in tourist cities, thus make energy savings and emission reduction objectives easier to meet in these cities.

Finally, it is urgent for tourist cities in China to plan and layout the airport ground transportation network in a reasonable manner. In recent years, the continuous expansion and improvement of the high-speed railway network in China has resulted in fierce competition with air traffic. Many empirical studies have examined the impact of HSR operation on air passenger flows, especially the reductions in short- and medium-distance passenger flows [19]. However, an efficient airport encompasses the ground transportation network of the surrounding tourist locations, which can improve tourist satisfaction by reducing travel times [9,29,56]. In turn, such a strategy will improve the probability of tourists choosing air traffic for travel [17] and increase the potential demand of air passengers. Air traffic is an important transportation mode and is irreplaceable in remote areas, especially in popular tourist cities that are difficult to access by HSR and high-speed networks [28]. Therefore, because air traffic in China is facing fierce competition from the rapid expansion of the HSR network [57], the competitiveness of air traffic must be urgently improved from the perspective of improving the accessibility of airport ground traffic to promote the sustainable development of HSR and aviation in tourist cities.

Holistically, this study can offer some insight and suggestions for the sustainable development of the environment and transportation in tourist cities. However, it should be noted that although Yunnan is a representative example, more in-depth exploration is required in the planning and practice phases of sustainable development in tourist cities. In this study, the spatial evolution characteristics of the service coverage of airports near tourist locations is analyzed without obtaining a clear result of whether the service coverage meets the tourist demand because of the lack of criteria for assessing accessibility.

Future research may focus on determining the tolerance threshold of airport accessibility through investigations of tourists to precisely estimate the airport service coverage. Meanwhile, the same methodology to other Chinese provinces will be implemented for the comparison of their differences in the tolerance threshold of airport accessibility. In addition, some scholars have suggested that

the attractiveness of a city does not necessarily depend entirely on its accessibility if it has some unique characteristics [58]. The sustainable development of transportation and tourism in tourist cities is influenced not only by traffic-related factors but also by social and economic factors, tourism enterprises, the tourist market, etc. [54]. Thus, sustainable development remains a major challenge in terms of incorporating these factors into a framework, systematically studying the spatial evolution mechanisms of the airport service coverage in tourist cities and optimizing development considering factors such as transfers and connections between airports and ground transportation, which should be explored in future studies.

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