Establishment of Prediction Method of Tourism Meteorological Index in Langzhong Ancient City

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Abstract Based on the meteorological data of Langzhong from 2010 to 2020, the human body comfort index was calculated, and tourism climate comfort was evaluated to establish the prediction equation of tourism meteorological index. OLS was used to compare the correlation between actual tourist flow and tourism meteorological index and test the model effect. Average correlation coefficient *R* was 0.701 7, so the correlation was strong, and *P* value was 0. The two were significantly correlated at 0.01 level (bilateral). It can be seen that the forecast equation of tourism meteorological index had a strong correlation with the actual number of tourists, and the predicted value was basically close to the actual situation, and the forecast effect is good.

Key words Tourism meteorological index; Climate assessment; Correlation analysis; Prediction method; Langzhong City

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Langzhong, located in the northeast of Sichuan Basin, has a subtropical monsoon mild climate, and is one of the four most intact ancient cities in China. It is known as the "world ancient city tourist destination" and "China's climate health land", and is also the largest "Fengshui Ancient City" in Sichuan. Therefore, it is necessary to study the impact of changes of weather and climate resources on tourist flow change in Langzhong Ancient City, which also has guiding significance for tourists to arrange their travel reasonably and scientifically[1].

1 Data sources and research methods

1.1 Data sources Langzhong national basic weather station (No. 57306, 105°58′ E, 31°35′ N) is at an altitude of 382.6 m, and is less than 2 km away from Langzhong Ancient City, so it has good data representation. The data of daily average temperature, maximum temperature, average relative humidity, precipitation, average wind speed, maximum wind speed, and sunshine duration from 2010 to 2020 was used[1]. The data of daily ticket sales of various scenic spots in Langzhong Ancient City from 2015 to 2018 (well reflecting the daily passenger flow) were provided by Langzhong Cultural Tourism Radio, Film and Television Bureau.

1.2 Research methods The daily average temperature, maximum temperature, average relative humidity, precipitation, average wind speed, maximum wind speed, sunshine hours and other related factors to passenger flow were studied. Besides, human comfort index was used to establish a tourism weather index forecast equation, and then the equation was tested according to the forecast data[1-2]. Human comfort index was used to evaluate the climate comfort of tourism in Langzhong Ancient City.

2 Relationship between weather and climate factors and tourist flow

2.1 Reference of human comfort and evaluation of tourism climate comfort The comfort index of human body (CIHB) is a biometrical index designed to evaluate human comfort in different climatic conditions from the meteorological point of view based on the heat exchange between human body and atmospheric environment[1-2]. Generally speaking, temperature, relative humidity, wind speed three meteorological elements have the greatest impact on human sensation. In this paper, the following formula which is suitable for the geographical characteristics of Sichuan was adopted.

$$CIHB = 1.8t - 0.55(1 - f)(1.8t - 26) - 3.2\sqrt{v} + 32 \quad (1)$$

where t is average temperature (℃); f is relative humidity (%); v is average wind speed (m/s).

In this paper, the local climate characteristics and the universal human comfort index level table were combined to make localization correction[1] (Table 1).

Table 1 Classification standard of daily average comfort index in Langzhong Ancient City

Daily average comfort index *I*	Sensation	Level
$30 \leq I < 40$	Very cold, and uncomfortable	-3
$40 \leq I < 50$	Cold, and mostly uncomfortable	-2
$50 \leq I < 60$	Cool, and partly uncomfortable	-1
$60 \leq I < 70$	Mostly comfortable	0
$70 \leq I < 75$	Hot, and partly uncomfortable	1
$75 \leq I < 79$	Very hot, and uncomfortable	2
$79 \leq I < 85$	Muggy, and very uncomfortable	3

According to formula (1), the daily average comfort index of Langzhong Ancient City was calculated based on the data of daily average temperature, daily average relative humidity and daily av-

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erage wind speed in Langzhong Ancient City during 2010 – 2020[1-2], and then the climatic comfort of Langzhong Ancient City was evaluated according to the classification standard of climate comfort index in Table 1. From Fig. 1, it can be seen that the annual average level of climate comfort in Langzhong Ancient City was almost between −2 and 2, and there was no cold or sultry weather. The climate was more comfortable, so Langzhong Ancient City is truly an ideal tourist area without hot summer or cold winter. In a year, the vast majority of days from March to June and from September to December were suitable for tourism, of which the periods from April to May and from September to October were the most suitable for tourism. The days only in January and from July to August were not suitable for tourism. The total number of days more suitable for tourism in the whole year was 232 d, accounting for 64% of the total number of days in the whole year, that is, nearly 2/3 of the days in a year were suitable for tourism, with a long tourism season and more days suitable for tourism[2].

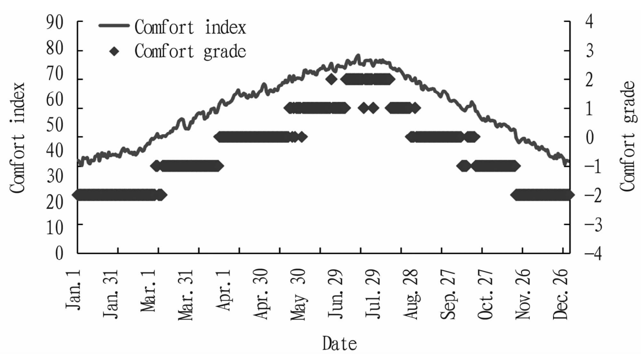

Fig. 1 Daily average comfort index and grade of Langzhong Ancient City from 2010 to 2020

2.2 Influence of daily maximum temperature on tourist flow Most of travel activities are conducted in the daytime, so the maximum temperature will directly affect the travel choice and experience pleasure of tourists[1]. Langzhong has the characteristics of "colder winter, longer summer, rain and heat in the same season". When the daily maximum temperature is over 35 ℃ in summer or below 16 ℃ in winter, it has a great impact on tourism. In Langzhong, daily maximum temperature exceeds 35 ℃ generally from May to September, and was below 16 ℃ generally from October to next April. Hence, when the forecast model of tourism meteorological index is established, the actual conditions of the maximum temperature in the summer half year (from May to August) and the winter half year (from November to next April) should be considered for revision[1].

2.3 Influence of daily rainfall on tourist flow From the analysis of the relationship between the daily rainfall in Langzhong and the daily tourist flow of scenic spots in the ancient city during 2017 – 2018 (Fig. 2, and the chart of 2018 is omitted), it can be seen that the daily tourist flow decreased with the increase of daily rainfall, and the greater the daily rainfall, the faster the decline. When the daily rainfall was greater than 25.0 mm (heavy rain level or above), the number of tourists declined obviously. As the daily rainfall was less than 10.0 mm, the impact on the number of tourists was not obvious[1].

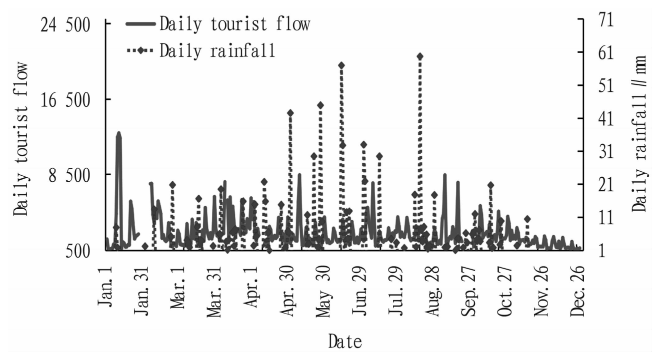

Fig. 2 Relationship between daily rainfall and daily tourist flow in 2017 (except important holidays)

2.4 Influence of sunshine hours on tourist flow The weather always brings different moods and feelings to tourists when they play, and here sunshine hours are used to reflect the weather. In this study, sunshine hours (D) can be divided into four grades according to the local climate characteristics, including $D=0$, $0<D\leqslant 4$, $4<D\leqslant 8$ and $D>8$. The daily sunshine hours of Langzhong and the daily tourist flow of scenic spots in the ancient city in the same period during 2017 – 2018 were compared and analyzed. As shown in Fig. 3, tourist flow was basically positively correlated with sunshine hours in the winter half year (from November to next March), while it rose firstly and then decreased with the increase of sunshine hours in the summer half year (from April to October)[1-2]. The reason for the decline may be that too more sunshine hours in the summer half year led to the reflection radiation on the ground and the rise in air temperature, resulting in sun exposure and heat stroke. In addition, strong light burnt the skin to make the human body feel uncomfortable.

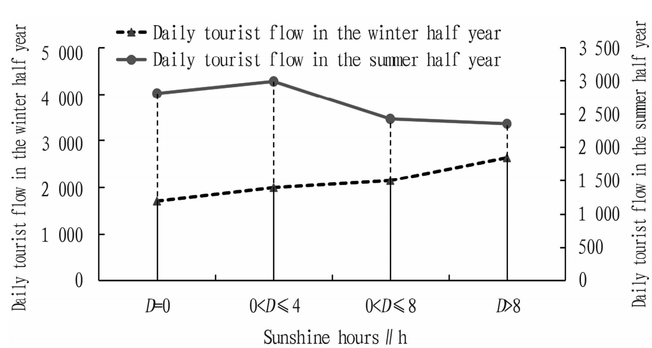

Fig. 3 Relationship between sunshine hours and daily tourist flow during 2017 – 2018 (except important holidays)

2.5 Adverse effects of extreme wind speed on tourist flow The adverse effects of daily extreme wind speed on the daily tourist flow of Langzhong during 2017 – 2018 are shown in Fig. 4 (the chart of 2018 is omitted). It can be seen that daily tourist flow decreased with the increase of daily extreme wind speed. When extreme wind speed was at level 6 – 7 ($10.8\ m/s\leqslant v<17.0\ m/s$), tourist flow dropped obviously. As extreme wind speed was at level 8 ($v>17.0\ m/s$), tourist flow decreased precipitously[1-2].

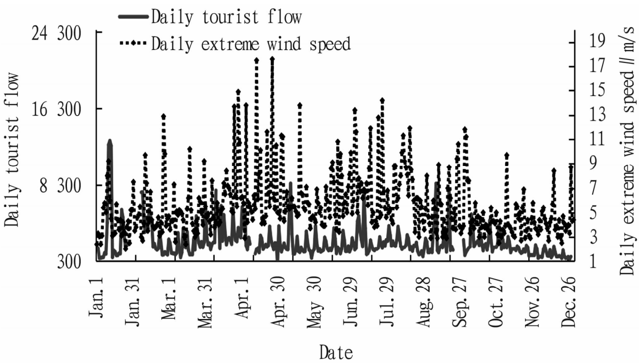

Fig. 4 Relationship between daily extreme wind speed and tourist flow during 2017 - 2018 (except important holidays)

3 Establishment of forecast equation of tourism meteorological index

Through the above analysis, it can be seen that tourism meteorological index is the result of the joint action or influence of various meteorological factors, so they should be comprehensively considered. Therefore, the influence degree of each meteorological factor should be "scored", and the prediction equation of tourism meteorological index should be established[1].

$$TMI = 100 - (C + R + S + F + T) \quad (2)$$

where TMI is tourism meteorological index; C is the score of comfort index; R is the score of daily rainfall; S is the score of sunshine hours; F is the score of extreme wind speed; T is the score of the maximum temperature.

The "scoring" criteria for each factor are set as follows: the score of human comfort index at various levels (C) is set as: 45 points for level -3, 25 points for level -2, 5 points for level -1, 0 point for level 0, 5 points for level 1, 25 points for level 2, and 45 points for level 3[1]. According to EC numerical forecast products, the forecast values of daily average temperature (t), daily average humidity (RH), and daily average wind speed within10 min (V) were obtained, and then the averages were substituted into formula (1) to get human comfort index. Finally, it was scored according to the "scoring" standard.

According to the analysis in section 2.3, daily tourist flow decreased with the increase of daily rainfall, and the larger the daily rainfall, the more obvious the decrease of daily tourist flow. Excessive rainfall would seriously affect the activities of tourists, so it was given greater weight[1-2]. The score of daily rainfall (R) is as follows: 0 point for 0 mm, 10 points for 0.1 - 0.9 mm, 20 points for 1.0 - 9.9 mm, 45 points for 10.0 - 24.9 mm, and 70 points for above 25 mm.

The weather only affects the inner feelings of tourists, and the influence of long sunshine hours on air temperature has been reflected in other factors, so the negative impact of sunshine hours (S) on passenger flow is small, and its weight is small here. The weather is directly determined by sunshine hours, and here is divided into 4 grades: overcast days ($S = 0$), overcast or cloudy days ($0 < S \leq 4$), cloudy days ($4 < S \leq 8$), cloudy or sunny days ($S > 8$). The scores in the summer half year and winter half year are shown in Table 2.

Table 2 Scoring standard of sunshine hours in the forecast equation of tourism meteorological index

Sunshine hours S	Weather	Score: Winter half year (November - next March)	Score: Summer half year (April - October)
$S = 0$	Overcast days	10	5
$0 < S \leq 4$	Overcast or cloudy days	5	0
$4 < S \leq 8$	Cloudy days	0	0
$S > 8$	Cloudy or sunny days	0	5

Extreme wind speed (F) has a great negative impact on tourism activities, so it is assigned a greater weight. The maximum level of gust in numerical forecast can be set as the level of extreme wind speed, and then the force of wind was scored as follows: 0 point for less than force 5, 20 points for force 5 - 6, 30 points for force 7, 50 points for force 8, and 70 points for more than force 9.

In the summer half year (from May to September), the influence of high temperature above 35 ℃ was mainly considered. In the winter half year (from October to next April), the influence of low temperature below 16 ℃ was mainly considered. Since temperature was analyzed to calculate comfort index, the maximum temperature (T) was only used as a supplement, and its weight is general or small (Table 3).

Table 3 Scoring standard of the maximum temperature in the forecast equation of tourism meteorological index

Time	Maximum temperature // ℃	Score
Summer half year (from April to October)	≤34.9	0
	35.0 - 35.9	5
	36.0 - 36.9	10
	37.0 - 37.9	15
	>38.0	20
Winter half year (from November to next March)	≥16.0	0
	14.0 - 15.9	5
	12.0 - 13.9	10
	10.0 - 11.9	15
	≤9.9	20

According to the conclusions of numerical prediction, each score was quantitatively calculated, and was substituted into formula (2) to obtain tourism meteorological index TMI. According to the level of the index in Table 4, whether to play or not was determined, and the corresponding tourism terms were published[1].

4 Analysis of correlation between tourist flow and tourism meteorological index and test of model effect

Since the tourist flow in April (the most suitable period for local tourism) and August (the least suitable period for local tourism) was less affected by holidays, the daily tourist flow in the ancient city in April and August of 2015 and 2016 was used. The relevant data of numerical forecast product in April and August of 2015 and 2016 was substituted into the prediction equation of tourism meteorological index, and it is found that tourist flow was positively correlated with tourism meteorological index (Fig. 5, the chart of April is omitted).

Table 4 levels of tourism meteorological index and tourism terms published

TMI	Level	Suitability	Terms published
>90	1	Extremely suitable	The weather is very fine, you can come out and enjoy the nature
71 – 90	2	Suitable	The weather is fine, and let's meet Langzhong Ancient City
51 – 70	3	Basically suitable	It's a nice day, and let's have time to go for a tour
31 – 50	4	Unsuitable	The weather is not good, but you can also experience the human atmosphere
≤30	5	Extremely unsuitable	The weather is bad, so you can come another day

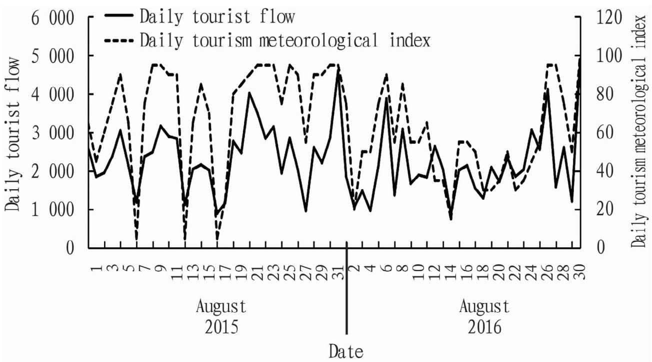

Fig. 5 Changes of daily tourist flow with daily tourism meteorological index in August 2015 and 2016

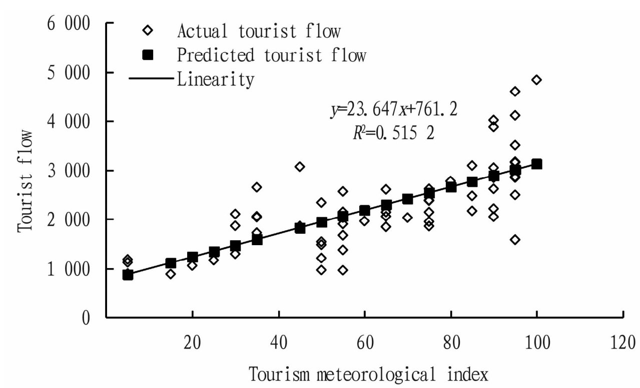

Fig. 6 Correlation between daily tourist flow and tourism meteorological index in August 2015 and 2016

The model of tourism meteorological index was tested by OLS. The results show that the predicted tourism meteorological index was positively correlated with the actual tourist flow, and the correlation coefficient R in April 2015 and 2016 was 0.685 6. In August 2015 and 2016, the correlation coefficient R was 0.717 8, and the correlation was strong. P value was 0.000, and the two were significantly correlated at 0.01 level (bilateral). It can be seen that the tourism meteorological index calculated by using the prediction equation had a strong correlation with the actual number of tourists, which was basically close to the actual situation, so the prediction effect was good[1-2] (Fig. 6).

5 Conclusions

By studying human comfort index as well as some meteorological factors (daily rainfall, sunshine hours, daily maximum wind speed and daily maximum temperature) affecting tourist flow, the prediction equation of tourism meteorological index suitable for the local area was established. Based on the numerical forecast product data, the correlation between tourism meteorological index and actual tourist flow during 2015 – 2016 was analyzed. The results show that Langzhong Ancient City is truly an ideal tourist area without hot summer or cold winter. In a year, the periods from March to June and from September to December were suitable for tourism, of which the periods from April to May and from September to October were the most suitable for tourism. The days only in January and from July to August were not suitable for tourism. Nearly 2/3 of the days in a year were suitable for tourism, with a long tourism season and more days suitable for tourism. This study provides strong technical support for the prediction of tourism meteorological index in Langzhong Ancient City[1-2].

References

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