

# Insights on defeating coronavirus disease (COVID-19) outbreak and predicting tourist arrival on the Chinese Hainan Leisure Island during the COVID-19 pandemic

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## Abstract

**Background:** Hainan province is a very popular leisure tourist arriving city in China. Coronavirus disease 2019 (COVID-19) emerged in China and rapidly in early 2020, and due to its rapid worldwide spread, the World Health Organization declared COVID-19 as a global emergency. During the COVID-19 pandemic in Hainan province, many businesses and economies were influenced in this unexpected event, especially in tourism.

**Methods:** This study used 2 classical forecasting methods to predict the number of tourists on Hainan Leisure Island from September to December in the second half of 2020 and to summarize the COVID-19 fighting experience during the pandemic. In addition, the Hainan government implemented epidemic control measures to resume production and work, and promote new tourism measures to acquire superior COVID-19 protection.

**Results:** Winter's method provides a statistical model for predicting the number of visitors to Hainan under normal conditions. The trend analysis method considers the impact of the black swan event, an irregular event, and only uses the data under the influence of the event to predict according to the trend.

**Conclusion:** If the impact of the black swan event (COVID-19) continues, the prediction can be made using this method. In addition, the Hainan government has undertaken timely and effective measures against COVID-19 to promote leisure tourism development.

**Abbreviations:** COVID-19 = coronavirus disease 2019, MAD = mean absolute deviation, MAPE = mean absolute percentage error, MSD = mean standard deviation.

**Keywords:** COVID-19, forecasting, leisure tourist arrivals, naive trend analysis, winter's method

## 1. Introduction

After the coronavirus disease (COVID-19) outbreak, on January 23, 2020, in Wuhan, China, the people's government of Hainan province on January 24 started a public health emergency II magnitude response and promoted the magnitude response of public health emergencies on the following day (January 25).

Other administrative regions of the People's Republic of China activated the first-level response on January 24th and 25th and closed nationwide cities.<sup>[1]</sup> This means that after January 24th, the internal movement of people was greatly restricted, and Hainan province was almost empty of tourists for a quarter of the time in January. Later, due to effective social management and

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GL and JC contributed equally to this work.

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The authors have no conflicts of interest to disclose.

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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medical treatment, the epidemic situation in China was successfully brought under control, and the population movement began to resume in an orderly manner. Therefore, accurate prediction of tourist arrival can enable the administration to adopt appropriate travel measures to promote the economy. The COVID-19 outbreak in Hainan province started in late January, followed by several clusters in early February.<sup>[2]</sup> At present, the number of confirmed COVID-19 cases is 0, and the epidemic in Hainan Leisure Island has been effectively brought under control. There were no newly confirmed cases since late February, 2020. By August 27, 2020, 171 cases had been confirmed, out of which 165 people were cured and 6 people died.

Hainan province is a very popular leisure tourist arriving city in China. COVID-19 emerged in China and rapidly in early 2020, and due to its rapid worldwide spread, the World Health Organization declared COVID-19 as a global emergency. The pandemic has influenced many businesses, including tourism on Hainan Island, which cause economy recession. It made tourist decrease to travel across regions and stay at home for preventing COVID-19 spread. The medical researchers will develop an effective vaccine that can completely counteract the subsequent effects.<sup>[3]</sup> The 21st century is an era of ocean tourism, and islands have become the golden zone of ocean tourism for vacationers or leisure tourists. Concerns about public health security emergencies, such as infectious diseases, can seriously influence the choice of destination, for example, an outbreak of new or exotic diseases such as the Zika virus<sup>[4]</sup> in the Caribbean and the America has deterred tourists from considering these choices of high-risk spread areas.<sup>[5,6]</sup> Leisure activity is a potential driver and key determinant of the spread of infectious diseases, and the basic feature of infectious disease pandemics is the direct person-to-person transmission in the rapid flow of people,<sup>[7]</sup> and emerging infectious diseases have become more frequent. Among them, island tourist destinations have a high incidence of emerging infectious diseases, which should be highly focused on. Providing essential health care services to more than 100,000 leisure islands in the Asia-Pacific region is a major challenge for public health.<sup>[8]</sup> Spain's Canary Islands are a popular entry point into the European Union, and HIV-positive migrants pose a threat to public health in Europe, including the Indian, Pacific, and Caribbean oceans in the last 10 years, causing outbreaks of viral infections such as dengue,<sup>[9]</sup> Chikungunya, and Zika on islands in the region. Tropical islands have become new centers for emerging infectious viruses.<sup>[10]</sup> Dengue fever among tourists in Bali, Indonesia has distinct characteristics of spatiotemporal changes<sup>[11]</sup>; high endemic areas of hepatitis B virus infection are concentrated in Southeast Asia and the Pacific Islands. In practice, almost all imported and exported cases in areas affected by COVID-19 are highly correlated with leisure island tourist destinations. Island infectious diseases and epidemic problems have been recognized internationally.

In mid-to-late February, the COVID-19 pandemic was well under control, and all industries in Hainan Island began to resume production and work. At present, the resumption of production and work in Hainan has been completed. The COVID-19 pandemic has had a significant impact on Hainan's tourism industry. In late March, 2020, there was no new case on Hainan Island for a month, and the pandemic situation remained low. After experiencing "winter", Hainan's tourism industry experienced a turnaround, with scenic spots gradually opening up, public transport gradually resuming, and the number of tourists gradually increasing. By 2025, the Chinese government

intends to create an "international center for tourism and consumption" on the Island of Hainan.<sup>[12]</sup> At present, Hainan's leisure island tourism has resumed.

Our previous study used artificial intelligence to mine prediction markers in medical hospitality.<sup>[13]</sup> Therefore, during the COVID-19 pandemic, the objective of this study was to forecast tourist arrival at Hainan leisure island from September to December in the second half of 2020 using Winter's method<sup>[14]</sup> and naive trend analysis method.<sup>[15]</sup> The main effective measures included epidemic control, measures to resume production and work, and new tourism measures to promote tourist arrivals in Hainan. Hence, it provided a useful COVID-19 fighting experience and predicted the tourist number in the latter half of the year to guide government promotion direction.

## 2. Methods

### 2.1. Data collection

The number of tourists at Hainan leisure island between January 2018 and August 2020 was collected from the official websites of the People's Government of Hainan Province, the Department of Ecology and Environment of Hainan Province, and the Health Commission of Hainan Province, and the relevant policy documents on epidemic prevention and control measures of Hainan leisure island were collected from January 24, 2020 to March 3, 2020. We then applied Winter's method and naive trend analysis method to predict tourist arrival data for Hainan Island from September to December in the second half of 2020. The ethical approval was waived as all data were from the official websites of the People's Government of Hainan Province.

### 2.2. Winter's method model

We used the Winter's multiplicative model to predict tourist numbers on Hainan Island from September to December in the second half of 2020; the calculated length was 24, and there were no missing data. The smoothing constant  $\alpha$  level was 0.6,  $\gamma$  trend was 1.0, and  $\delta$  season was 0.1. The key reference indicators were as follows: mean absolute percentage error (MAPE) was 14.6, mean absolute deviation (MAD) was 89.8, and mean standard deviation (MSD) was 11611.5. The MAPE, MAD, and MSD were 14.6, 89.8, and 11611.5, respectively.

The formula of the Winter's method is as follows:

1. Exponential smoothing series, or level estimation:

$$L_t = \alpha \frac{Y_t}{S_{t-s}} + (1-\alpha)(L_{t-1} + T_{t-1}) \quad (1)$$

2. Trend estimation:

$$T_t = \beta(L_t - L_{t-1}) + (1-\beta)T_{t-1} \quad (2)$$

3. Seasonal estimation:

$$S_t = \gamma \frac{Y_t}{I} + (1-\gamma)S_{t-s} \quad (3)$$

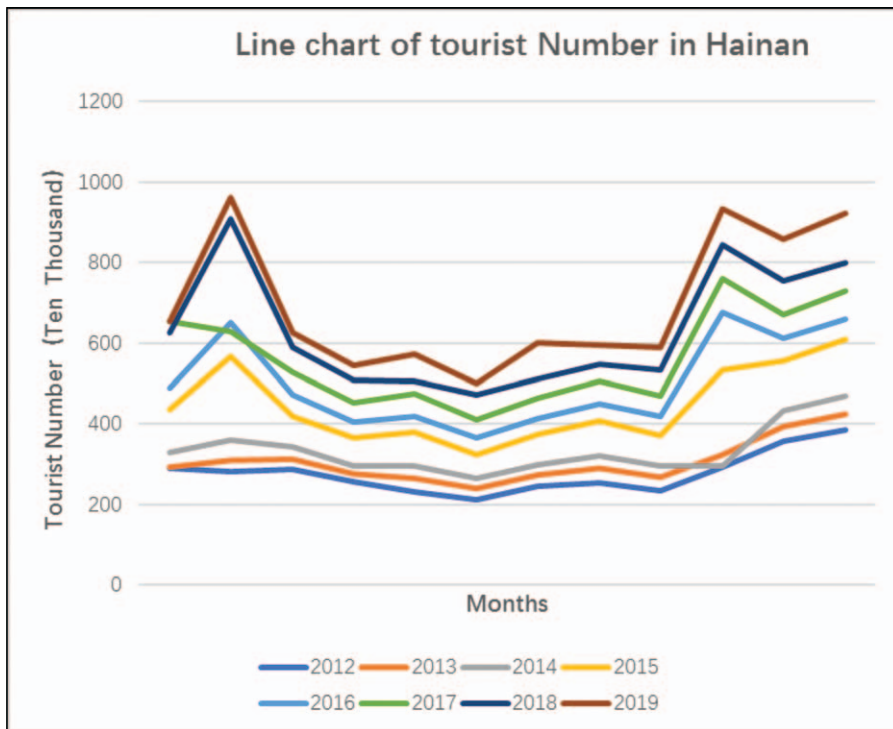


Figure 1. Line chart of the number of Hainan tourists from 2012 to 2019.

4. Projections for future P issues:

$$\hat{Y}_{t+p} = (L_t + pT_t)S_{t-s+p} \tag{4}$$

The meaning represented by the symbol is as following:

- $L_t$  = new smoothing value or current level estimate
- $\alpha$  = level of smoothness constant
- $Y_t$  = new observed or actual values during period T
- $\beta$  = smoothing constant for trend estimation
- $T_t$  = trend estimation
- $\gamma$  = smoothing constant for the seasonal estimation
- $S_t$  = seasonal estimation
- $p$  = predicted period in future
- $s$  = length of the seasons
- $\hat{Y}_{t+p}$  = prediction of the future P phase

**2.3. Naive trend - secondary trend analysis model**

Tourist data were collected between February and August during the COVID-19 pandemic. We used the quadratic trend model to predict tourist numbers on Hainan Island; the calculated length was 7, and there were no missing data. The fit trend equation is as follows:

$$Y_t = 49.8 + 89.4t + 2.15t^2$$

The naive trend analysis method - secondary trend model obtained the best fitting result, and its key reference indexes are as

follows: MAPE 4.835, MAD 17.249, and MSD 565.565. The MAPE, MAD, and MSD were 4.835, 17.249, and 56.565, respectively.

**3. Results**

**3.1. Model performance indexes evaluation**

To assess the prediction performance of the involved models, 3 error measures, MAPE, MAD, and MSD, were utilized in the forecasting experiments.

MAPE indexes can be defined as:

$$MAPE = \frac{1}{N} \sum_{i=1}^N \frac{|q_p(i) - q_o(i)|}{q_o(i)} \times 100\% \tag{5}$$

**3.2. Results of winter's method model**

As shown in Figure 1, the changes in the number of tourists to Hainan from 2012 to 2019 have both trends and seasonality. Table 1 shows Winter Model to predict Tourist number to Hainan Leisure Island and Table 2 shows the predicting tourist arrival of the latter half year 2020. In general, the number of visitors to Hainan rises seasonally: the number of visitors to Hainan leisure island peaked in the first quarter of February around the Chinese Lunar New Year, and the second peak occurred in the fourth quarter of October, namely the National Day golden week, or December, and a large number of companies often choose to spend the company's annual leave at the end of

**Table 1**  
Winter model to predict tourist number to Hainan Leisure Island.

Time months	Tourist number	Smoothness	Predict	Error
1	625.51	724.581	665.388	-39.878
2	908.23	848.975	738.967	169.263
3	589.01	713.616	706.441	-117.431
4	506.95	630.247	553.314	-46.364
5	504.73	470.742	376.905	127.825
6	472.07	606.685	583.757	-111.687
7	510.58	432.003	356.812	153.768
8	547.36	446.752	463.734	83.626
9	533.99	467.202	528.255	5.735
10	842.47	697.131	781.693	60.777
11	754.04	699.402	802.863	-48.823
12	799.08	764.115	837.376	-38.296
13	654.55	735.909	781.346	-126.796
14	961.85	927.058	886.782	75.068
15	625.25	792.202	796.253	-171.003
16	543.19	685.616	588.207	-45.017
17	571.39	504.412	392.582	178.808
18	500.75	663.955	657.917	-157.167
19	599.71	472.918	388.727	210.983
20	593.86	512.770	554.959	38.901
21	590.13	528.919	588.853	1.277
22	932.39	763.509	842.111	90.279
23	856.97	772.985	887.490	-30.520
24	921.16	853.235	947.664	-26.504

**Table 2**  
Predicting tourist arrival of the latter half year 2020 (all people number units were 10,000).

Mo	Predict	Lower limits	Upper limits
25	921.62	701.554	1141.69
26	1291.25	980.033	1602.48
27	1187.48	766.086	1608.88
28	1244.45	705.398	1783.50
29	1208.16	547.958	1868.36
30	1663.76	880.537	2446.98
31	1507.01	599.648	2414.36
32	1558.20	525.992	2590.40
33	1494.70	337.164	2652.23
34	2036.27	753.068	3319.46
35	1826.53	417.416	3235.65
36	1871.94	336.726	3407.16

the new calendar year. There was no obvious abnormality in the fluctuation of tourist data of Hainan province from 2012 to 2019, and it is preliminarily believed that there is no irregularity in the 8-year data (Fig. 1).

To further verify that there was no irregular component in the collected data, the author calculated the total number of annual

visitors from 2012 to 2019, the average number of monthly visitors in that year (Fig. 2), and the average number of visitors from January to December (Fig. 3).

Figures 1, 2 and 3 show the trend and seasonality of the tourist statistics of Hainan province from 2012 to 2019. The trend is an upward trend, that is, the number of tourists visiting Hainan steadily increases each year. Its seasonal performance has an obvious peak and the valley value, with February being the peak and October and December being the second peak each year. In Figure 3, the monthly average over the years is plotted; that is, the January data from 2012 to 2019 are added together, the monthly average is calculated, and the average in December is calculated. From the graph, there is no irregularity in the data. In conclusion, the ideal tool for processing this dataset is Winter's method. The parameters of the best fitting result of Winter's multiplicative method are a horizontal weight of 0.6, trend weight of 1, and

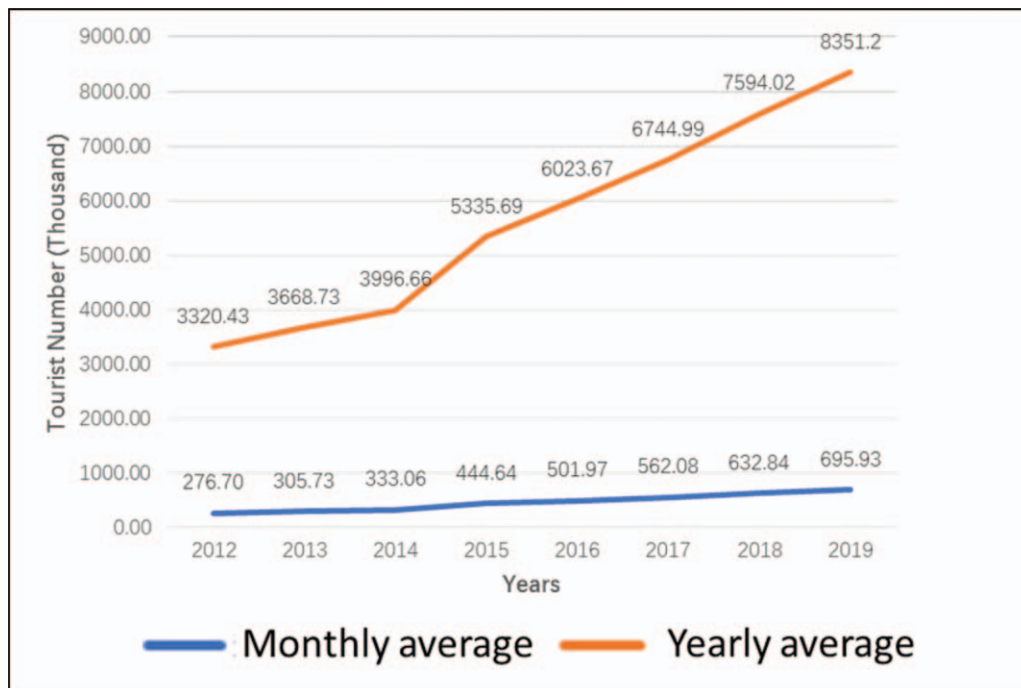


Figure 2. The number of tourists to Hainan from 2012 to 2019 and the average number of tourists per month in that year.

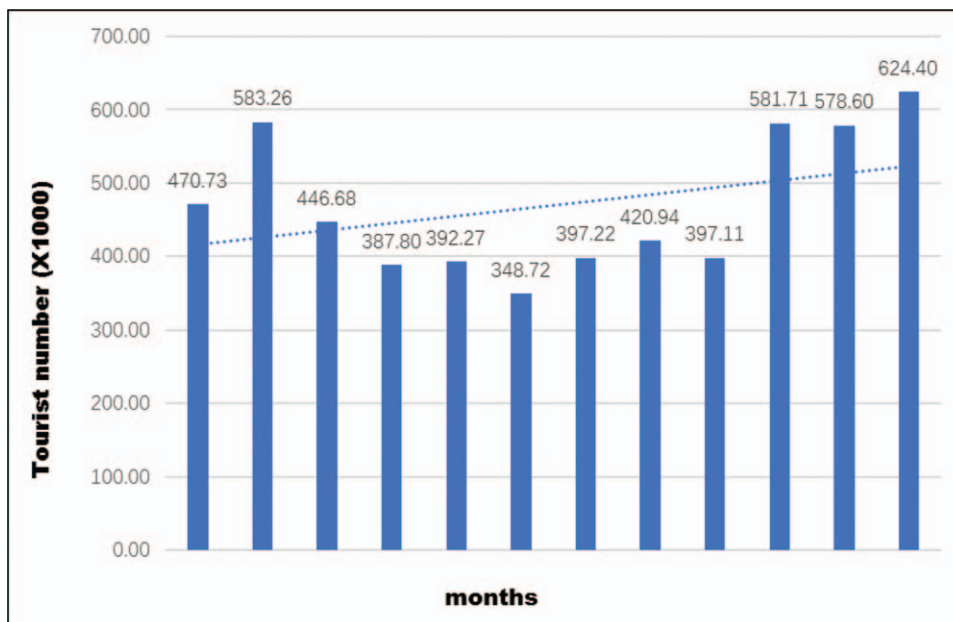


Figure 3. Average number of visitors to Hainan from January to December (2012–2019).

seasonal weight of 0.1. The fitting results are shown in Figure 4. Figure 5 depicts the parameter of forecasting tourist number using Winter’s method.

**3.3. Forecasting performance of naive trend analysis**

After the decomposition of Hainan leisure island tourist arrivals data, the decomposed components are predicted, and then the comprehensive prediction is combined to obtain the final prediction result. Table 3 shows the trend between February and August tourist numbers to Hainan, and Figure 6 depicts the forecasting of the number of tourists using the naive trend analysis method. The fitting results are shown in Figure 6A, and the residual figure is shown in Figure 6B. The parameter for forecasting the number of tourists using the naive trend analysis method is described in Figure 7. First, the quadratic trend model was used to predict the number of tourists to Hainan (Table 3).

Table 4 shows the prediction of tourist arrival in the latter half of 2020, from September to December. Table 5 summarizes the results of naive trend analysis.

Before the effects of the black swan event (COVID-19) were fully dissipated or COVID-19 reappeared in the coming winter, the naive trend analysis method was relatively accurate in predicting visitors to Hainan Island.

In conclusion, we established these methods to forecast tourism and provide a tourism guide for the Hainan government to take measures to fight the COVID-19 pandemic and promote economic development in Hainan leisure island.

**4. Discussion**

During the COVID-19 pandemic in Hainan province, many businesses and economies were attacked in this unexpected event, especially in tourism. This study used 2 classical forecasting

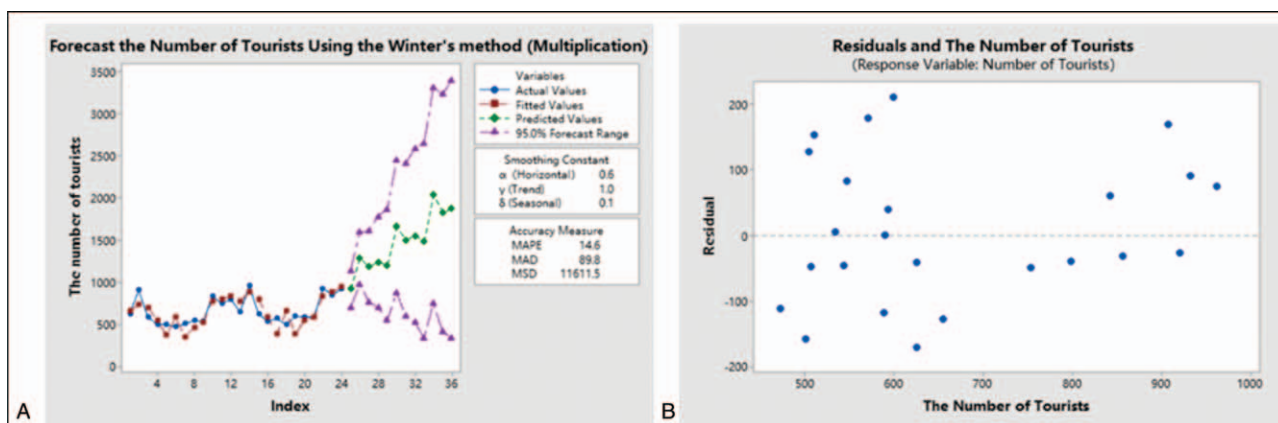
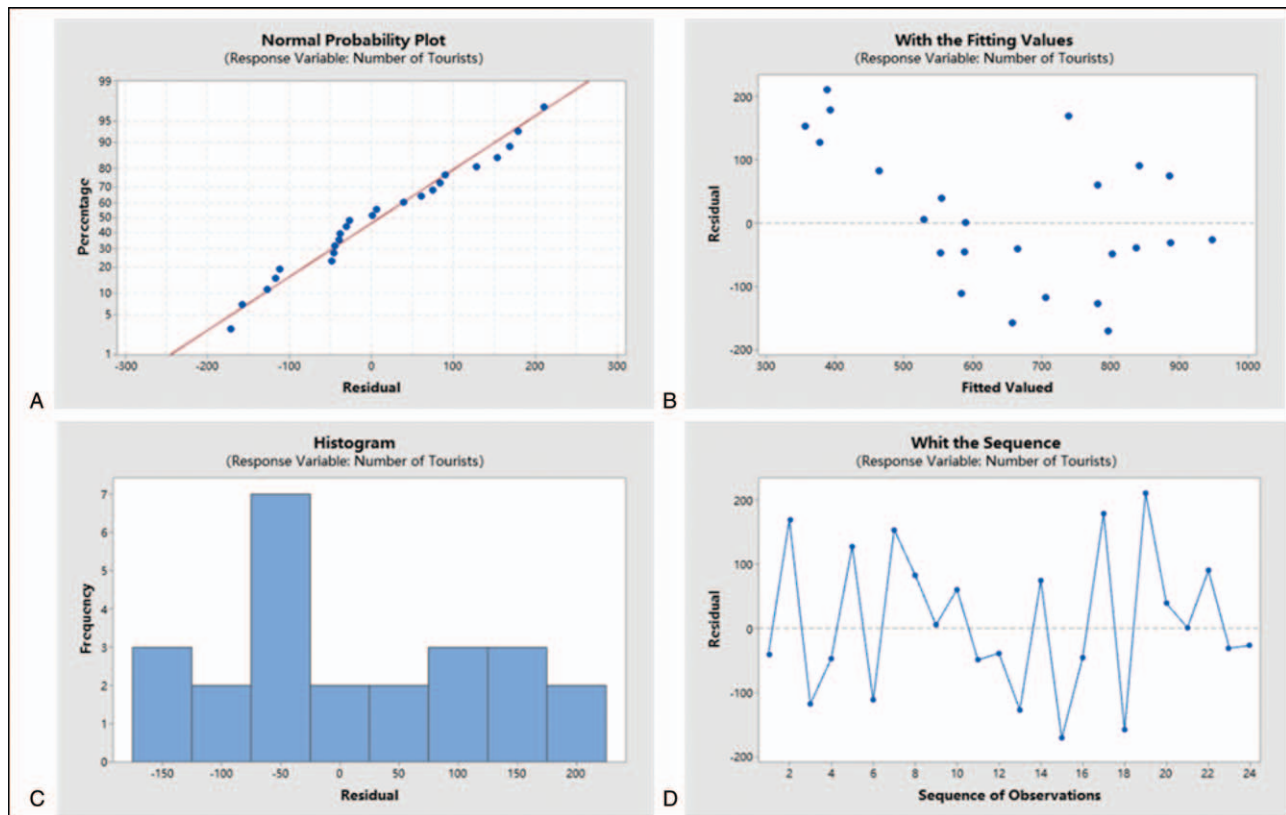


Figure 4. Forecasting the number of tourists using Winter’s method. (A) The performance of predicting using Winter’s method. (B) The relationship of residuals and number.



**Figure 5.** The parameter of forecasting the number of tourists using Winter's method. (A) Normal probability plot of the percentage with residual. (B) With the fitting value of residual. (C) Histogram of frequency with residual. (D) With the sequence of residual with observation.

methods and summarized the COVID-19 fighting experience. If full monthly data for 2020 are available in the future, the number of visitors till June 2021, still under the influence of events, can be predicted in combination with seasonality and trends.<sup>[16]</sup>

In the future, medical researchers will develop an effective vaccine that can completely counteract the subsequent effects of the black swan event. The Winter's method could use more complete cycle data to continuously improve and predict the number of visitors to the city in general. Therefore, we developed 2 methods for forecasting tourist arrivals in Hainan in 2020, from September to December. Our findings indicate that several measures were undertaken to fight the COVID-19 pandemic in Hainan Leisure Island, and they acquired some effect.

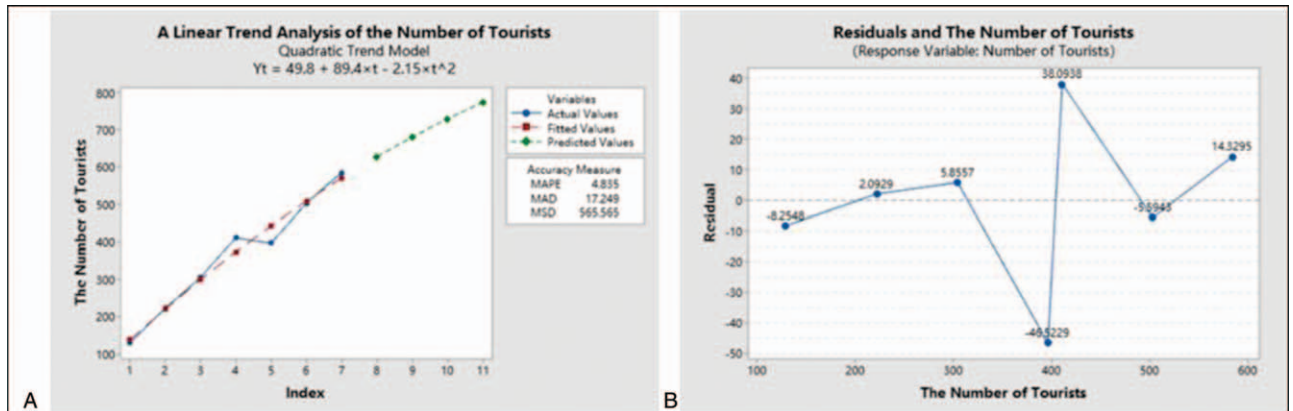
First, the Hainan government banned large indoor events and reduced staff gatherings. Standardized and humanized manage-

ment should be carried out for the retained viewpoints, and the unqualified retained viewpoints should be promptly reformed. These include extensive contact tracing and border control measures and community-transmission control measures,<sup>[17]</sup> including cancelling the leave of personnel in key positions and ensuring that relevant personnel are on duty during holidays and implementation of the territorial responsibility system. Governments worldwide should immediately set up a novel COVID-19 epidemic prevention and control organization that would strengthen the control of people entering the island. Strict implementation of an information-reporting system is a must. Localized management needs to be implemented for epidemic information reporting. Strengthening the management of medical and health institutions and provincial medical and health institutions at all levels should resolutely implement the system of preexamination triage and fever clinics for infectious diseases. Moreover, all countries should formulate targeted publicity and educational programs in light of the local epidemic situation. We should strengthen the collection and response of public opinion on infectious diseases. Prevention and control of the masses needs to be strengthened. We should implement extensive social mobilization and jointly undertake effective measures to prevent the spread of the epidemic.

Second, some measures to resume production and work on Hainan Leisure Island were undertaken. The epidemic prevention and control of provincial administrative areas (such as drugs, protective equipment, and medical treatment equipment production, transportation, sales) secured running necessities (for water

**Table 3**  
**Quadratic trend model to predict tourist number to Hainan Leisure Island.**

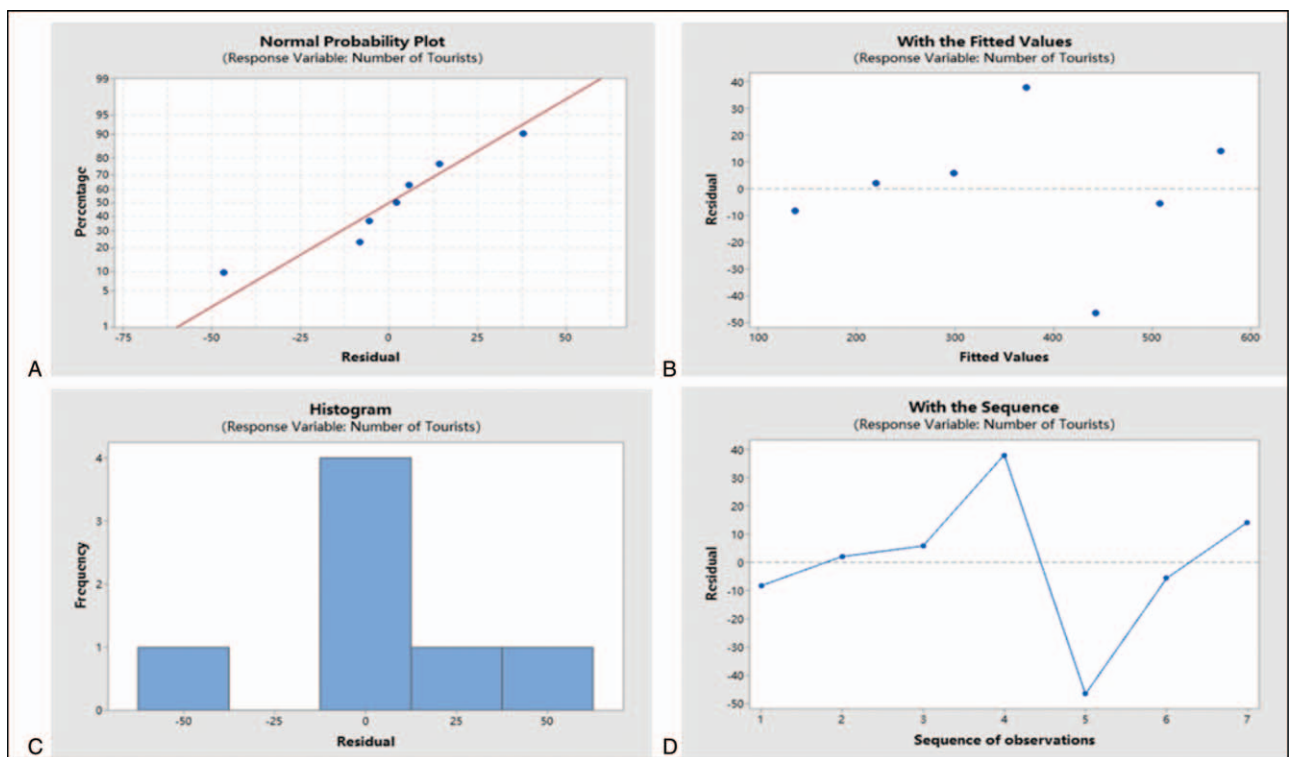
Mo (time)	Tourist number	Trend	Remove trend
2	128.75	137.005	-8.2548
3	222.03	219.937	2.0929
4	304.43	298.574	5.8557
5	411.01	372.916	38.0938
6	396.44	442.963	-46.5229
7	503.12	508.714	-5.5943
8	584.50	570.170	14.3295



**Figure 6.** Forecasting the number of tourists using the Naive trend analysis method. (A) The performance of predicting using Naive trend analysis's method. (B) The relationship of residuals and number. MAD = the mean absolute error, MAPE = mean absolute percentage error, MSD=the mean standard deviation.

supply, electricity, oil and gas, communication, municipal, public transportation, etc), mass life necessities (supermarket stores, food production, supply, logistics, property, etc), constructed key projects, and other projects important to national economy and people's livelihood to facilitate proper work force.<sup>[18]</sup> Improving the management system for leaving Hainan during the epidemic period is stable employment for enterprises. Small and medium-sized enterprises, which have difficulties in production and operation due to the impact of the epidemic, may, through consultation with their employees, stabilize their jobs by adjusting salaries, taking shifts of duty, shortening working

hours, waiting for posts, and minimizing layoffs.<sup>[19]</sup> From January 2020 to the month of the end of the epidemic, the registration of insurance participation, the declaration of payment base, and the payment of insurance premiums was extended to 3 months after the end of the epidemic. Reduce operating costs. The rent for the first quarter of 2020 was reduced or exempted for small and medium-sized enterprises that rent state-owned (including collective) property housing.<sup>[20]</sup> For the electricity, water, and gas needed by the production and operation of small and medium-sized enterprises, the fees was deferred for 3 months from the date of the issuance of this



**Figure 7.** Forecasting the number of tourists using Naive trend analysis method. (A) The performance of predicting using Winter's method. (B) The relationship of residuals and number.

**Table 4**  
The prediction of tourists' arrival in the latter half year 2020.

Time (mo)	Predict
9	627.331
10	680.197
11	728.768
12	773.043

circular. During the deferment period, the measures of "continuous supply of overdue fees" were implemented, and overdue fines were exempted. Starting from the date of issuance of this notice, the government would pay the housing accumulation fund at the rate of 3% for 6 consecutive months, which would reduce the tax burden.<sup>[21]</sup>

Due to the impact of the pandemic, the property tax and urban land use tax payable by the government in the first quarter of 2020 were reduced or exempted. For small and medium-sized enterprises that had difficulty in filing declarations due to the epidemic situation, the enterprises were allowed to apply for the delay in filing declarations following the law. To ensure the new loans of key national COVID-19 prevention and control enterprises in 2020, based on preferential interest rate credit provided by financial institutions supported by the special re-loan of the People's Bank of China, central and provincial finance will give discount interest at 50% and 30%, respectively.<sup>[22]</sup> For key enterprises in health and epidemic prevention, pharmaceutical products, and medical equipment that play prominent roles in supporting epidemic prevention and control work in our province, the provincial finance will give a discount of 30% of the basic loan interest rate on the date of signing the loan contract in 2020.

Third, measures to restore and revitalize tourism in Hainan Leisure Island were undertaken. The policy of adherence to the principle of zoning and classification rather than "one-size-fits-all" was implemented. The emergency plan for COVID-19 prevention and control in tourist attractions was prepared in advance before the scenic spots were reopened, and the emergency measures and procedures for epidemic prevention and control were clarified. Initiative to conduct publicity and guidance<sup>[23]</sup> were undertaken. Strengthening the health monitoring and management of staff in the scenic spots, reporting of staff, strengthening the training of epidemic prevention and control, and strictly enforcing the working standards were done. Cleaning and disinfection were strengthened, medical services were provided, and a subdivision opening was implemented to ensure the safety of the equipment. It was necessary to take effective measures such as ticket reservation, intelligent guidance, diverting tourists, and ensuring the pre-control of tourist flow

**Table 5**  
Summary of quadratic trend model analysis results.

	MAPE	MAD	MSD
Liner	6.133	18.476	620.912
Growth curve	12.7	40.36	2259.75
The secondary trend	4.835	17.249	565.565
S-curvilinear trend	8.884	23.574	844.773

MAD = the mean absolute error, MAPE = mean absolute percentage error, MSD = the mean standard deviation.

at gateways. Visitors were arranged to enter the park at different intervals.

The limitations of this study are as follows: The 2 methods need an updated algorithm to predict the results more accurately. This would be effective by undertaking various measures. More algorithms need to be added to compare the differences in the prediction. The entrances and exits of scenic spots, important views, and other places prone to crowd gathering should be equipped with management personnel to strengthen the management of tourists, such as optimizing the setting of tour routes and implementing real-name registration.<sup>[18]</sup> It is encouraged that scenic spots adopt e-ticket selling, 2-dimensional code ticket checking, and other methods to effectively reduce personnel contact. Visitors can enter the park only after taking their temperature and wearing a mask. Maintaining traffic, ticket buying, sightseeing, catering, and other social distancing protocols should be followed.<sup>[1]</sup> Food and beverages service units should strengthen recycling using tableware cleaning and disinfection or using disposable tableware. Strengthening on-site inspections, publicity of prevention and control knowledge, timely and effective management of abnormal situations should be done. Furthermore, strengthening the linkage with local health and epidemic prevention departments, cultural tourism, and other departments, and timely reporting of abnormal situations, such as cases of scenic spots with suspected symptoms should be immediately isolated, close contact tracing should be done, disinfection measures should be strengthened, and scenic spots should be temporarily closed until the situation is under control and approved following the procedures.<sup>[24]</sup>

## 5. Conclusion

Winter's method provides a statistical model for predicting the number of visitors to Hainan under normal conditions. This model can improve the fitting degree by increasing the effective period data and fine-tuning the 3 parameters of level, trend, and weight, thus increasing the accuracy of the prediction. The trend analysis method considers the impact of the black swan event, an irregular event, and only uses the data under the influence of the event to predict according to the trend. If the impact of the black swan event (COVID-19) continues, the prediction can be made using this method. In addition, the Hainan government performs timely and effective fighting COVID-19 measurements to promote tourism development.

## Author contributions

**Conceptualization:** Gang Liu, GuanLai Zhu, Xin Li.

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**Formal analysis:** Jingyao Chen, Zhuo Chen, Shidao Lin, Shigao Huang.

**Funding acquisition:** Zhuo Chen.

**Investigation:** Gang Liu, Jingyao Chen, GuanLai Zhu.

**Methodology:** Gang Liu, Shigao Huang.

**Resources:** Shigao Huang.

**Software:** Shidao Lin.

**Supervision:** Shigao Huang, Xin Li.

**Validation:** Jingyao Chen, Zhuo Chen, Shidao Lin.

**Writing – original draft:** Jingyao Chen, GuanLai Zhu.

**Writing – review & editing:** Shigao Huang, Xin Li.



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