

FORECASTING INTERNATIONAL AIR TRAFFIC USING REAL-TIME FLIGHT DATA: A CASE STUDY OF KYRGYZSTAN AIRPORTS

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Abstract This article examines the problem of forecasting air traffic at international airports in Kyrgyzstan using time series analysis. Bishkek and Osh airports were chosen as the study sites. Initial data on daily aircraft arrivals and departures was obtained from the FlightAware platform. Data collection, cleaning, and preprocessing were performed, including timestamp conversion and missing observation recovery. The Facebook Prophet model, which takes into account trend and seasonal components of the time series, was used for forecasting. Data for the period 2019–2025 was analyzed, allowing us to identify the impact of the COVID-19 pandemic on the aviation industry, the specifics of air travel recovery, and the presence of stable annual seasonality. Based on the constructed model, a forecast of air traffic for 2026 was obtained.

Keywords: air traffic; time series forecasting; Facebook Prophet; civil aviation; Kyrgyzstan airports; FlightAware.

1 INTRODUCTION

Hence, air transport is a crucial element of the modern transportation organisation, ascertain population mobility, arise international economical ties, and integrate states into the global place [9]. For countries with craggy terrain and significant distances between settlements, aviation recreate a particularly important character, process as an efficient means of rider and cargo transportation. In addition, In Kyrgyzstan, the turgid aviation hubs are Bishkek and Osh external airport, which handle the bulk of international and domestic air dealings.

Moreover, originate air travel volumes, changing passenger flow patterns, and the impact of external factors demand the use of modern analysis and foretelling methods. Therefore, Accurate forecast enable aviation authorities, airports, and airway to more in effect plan substructure utilization, allocate resources, optimize schedules, and improve passenger service. This task has become especially urgent take after the COVID-19 pandemic, which has led to an unprecedented decrease in aura traffic worldwide and significantly altered the dynamics of the air manufacture [10].

Modern time serial analysis method acting allow us to place hidden patterns in data, measure the impact of seasonality, and work up forecasts ground on historical observations [1, 2, 5]. Among the nearly popular prediction puppet is the Facebook Prophet framework, developed by Meta for canvas meter series with say seasonality and style changes [6]. This model is full-bodied to missing data, able to report for structural changes in the time serial, and offers extremely explainable results, making it a hopeful tool for air traffic enquiry [7].

In contrast, The purpose of this study is to analyze air traffic dynamics at Kyrgyzstan is external drome and augur their development free-base on actual flight data. On the other hand, To reach this goal, the take after tasks were make out: collecting and preparing data on arriving and departing trajectory, studying the structure of time series, identifying seasonal and trend components, and constructing a forecast example utilize the Facebook Prophet algorithm.

Furthermore, The scientific novelty of this study lies in the application of time series forecasting methods to real - world air traffic datum from Kyrgyzstan is airport, obtained from the international flight monitoring organisation FlightAware [11]. The pragmatic significance of this research lies in the potential use of the

obtained result to hold determination - making in aviation substructure management, transportation planning, and measure the development prospects of the country is aviation industry.

In contrast, thence, the cogitation aspire to investigate the patterns of aviation traffic changes and develop a forecasting tool up to of providing to a greater extent informed strategic planning in the context of a dynamically developing air conveyance market.

2 RATIONALE FOR CHOOSING THE FACEBOOK PROPHET MODEL FOR AIR TRAFFIC FORECASTING

Moreover, The Facebook Prophet model is one of the most popular metre series prediction tools and is well suited for melodic phrase traffic psychoanalysis, as it accounts for trends, seasonality, and potential gaps in data [6]. Aircraft arrivals and departures represent a meter series that is charm by seasonal variation, economic factors, and outside events, including pandemic and air travel restrictions [7, 10].

Therefore, Prophet is based on an additive manikin, which debate a time series as the sum of a drift, a seasonal component, and additional effects [4,6]. Therefore, The drift reflects long - term changes in air traffic, while seasonality allows for accounting for regularly recurring fluctuations throughout the yr.

Therefore, One of the model is key reward is its hardiness to missing values and its ability to automatically accommodate to slue changes [6, 12]. In addition, This allows Prophet to effectively work with real - man transport data, where gaps in reflexion and sudden alteration in passenger traffic are possible.

Nonetheless, In addition to incur prognosis economic value, the good example admit for the depth psychology of individual ingredient of the time serial publication, which improves the interpretability of the resolution and facilitates the identification of factors influencing the dynamics of air travel [4].

Thus, habituate Facebook Prophet is a viable solution for forecasting air dealings at Bishkek and Osh airports, as the model combines simplicity of use, robustness to literal - world information, and the ability to produce accurate and interpretable forecasts [6,7].

3 DATA SOURCE

The study utilized data from the FlightAware platform, one of the world is expectant aura traffic monitoring system of rules [11]. The platform ply substantial - clip flight trailing, historical data storage, and analytics and forecasting tools.

Therefore, data is collected practice ADS - B applied science, satellite monitoring data, and multilateration algorithms (MLAT), allowing for aircraft positioning data to be obtained even in areas with limited ground coverage. Nonetheless, The data is also sync with official escape plan and weather study [11].

Nevertheless, This study used data on the operations of Osh International Airport (ICAO: UCFO). In addition, The original dataset contains data on the day-by-day number of aircraft arrival and departures. As a result, The data was exported in JSON format for subsequent processing and depth psychology use Python.

4 DATA PREPROCESSING AND CLEANING

The beginning stage of processing was converting timestamps from UNIX Time to a standard date and prison term format. Hence, Analysis let out that the information spanned a uninterrupted time menses and was ab initio sorted in reverse chronological rules of order — from newest to earliest records.

Therefore, To train the data for further analysis, cleanup and transformation process were performed: checking the validness of timestamps, sorting records by ascending date, ensure for overlook values, and consolidating the data into a unified format. Nevertheless, This resulted in a structured time series suitable for statistical psychoanalysis, visualization, and make machine scholarship poser [1, 5].

```
{
  "chart_data": [
    { "date": 1761696000, "arrivals": 40, "departures": 38 },
    { "date": 1761609600, "arrivals": 41, "departures": 38 },
    { "date": 1761523200, "arrivals": 41, "departures": 39 },
    { "date": 1761436800, "arrivals": 41, "departures": 39 },
    { "date": 1761350400, "arrivals": 41, "departures": 38 },
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    { "date": 1760313600, "arrivals": 43, "departures": 39 },
  ]
}
```

Figure 1. Source data in JSON format

Next, the data for Bishkek and Osh airports from the JSON files is win over into tables. Nevertheless, The unexpended image shows the information for Bishkek airport, and the right image demo the data for Osh airport (Figure 2.2) .

	date	arrivals	departures
0	1761696000	40	38
1	1761609600	41	38
2	1761523200	41	39
3	1761436800	41	39
4	1761350400	41	38
...	...	...	...
2485	1546646400	19	19
2486	1546560000	18	19
2487	1546473600	17	18
2488	1546387200	15	15
2489	1546300800	13	12
2490 rows x 3 columns			

	date	arrivals	departures
0	1762128000	15	14
1	1762041600	15	14
2	1761955200	15	15
3	1761868800	15	15
4	1761782400	15	15
...	...	...	...
2423	1546646400	8	7
2424	1546560000	8	6
2425	1546473600	8	6
2426	1546387200	10	7
2427	1546300800	9	6
2428 rows x 3 columns			

Figure 2. Initial data in tabular form

Furthermore, the info() method show that the Bishkek Airport dataset contains 2,490 records, while the Osh Airport dataset contains 2,428 platter. As a result, Both datasets include three columns: date, comer, and departures.

On the other hand, All columns are of the int64 data point type. Therefore, The appointment field is stored in numeric format and necessitate conversion to datetime for time serial analysis. Furthermore, There are no missing value, confirming the completeness and calibre of the data.

On the other hand, thence, the data represent structured time series of aircraft arrivals and departures and can be used to analyze air travel dynamic and ramp up predictive models [2, 12].

```

bishkek_df.info()
osh_df.info()

*** <class 'pandas.core.frame.DataFrame'>
RangeIndex: 2490 entries, 0 to 2489
Data columns (total 3 columns):
#   Column      Non-Null Count  Dtype
---  ---
0    date        2490 non-null   int64
1    arrivals    2490 non-null   int64
2    departures  2490 non-null   int64
dtypes: int64(3)
memory usage: 58.5 KB
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 2428 entries, 0 to 2427
Data columns (total 3 columns):
#   Column      Non-Null Count  Dtype
---  ---
0    date        2428 non-null   int64
1    arrivals    2428 non-null   int64
2    departures  2428 non-null   int64
dtypes: int64(3)
memory usage: 57.0 KB

```

Figure 3. General structure of data sets

After converting the date column to datetime format, the time series was turn back for missing dates. Nonetheless, analytic thinking unveil that only four day were missing from the Bishkek airport data, indicating a high level of completeness and persistence in the dataset. Moreover, Seventy - one missing days were identified in the Osh airport data, the majority of which fall out between March and June 2020. In contrast, These are most likely due to air travel restrictions during the COVID-19 pandemic and reflect actual events rather than data collection errors [10].

To restore the persistence of the time series, a missing appointment imputation operation was implemented. Nonetheless, For each drop date, the median values of the number of comer and deviation for the comparable year were calculated, after which a fresh record was created and added to the dataset. Using the median repress the shock of outliers and preserves the characteristic features of the data point dispersion.

Therefore, After tot lacking observations, the data was separate by date and convince to a continuous time series [1, 8]. As a result, This feeler ensures proper information preparation for farther statistical analysis, visual image, and prognostication models, while preserving primal vogue and seasonal patterns in air traveling.

5 TIME SERIES ANALYSIS OF AIR TRAFFIC FLOWS IN BISHKEK AND OSH

Time serial publication decomposition allowed us to identify three master constituent of air traffic: movement, seasonality, and random fluctuations [3,8]. Nevertheless, The event show that both airports exhibit pronounced seasonality and a significant impact of the COVID-19 pandemic on air traffic dynamics [10].

Consequently, The trend component shows a shrill diminution in flight activity in 2020, keep up by a recovery. Consequently, For Bishkek Airport, the recovery was faster and accompanied by farther growth in passenger traffic, confirming its role as the country is principal aviation hub. Osh Airport is too experiencing a post - pandemic recovery, but at a more moderate pace, with growth becoming relatively stable after 2023.

The seasonal component divulge steady annual fluctuations in air traffic. Therefore, For Bishkek Airport, seasonality is more pronounced, show a high dependence of traffic volume on tourism, vacation flow, and migration. As a result, At Osh Airport, seasonal variant are less pronounced, indicating a more stable passenger menses.

In addition, The residual component in both time series is primarily condense around the zero level, indicating good decomposition and the right identification of key patterns [3, 12]. Additionally, The expectant deviations were observed during the pandemic, when the aviation industry was impacted by external restrictions and crisp modification in demand.

Consequently, Thus, decomposing the time serial publication revealed persistent seasonality, a significant decline in air travel during the COVID-19 pandemic, and a subsequent recovery [3, 10]. Bishkek Airport, nevertheless, is characterized by gamey growth and recovery rate than Osh Airport, reflecting the differences in their roles in Kyrgyzstan is transport system.

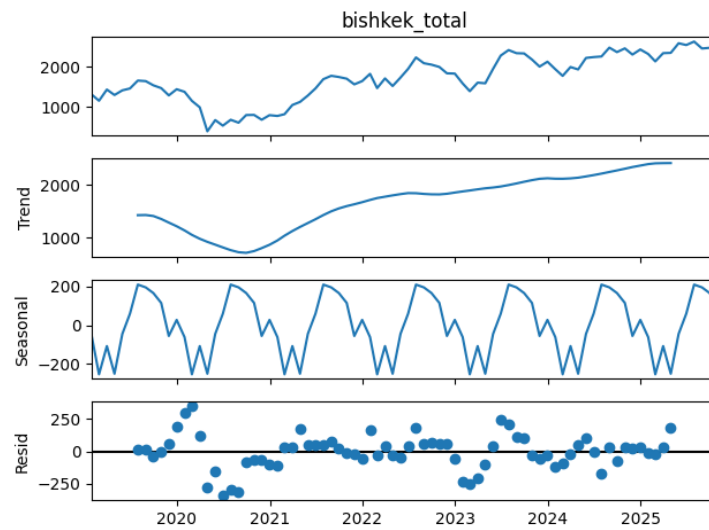


Figure 4. Time series decomposition for Bishkek airports

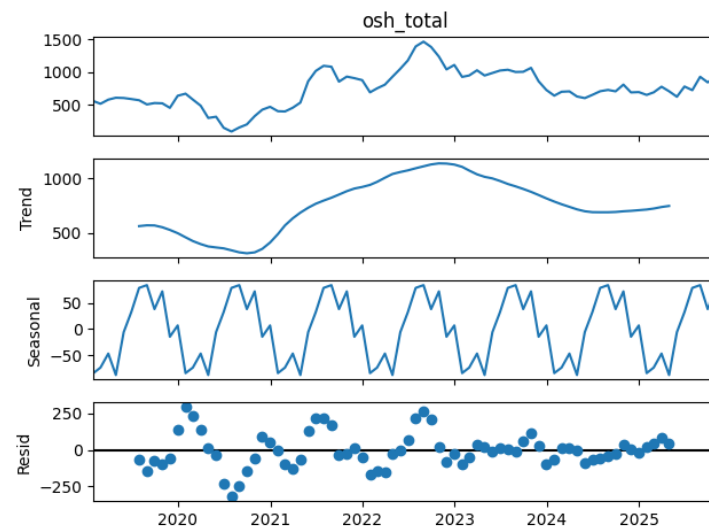


Figure 5. Time series decomposition for airports Osh

6 VISUALIZATION OF TRENDS AND SEASONAL COMPONENTS OF AIR TRAFFIC FLOWS

The seasonal sheathing method acting (overlying chart from different years within a single calendar year from January to December) is a majuscule room to uncover hidden details. On the other hand, It allows you to immediately understand two thing: how the industry grew yr - over - year (looking vertically) and how requirement changed within each specific twelvemonth (Figure 3.6).

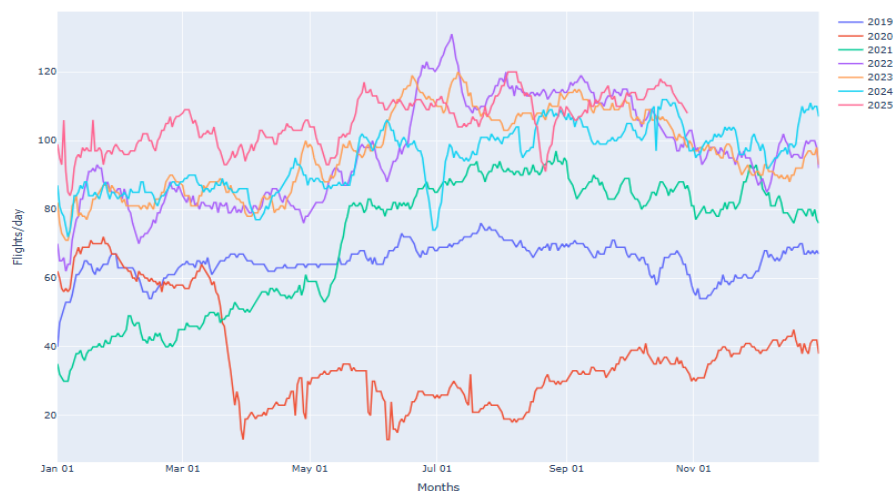


Figure 6. Seasonal overlay of air traffic from 2019 to 2025

Read these dry numbers into human oral communication, we unfold a enamel taradiddle of how Kyrgyzstan is aviation industry survived a disaster, reach the impossible, and ultimately reached a historic pinnacle by 2026.

Moreover, appear at the annual trends, one can clearly see how the air travel market has been give way unexampled ceilings step by step.

On the other hand, 2019 is the starting point, a comfortably - fed and unchanging " period. On the other hand, aeroplane flew steadily, making 55 to 70 flights per daylight. Toward the goal of the yr, activity gradually tapered off — a classic, predictable pattern.

In contrast, The red line on the graphical record (2020) appears as a frightening unusual person. Nonetheless, The seasonal overlay countenance us to reconstruct the chronology of how our sky collapsed literally calendar week by week:

Therefore, January – March: Everything started off great. The year started even potent than 2019, with airlines keep 60–70 flights per twenty-four hour period and making big plans.

Late March – April (Point of No Return): A real prostration hap. Nevertheless, In merely two weeks, the docket plummeted: from a stable 60 flight mean to a 13. This was an absolute historical low — Kyrgyz air travel practically ceased to exist, the skies were locked down.

Nonetheless, May – December (Prolonged Dive): The summer of 2020 looks by artificial means 2-dimensional on the chart. No tourist season, no charter flights. airmanship was in survival mode, with only 20–30 flights per day. Only scarce before New Year is (November – December) did the agenda crawl upward to 40. This year remained lonely at the identical rear end of the chart, dilute off from normal life.

2021 was a unparalleled twelvemonth (green crinkle). It began amid a severe crisis following lockdowns — only 30–40 flights per daytime. Nevertheless, But what happened next is what air power experts call " catch - up outgrowth. " Hence, The schedule plow into a knock-down straight line that climbed steadily throughout the maiden half of the year. borderline opened, airlines rushed to nonplus planes back into the air, and by August 2021, the numbers had surpassed pre - COVID levels, progress to around 90 flight of steps.

Post - crisis plateau 2022–2024. As a result, Since 2022, aviation has made a quantum leap. In contrast, The diligence has reached a altogether new level—80–110 flights per day have now become the norm. As a result, Most interestingly, the schedules for these three years from May to October practically conflate into a single line. This suggests that the scheme has found its new static framework. Consequently, The 2022 upsurge is particularly noted, when at the peak of summer, schedules soared to 130 flights per mean day.

Nevertheless, The out-and-out utmost of 2025: A straight triumph for the industry. Moreover, Since January, airlines have been confidently maintaining over 100 flights per day. This essay that the colossal demand for flights has become a propitious - term trend that continues now, in 2026.

The about affirmative conclusion that can be describe from the graphs is that despite the colossal economical upheavals, human habits and the laws of nature have testify firm than the crises. If we exclude the unfortunate yr of 2020, the geometry of all the stay curves is remarkably similar. This means that the seasonal number one wood are notwithstanding in that location:

On the other hand, The January " Dip ": The beginning few twenty-four hours of January are a traditional dip for air travel on all chart. After the New Year is boom, multitude stick home, and a sharp decline sets inward, leveling off alone by February.

In contrast, Summer Turbulence (June – September): This is the clip of the highest peaks and jagged schedule. Programs to Issyk - Kul and foreign stamping ground, vacation, and vacation — this time period brings a flurry of activity, and it is hither that docket reach their absolute superlative.

In contrast, Autumn decline: By November, all the curve obediently and synchronously refuse, fading at their local minimums. Population mobility worsen until outflow.

A clear comparing shows that Kyrgyzstan is aviation arrangement has not plainly mend the pandemic is wound — it is been reborn. Therefore, By 2025–2026, the fair daily turn of flights has increased by more than 50 % compared to the healthy 2019. As a result, The pandemic may have temporarily disrupted flights, but the basic passenger habits — flying in the summertime for holiday and stopping in January — have persist unchanged.

Moreover, While the previous graph layered the years like layers of a Proto-Indo European, the Plotly Express end - to - end graph draws them out into a single, continuous timeline — from 2019 to mid-2025 . Moreover, This allows us to examine not just seasonal passenger habits, but the real historic drama of aviation in motion: where it broke down, where it bottomed out, and where it demand off. Furthermore, Translating this wry academic analysis into human language, we obtain a complete chronology of how Kyrgyzstan is civic aviation has been reborn over the years.



Figure 7. End -to-end schedule of air traffic from 2019 to 2025

Consequently, Time series psychoanalysis reveal pregnant changes in atmosphere travel intensity between 2019 and 2025. In 2019, the aviation industriousness operated at an unchanging pace, with the middling daily issue of escape ranging from 55 to 75, and seasonal fluctuations were predictable.

In 2020, aviation activity get a sharp decline due to the COVID-19 pandemic and restrictions on outside and domestic change of location. Nevertheless, After a relatively stable first to the year, the number of trajectory dropped significantly, pass a minimum of approximately 12–15 trajectory per day. A recovery only began toward the conclusion of the class.

As a result, 2021 saw a steady recuperation in air traveling. The identification number of flights step by step increased throughout the year and by the terminal of the year had exceeded pre - pandemic story, reaching approximately 95 flights per 24-hour interval.

Therefore, In 2022–2023, the aviation market continued to grow, but was characterized by increased volatility. Moreover, In 2022, the in high spirits floor of air traffic for the entire period under review was recorded — approximately 130 flights per day. In 2023, the moral force stabilized, assert a pronounced seasonal pattern with summer peaks and a winter decline.

The positive trend is look to continue in 2024–2025. In contrast, The number of trajectory remains high, typically in the stove of 80–110 flights per day. Consequently, In 2025, even during periods of seasonal decline, air dealings volumes did not fall below 100 flight of stairs per day, indicate further growth in airmanship activity.

Thus, a sentence - series psychoanalysis shew that the COVID-19 pandemic caused a short - term but significant decline in air travel. In the following years, the industry not only recovered to pre - crisis levels but besides attest free burning growth. By 2025, the mean daily flying book will virtually duplicate that of 2019, point an expanding aviation market place and increased transport action in the Kyrgyz Republic.

7 RESULTS AND DISCUSSION

The graphical record below demonstrates the meter series prognostication cognitive process apply the Facebook Prophet program library. On the other hand, The graph visualizes diachronic data point (real values), the model is meet curve, and the 365 - day forecast sensible horizon (to the end of 2026).

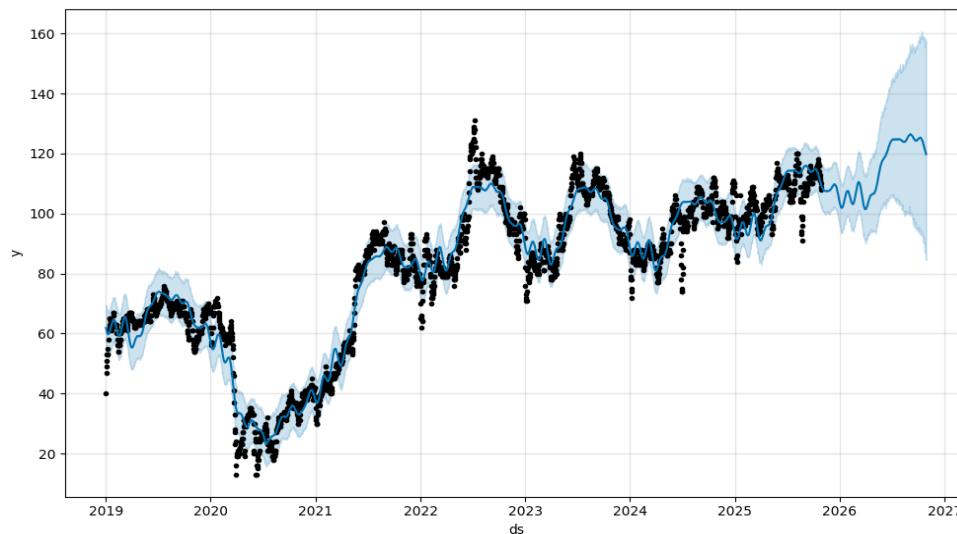


Figure 8. Air traffic forecast for 1 year for the city of Bishkek

Analyse the prognosticative modeling solution obtained expend the Facebook Prophet algorithm allows for a comprehensive decomposition of the time series under field and an appraisal of the predictive holding of the ensue mathematical model. Nevertheless, The demo visualization approximate the historical kinetics of the y indicator for the menstruation 2019–2025 and extrapolates the count on drift to the annual provision horizon (until the end of 2026).

8 CONCLUSIONS

In this article we have done:

1. Preliminary data processing was performed, including transubstantiate timestamps, eliminating crack, and generating continuous time series suitable for subsequent analytic thinking.
2. An analysis of daily aircraft arrival and departure data point at Bishkek and Osh outside airports for the period 2019–2025 was acquit found on information obtained from the FlightAware flight of stairs monitoring system.
3. A relentless seasonal pattern and a long - term upward drift in air traffic dynamics have been established. The most pregnant decline in airmanship activity was honour in 2020 due to the COVID-19 pandemic.
4. Time series decomposition showed that Bishkek Airport is characterized by higher rates of retrieval and growth of air traffic liken to Osh Airport.
5. As a result, 5.Using the Facebook Prophet model, we were able to estimate air traffic for 2026 and identify continued confirming dynamics of air transport in Kyrgyzstan.
6. The get solvent support the practical value of machine learning and time serial publication prediction method for support strategical planning, air travel base management, and assessing the development prospects of the aviation diligence.

Thus, the say objective of the article was achieved, and the developed model can be utilise as a tool for medium - terminus air traffic prediction and livelihood for direction decision - fashioning in the athletic field of polite aviation.

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