Efficient Use of Natural Tourism Resources Within Sustainable Tourism Along the Silk Road: Forecasting Tourist Flows in Uzbekistan Based on the ARIMA Model

Bahodirhon Safarov[1,2], Mansurova Nargiza[2(✉)], and Mustafokhon Toshkhujaev[3]

[1] Samarkand Branch of Tashkent State University of Economics, Samarkand 140147, Uzbekistan

[2] "Silk Road" International University of Tourism and Cultural Heritage, Samarkand 140104, Uzbekistan

n.sh.mansurova@gmail.com

[3] Samarkand State University named after Sharof Rashidov, Samarkand 140104, Uzbekistan

Abstract. This study evaluates the efficiency of natural tourism resource use in Uzbekistan from the perspective of sustainable tourism development. The central premise of the research is that the dynamics of tourist flows reflect not only the overall scale of tourism activity, but also, indirectly, the level of utilization and economic significance of natural tourism resources. For this purpose, the total number of tourists was analyzed using annual time-series data for the period 2010–2024. This indicator was constructed as the sum of domestic tourists and inbound foreign visitors. To identify the future dynamics of tourist flows, the AutoRegressive Integrated Moving Average (ARIMA) model was employed. The Dickey–Fuller test confirmed that the series became stationary after second differencing. Based on the analysis of autocorrelation and partial autocorrelation functions, as well as the Akaike and Bayesian information criteria, the ARIMA(1,2,1) specification was selected as the most appropriate model. The findings demonstrate the growing economic importance of tourism based on natural tourism resources in Uzbekistan. At the same time, the projected increase in tourist flows implies a higher intensity of resource use, which makes rational management, stronger environmental monitoring, and scientifically grounded regional tourism planning increasingly necessary. The study substantiates tourist-flow forecasting as an important analytical instrument for assessing the efficiency of natural tourism resource use and for shaping sustainable tourism policy.

Keywords: Natural tourism resources · sustainable tourism · tourism demand forecasting · ARIMA model · resource efficiency

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1 Introduction

Contemporary global development trends demonstrate that tourism has emerged as one of the fastest-growing sectors of the world economy. At the same time, the long-term sustainable growth of the tourism industry largely depends on the extent to which natural tourism resources are utilized in a rational and efficient manner. Natural landscapes, climatic conditions, water resources, mountainous areas, and protected natural sites constitute the principal sources of tourist attractiveness in many destinations. According to the World Tourism Organization (UN Tourism), in 2024 the tourism sector generated an additional 27.4 million new jobs, supporting approximately 348 million jobs worldwide; furthermore, 1.4 billion international tourist arrivals were recorded globally, while tourism export revenues reached USD 1.9 trillion [1]. In this context, tourism's contribution to gross domestic product (GDP) amounted to USD 11.1 trillion in 2024, representing 10% of global GDP [2].

At present, within the framework of sustainable tourism development, scholarly research aimed at improving the economic mechanisms for the efficient use of natural tourism resources is expanding steadily. These studies place particular emphasis on assessing the condition of such resources, determining the efficiency of their use for tourism purposes, conducting comparative analyses of the experiences of different regions, and modeling and forecasting possible scenarios for tourism development. This demonstrates that the significance of statistical analysis and economic–mathematical modeling methods is continuously increasing in the study of tourism based on natural resources [3, 4].

In Uzbekistan, the development of a green economy, the promotion of environmental sustainability, and the rational use of existing natural resources are being identified as key priorities of state policy. This priority further reinforces the need, within the tourism sector, to develop economic mechanisms that comply with environmental requirements, improve methods for their assessment and monitoring, and foster the establishment of sustainable tourism infrastructure in the regions. In particular, the scientifically grounded assessment of the scale of natural resource use in tourist areas, the determination of the efficiency of such use, and the forecasting of future development trends through econometric methods are of crucial importance for the effective management of sustainable tourism.

From this perspective, the purpose of the present study is to reveal the economic essence of the efficiency of natural tourism resource use in Uzbekistan, to forecast the dynamics of the total number of tourists on the basis of the ARIMA model, and, based on the results obtained, to develop practical proposals and recommendations for the advancement of sustainable tourism. To achieve this objective, theoretical and methodological approaches to natural tourism resources are analyzed, the temporal dynamics of tourist flows are examined, an econometric forecasting model is applied, and scientific as well as practical conclusions are formulated on the basis of the findings. Such an approach makes it possible to provide a deeper assessment of the economic efficiency of natural tourism resource use, improve the quality of strategic decision-making in the tourism sector, and ensure sustainable tourism development at the regional level [5].

2 Literature Review

The sustainable development of the tourism sector largely depends on the availability of existing resources, particularly natural tourism resources. In many regions, unique natural landscapes, mountain air, therapeutic water sources, and protected natural sites constitute the principal factors attracting tourist flows. For this reason, natural tourism resources are regarded not only as the resource base of tourism, but also as a factor stimulating regional economic activity.

In the scholarly literature, the concept of "natural tourism resources" has been interpreted in different ways. In particular, Horun Ar Rashid defines these resources as natural factors that attract tourists to a specific area and includes within their composition geomorphological, climatic, hydrographic, and biogeographical resources, as well as protected natural heritage sites [6]. Other approaches interpret natural tourism resources as a set of natural factors that are not created by humans, exist in nature, and are suitable for use in tourism activities. In the present study, this concept is understood as a system of natural factors that shape tourist attractiveness and exert a direct or indirect influence on tourist flows [7]. P.K. Thornton and co-authors emphasize that problems related to the management of natural tourism resources and the environment are particularly pronounced in low-income countries [8]. In their view, this situation arises from the interrelationship of economic, social, and institutional problems. Natural resources constitute an important source of livelihood for such countries, and their improper management may lead to ecological imbalance and pose a threat to long-term sustainability. This approach is also highly relevant in the context of Uzbekistan, since many forms of tourism are directly based on the use of natural resources [9]. D.A. Ruban defines natural landscape elements that are considered valuable for tourism and attractive to visitors as tourism-related natural resources. He identifies geomorphological, geological, hydrological, and biological resources as the main components of this category [10]. This approach makes it possible to assess natural tourism resources not merely as aesthetic or recreational objects, but also as the material foundation of tourism development.

The analyzed studies primarily focus on the territorial distribution of natural resources, the factors enhancing tourist attractiveness, the innovative development of the tourism sector, the improvement of infrastructure, and issues of economic management [11]. At the same time, certain attention has also been paid to the influence of natural resources on tourism potential, the economic aspects of their sustainable use, and the territorial organization of tourism. It should be particularly emphasized that the existing studies provide an important scientific and methodological foundation for the development of the sector. However, in the context of Uzbekistan, the issue of comprehensively assessing the economic mechanism for the efficient use of natural tourism resources in relation to the future dynamics of tourist flows has not been sufficiently explored empirically [12, 13]. In particular, limited attention has been given to approaches that treat the total number of tourists as an integral indicator of the effectiveness of natural resource use, forecast it on the basis of time-series analysis, and, on this basis, assess the potential pressure exerted on resources.

3 Materials and Methods

This study employed annual time-series data covering the period from 2010 to 2024. The total number of tourists in Uzbekistan was selected as the main variable of analysis. This indicator was calculated as the sum of domestic tourists and inbound foreign tourists. Such an approach provides a more comprehensive assessment of the country's tourism potential, as tourism development is determined by the combined effects of both domestic and international tourist activity.

To evaluate the future dynamics of tourist flows, the AutoRegressive Integrated Moving Average (ARIMA) model was applied. This model is widely used in time-series forecasting because it captures the internal structure of a variable through its trend, autocorrelation pattern, and random disturbances. In the present study, the ARIMA approach was considered appropriate because the objective was to forecast the total number of tourists on the basis of its historical dynamics without explicitly incorporating exogenous explanatory variables. In this respect, the model makes it possible to identify and project the underlying temporal movement of tourist flows on the basis of their own stochastic structure.

In general form, the ARIMA model can be expressed as *ARIMA*(*p,d,q*), where p denotes the autoregressive order, d the degree of differencing, and q the moving average order. The general specification of the model is given as follows:

$$\Delta^2 Y_t = c + \sum_{i=1}^{p} \phi_i \Delta^2 Y_{t-1} + \sum_{j=1}^{q} \theta_j \varepsilon_{t-j} + \varepsilon_t \quad (1)$$

where Y_t -is the total number of tourists in period tc is a constant term,

ϕ_i represents autoregressive coefficients, θ_j denotes moving average coefficients, and ε_t is the random error term. This approach allows modeling the stochastic nature of tourist flows while accounting for the serial dependence of the data series.

Theoretically, the ARIMA methodology is based on the Box–Jenkins approach, which consists of three main components: autoregression (AR), integration (I), and moving average (MA). The autoregression element expresses the dependence of the current value on its previous values. The integration part eliminates the non-stationarity of the series by differentiation. The moving average component reflects the influence of random errors in previous periods on the current value. It is precisely because of these features that the ARIMA model is particularly convenient for forecasting tourism indicators characterized by stable continuity, structural fluctuations, and non-stationary time-series behavior.

Before evaluating the model, the stationarity of the series was checked using the Dickey–Fuller test. The analysis showed that the total number of tourists was initially non-stationary: the test statistic was −0.254, and the p-value was 0.9318. The series did not reach a stationary state even after first-order differentiation, with the test statistic equal to −2.444 and the p-value equal to 0.1296. However, after second-order differentiation, the series reached a stationary state. This is confirmed by the test statistic being −3.108 and the p-value being 0.0259. Therefore, the integration level in the model was assumed to be d = 2. The second-order differentiation process is expressed as follows:

$$\Delta^2 Y_t = Y_t - 2Y_{t-1} + Y_{t-2} \quad (2)$$

This transformation was necessary to eliminate the trend component and stabilize the mean of the series prior to forecasting.

After the series was stationary, the autoregressive and moving-average orders of the model were determined from the autocorrelation function (ACF) and partial autocorrelation function (PACF) plots of the second-order differentiated series. The ACF plot showed significant peaks at the first and second lags, suggesting that q = 1 or q = 2 might be appropriate. Similarly, the PACF plot showed significant partial autocorrelations at the first and second lags, suggesting that p = 1 or p = 2 might be appropriate. On this basis, several alternative ARIMA models were evaluated. In this case, different combinations of model parameters were tested, and values of 0, 1, and 2 were obtained for the indicators p and q.

The final model was selected using the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC), which are commonly employed to identify the most parsimonious specification with the best statistical fit. Among the estimated alternatives, the ARIMA(1,2,1) model produced the lowest information criterion values (*AIC = 268.241; BIC = 270.50*) and was therefore selected as the optimal forecasting model. The estimated form of the selected specification can be written as:

$$\Delta^2 Y_t = c + \phi_1 \Delta^2 Y_{t-1} + \theta_1 \varepsilon_{t-1} + \varepsilon_t \tag{3}$$

The estimated coefficients of the selected model further confirmed its empirical adequacy. In particular, the constant term was estimated at 300.479 ($p = 0.4939$), the autoregressive coefficient θ_1 at 0.317733 ($p = 0.2491$), and the moving average coefficient θ_1 at −0.999998 ($p < 0.0001$). The statistical significance of the moving average term indicates that short-term shocks play an important role in shaping changes in the differenced tourist series. In addition, the model exhibited acceptable goodness-of-fit characteristics, including R2 = 0.664833, adjusted R2 = 0.634364, and a log-likelihood value of −130.1206.

To assess the adequacy of the selected model, additional diagnostic tests were performed on the residual terms. First, the ARCH test was used to determine whether the residuals were heteroskedastic. According to the test result, the statistical indicator was 0.384078, and the corresponding p-value was 0.535429. Since this value was higher than the 5% significance level, the null hypothesis of the absence of the ARCH effect was not rejected. This means that the residual variance remained stable over time.

Then, the Breusch–Godfrey LM test was performed to determine the presence of autocorrelation in the residuals up to the third lag. The test statistic was 5.23675, indicating no statistically significant autocorrelation in the residuals. In general, these diagnostic tests confirm that the ARIMA(1,2,1) model is sufficiently suitable from an econometric perspective and for forecasting. Based on the evaluated ARIMA(1,2,1) model, forecast values for the total number of tourists in Uzbekistan for 2025–2030 were calculated. During the forecasting process, not only expected values, but also standard errors and 95% confidence intervals were determined. This allowed us to assess the likely future direction of tourist flows and indicate the level of uncertainty associated with the forecast results. Model evaluation, selection of the most optimal option, diagnostic tests and forecast calculations were all carried out using the Gretl statistical program.

The forecast results allow us to empirically assess the expected growth in tourist flows in Uzbekistan and anticipate potential pressure on natural tourist resources. In

this regard, this model is not only a forecasting tool but also an important analytical instrument for developing strategic decisions on sustainable tourism development, the rational use of resources, and the long-term management of tourism growth.

4 Results

4.1 Dynamics of Tourist Flows in Uzbekistan

The dynamics of tourist flows in Uzbekistan during 2010–2024 showed a steady growth trend in both domestic and foreign tourism (Fig. 1). In 2010, the number of domestic tourists was 2,065 thousand, and the number of foreign tourists visiting the country was 741 thousand. During the study period, domestic tourism, in particular, developed at a relatively rapid pace. In particular, by 2013, the number of domestic tourists reached 6,564 thousand, indicating the growing role of domestic tourism in the country's tourism development.

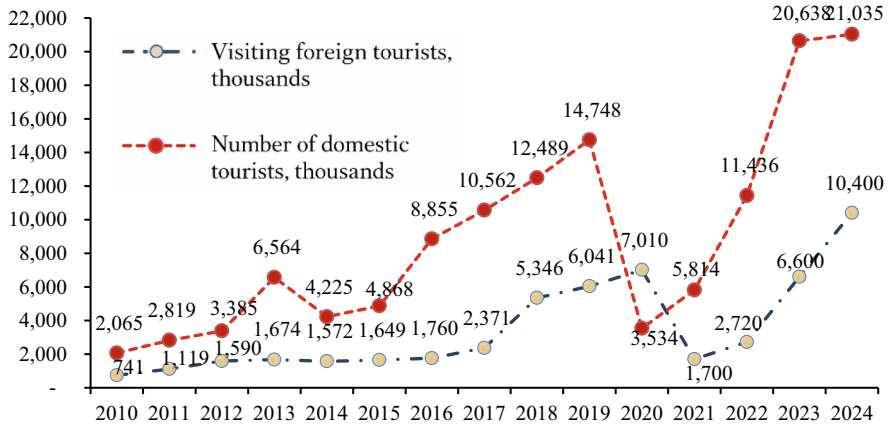

Fig. 1. Dynamics of domestic and foreign tourist flows in Uzbekistan, 2010–2024.

In particular, a significant increase was observed in 2016–2019. During this period, natural resource-based tourism, including ecological, mountain, and agrotourism, developed more actively. Despite a temporary decline during the pandemic years, demand for tourism related to natural areas remained stable and entered a clear recovery phase in 2021–2024. By 2024, the number of domestic tourists exceeded 21 million, while the number of foreign tourists surpassed 10 million. These patterns indicate that tourist activity in Uzbekistan has regained momentum and continues to expand in the post-pandemic period.

4.2 Stationarity of the Tourist Series

Before estimating the forecasting model, the stationarity of the total number of tourists was examined using the Dickey–Fuller test [14, 15]. The results are presented in Table 1.

As shown, the tourist series was non-stationary in its level form, with a test statistic of −0.254 and a p-value of 0.9318. The first-differenced series also remained non-stationary, as indicated by a test statistic of −2.444 and a *p*-value of 0.1296. However, after second differencing, the series became stationary, with a test statistic of −3.108 and a p-value of 0.0259. These results justify the specification of the integration order as $d = 2d$ in the ARIMA framework.

Table 1. Dickey–Fuller test results for the stationarity of the total number of tourists

Variable	Test statistic	Critical value (5%)	p-value	Conclusion
TurSoni	−0.254	−3.000	0.9318	Non-stationary, I(0)
d_TurSoni	−2.444	−3.000	0.1296	Non-stationary, I(1)
d2_TurSoni	−3.108	−3.000	0.0259	Stationary, I(2)

Following the results of the stationarity test, the tourist series was transformed through second differencing, and the forecasting model was subsequently estimated on the stationary series.

4.3 Identification and Selection of the ARIMA Model

The identification of the autoregressive and moving average orders was based on the analysis of the autocorrelation function (ACF) and partial autocorrelation function (PACF) of the second-differenced tourist series (Figs. 2 and 3). The ACF plot exhibited notable spikes at the first and second lags, suggesting plausible values of q = 1or q = 2q. Similarly, the PACF plot displayed significant spikes at the first and second lags, indicating that p = 1p 2p = 2 could be considered appropriate. On this basis, several candidate ARIMA(p,2,q) specifications were estimated in the Gretl statistical software package, where $p \in \{0, 1, 2\}$ and $q \in \{0, 1, 2\}$. Model selection was carried out using the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC). Among the alternative specifications, the ARIMA(1,2,1) model yielded the lowest information criterion values (AIC = 268.241; BIC = 270.50), and was therefore selected as the optimal model for forecasting the total number of tourists.

4.4 Estimation Results of the ARIMA(1,2,1) Model

The estimation results of the selected ARIMA(1,2,1) model are reported in Table 2. The coefficient of the moving average term ($\theta_1 = -0.999998$) was found to be highly statistically significant ($p < 0.0001$), while the constant and autoregressive coefficients were not statistically significant at conventional levels. This suggests that short-term shocks and error-adjustment effects play an important role in explaining the dynamics of the differenced tourist series.

The model also demonstrated satisfactory statistical properties. In particular, the coefficient of determination reached $R2 = 0.664833$, while the adjusted R^2 amounted

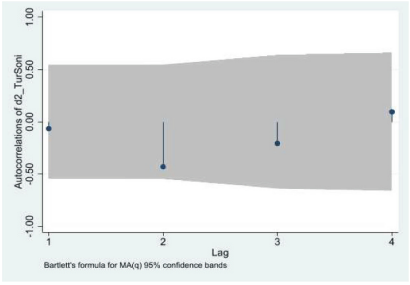

Fig. 2. Autocorrelation function (ACF) of the second-differenced series of the total number of tourists

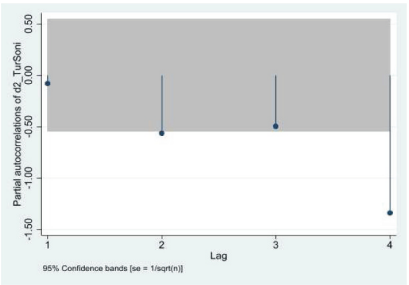

Fig. 3. Partial autocorrelation function (PACF) of the second-differenced series of the total number of tourists

to 0.634364. The log-likelihood value was estimated at -130.1206. These results indicate that the selected model captures a substantial proportion of the variation in the transformed series and is suitable for forecasting purposes.

Table 2. Estimation results of the ARIMA(1,2,1) model for the total number of tourists

	Coefficient	*Std. Error*	*z*	*p-value*	
const	300.479	439.179	0.6842	0.4939	
phi_1	0.317733	0.275709	1.152	0.2491	
theta_1	−0.999998	0.204465	−4.891	<0.0001	***
Mean dependent var	235.7769		S.D. dependent var	6532.384	
Mean of innovations	−228.2626		S.D. of innovations	4972.484	
R-squared	0.664833		Adjusted R-squared	0.634364	
Log-likelihood	−130.1206		Akaike criterion	268.2411	
Schwarz criterion	270.5009		Hannan-Quinn	267.7767	

4.5 Residual Diagnostic Results

To evaluate the adequacy of the estimated ARIMA(1,2,1) model, additional residual diagnostic tests were conducted. First, an ARCH test of order one was applied to detect possible heteroskedasticity. The test statistic was 0.384078, with a corresponding p-value of 0.535429. Since this value exceeds the 5% significance level, the null hypothesis of no ARCH effects cannot be rejected, indicating that the residual variance remains stable over time.

Second, the Breusch–Godfrey LM test was performed to assess the presence of residual autocorrelation up to the third lag. The test statistic amounted to 5.23675. On this basis, no substantial residual autocorrelation was identified in the model residuals. Taken together, the diagnostic results confirm that the selected ARIMA(1,2,1) specification is econometrically adequate and statistically reliable for forecasting the future dynamics of tourist flows (Table 3).

Table 3. Residual diagnostic test results for the ARIMA(1,2,1) model

Diagnostic test	Test statistic	p-value	Conclusion
ARCH test (lag 1)	0.384078	0.535429	No heteroskedasticity detected
Breusch–Godfrey LM test (up to lag 3)	5.23675	n/a	No substantial residual autocorrelation detected

4.6 Forecast Results for 2025–2030

Based on the estimated ARIMA(1,2,1) model, forecast values for the total number of tourists in Uzbekistan for 2025–2030 were calculated. The forecast results, standard errors and 95% confidence intervals are presented in Table 4, while the forecast direction is depicted in Fig. 4. The results obtained indicate that a stable growth trend in tourist flows will be maintained throughout the forecast period.

More specifically, the total number of tourists in Uzbekistan is expected to reach 35,922.4 thousand in 2025. The 95% confidence interval for this indicator is from 26,176.5 thousand to 45,668.3 thousand. The growth trend will continue in the following years. In particular, by 2030, the forecast value is expected to reach 62,843.8 thousand people, with a 95% confidence interval of 30,326.8 thousand to 95,360.9 thousand people. In subsequent years, the expansion of the confidence interval indicates that uncertainty increases as the forecast period lengthens. This is typical for medium-term time series forecasts.

The indicators of forecast quality also confirm the model's practical usefulness. In particular, the Mean Error was −228.26, the Root Mean Squared Error (RMSE) was 4972.5, and the Mean Absolute Error (MAE) was 3437.2. Also, the Mean Absolute Percentage Error (MAPE) was 29.221, and the Theil's U statistic was 0.7946. These results show that the ARIMA(1,2,1) model is a sufficiently robust and acceptable tool for forecasting the total number of tourists in Uzbekistan in the medium term.

Table 4. Forecast values of the total number of tourists in Uzbekistan for 2026–2030

Year	Forecast value	Standard error	95% confidence interval
2026	40706.8	8225.55	24585.0–56828.6
2027	45790.7	10836.3	24552.0–67029.4
2028	51174.7	13017.9	25660.1–76689.3
2029	56859.0	14907.7	27640.4–86077.6
2030	62843.8	16590.6	30326.8–95360.9

Note: *Mean Error = -228.26; Root Mean Squared Error (RMSE) = 4972.5; Mean Absolute Error (MAE) = 3437.2; Mean Percentage Error (MPE) = -8.6905; Mean Absolute Percentage Error (MAPE) = 29.221; Theil's UUU statistic = 0.7946; Bias proportion (UM) = 0.0021; Regression proportion (UR) = 0.1181; Disturbance proportion (UD) = 0.8798.*

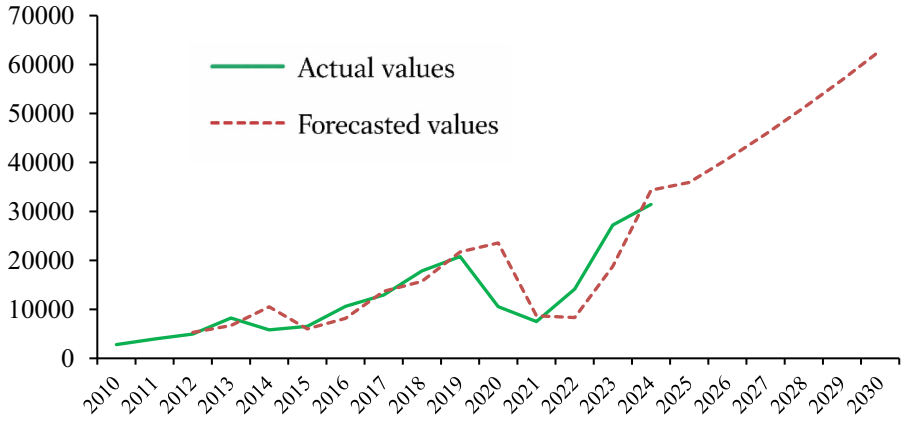

Fig. 4. Forecast trajectory of the total number of tourists based on the ARIMA(1,2,1) model.

Overall, the forecast results indicate that the total number of tourists in Uzbekistan will continue to grow steadily in the medium term. The most reliable forecast intervals fall in the near future, especially 2026–2027. The range of uncertainty increases as the forecast period lengthens. Nevertheless, the central forecast indicators indicate that tourist flows will continue to grow consistently in all years.

5 Discussion

The study's results show that the total number of tourists in Uzbekistan will continue to grow over the forecast period. This means that the demand for tourism in the country will remain high in the medium term. In the context of this study, this growth not only reflects the expansion of the tourism sector but also indicates the growing economic importance of natural tourist resources. Since a significant part of tourist activity in Uzbekistan is directly related to mountainous areas, protected natural areas, ecological destinations and other nature-based tourism objects [16].

The results obtained are consistent with previous scientific studies that emphasize that natural resources are among the main factors in tourism development [17, 18]. In previous empirical stages of the study, it was found that indicators directly related to natural resources, particularly protected areas and environmental sustainability factors, have a positive, statistically significant impact on tourist flows [8, 19–21]. In this regard, this forecast based on the ARIMA model does not contradict previous conclusions, but rather complements them. That is, it indicates that the growth trend in the number of tourists is likely to continue in the coming years.

Another important aspect of the study is that the projected increase in tourist flows has a dual meaning. On the one hand, this situation creates opportunities to increase tourism revenues, expand employment, and strengthen regional economic activity [22]. On the other hand, it means that the intensity of use of natural tourist resources may also increase. This is especially important for regions with limited ecological capacity. Since in such places, an increase in tourist numbers can put greater pressure on natural landscapes and recreational infrastructure. Therefore, the projected growth in the number

of tourists should be interpreted not only as a positive economic indicator but also as a signal of the need for more balanced resource management.

The fact that the selected ARIMA(1,2,1) model provides statistically acceptable results further strengthens the analytical significance of the forecast. The absence of significant heteroscedasticity and significant autocorrelation in the model residuals confirms its reliability as a basis for medium-term forecasting. At the same time, the widening of the confidence interval in the later years of the forecast period indicates an increase in uncertainty over time. This is a natural setting for time-series forecasting. Nevertheless, the forecast remains stable, indicating that tourist activity will continue to grow in the future.

Another important aspect is the clear reflection of the post-pandemic recovery process in the time series. After the decline observed during the pandemic, the flow of tourists has begun to recover and has entered a phase of stable growth. This indicates that the demand for tourism in Uzbekistan, including interest in natural and recreational destinations, is relatively stable. Therefore, the forecast results can be viewed as additional evidence that natural resource-based tourism will continue to play an important role in the country's long-term tourism development.

Overall, the results of the study suggest that forecasting the total number of tourists can serve as an important analytical tool for assessing the efficiency of future use of natural tourist resources [18, 23]. In this sense, the expected growth in tourist flows provides an important empirical basis for improving the tourism planning system, strengthening environmental control, and ensuring a more sustainable balance between tourism expansion and natural resource conservation.

6 Conclusion

This study shows the need to assess the effective use of natural tourist resources in Uzbekistan not only as an environmental or territorial issue, but also as an important economic factor directly affecting tourism development. The forecast results from the ARIMA(1,2,1) model confirm that the total number of tourists will steadily increase in the medium term. This means that demand for tourism in the country will continue to expand, and the role of natural resource-based tourism in the national tourism system will further strengthen.

One of the important conclusions of the study is that the growth of tourist flows simultaneously creates economic opportunities and exacerbates resource management problems. On the one hand, an increase in the number of tourists contributes to higher tourism revenues, expanded employment, and increased regional economic activity. On the other hand, this process further increases the pressure on natural tourist resources, especially in ecologically sensitive and attractive regions. Therefore, tourism development policy should not be limited to economic priorities, but should also be based on the principles of environmental sustainability and the rational use of resources.

The results obtained show that forecasting tourist flows is not a simple auxiliary analytical method, but an important practical tool for effective management of sustainable tourism. Assessments based on forecast results provide a solid empirical basis for determining future tourist pressure, improving the efficiency of natural resource use,

enhancing regional tourism strategies, and strengthening the environmental monitoring system. In this sense, the research results provide a scientific and practical basis for ensuring a balanced approach between tourism growth and the preservation of natural tourist resources in Uzbekistan.

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