Research Article

From Black Box to Insights: XGBoost and SHAP for Interpretable Tourism Forecasting in Albania

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Abstract

This study proposes an interpreted machine learning framework for monthly forecasting of non-resident tourist arrivals in Albania, using the XGBoost algorithm in combination with SHAP. The model received training data from 2016 to 2024, which included time variables, lagged values and seasonal components to detect intricate tourist flow patterns. The evaluation results demonstrate strong predictive accuracy, and the SHAP analysis reveals how each feature affects the outcome by showing that time variables and historical values play the most influential roles. The analysis examined external factors, including gross domestic product (GDP) and exchange rates, but these variables had a lesser impact than the dominant seasonal and lagged data. The method provides both precise forecasting capabilities and clear interpretive insights, which makes it ideal for strategic market decisions in developing tourism sectors.

Keywords: tourism demand forecasting, XGBoost, SHAP, Interpretable machine learning, Time series, Albania.

1. Introduction

The process of predicting tourism demand remains a persistent challenge for decision-makers and destination managers, particularly in developing countries such as Albania, because they face restricted data availability and traditional models do not effectively handle tourism flow complexities. While tourism remains one of the most important sectors for economic development and employment, the need for more sophisticated and interpretive approaches to data analysis has become increasingly evident.

The development of artificial intelligence technology enables the creation of powerful and transparent predictive models which can process extensive data sets containing strong nonlinear patterns and seasonal elements. The practical application of these models in policymaking and strategic planning faces an essential challenge because of their interpretability needs.

This study aims to address this gap by integrating the XGBoost algorithm – known for its high performance in time regression tasks – with the interpretive SHAP analysis to provide not only an accurate predictive model but also a comprehensible framework of the impact of various factors on the flow of non-resident tourists in Albania. The proposed approach is based on official data for the period 2016–2024 and explores the role of temporal, seasonal and macroeconomic variables in the dynamics of tourist arrivals.

The research combines machine learning benefits with game theory interpretive capabilities to enhance tourism forecasting knowledge and provide useful guidance for tourism and regional development policymakers. The research design follows a specific structure to enable readers to understand both the theoretical and empirical components of the study.

First, section 1.1 discusses the contemporary developments and applications of AI in tourism, with particular emphasis on its role in demand forecasting and travel experience personalization. Then, section 2 provides a detailed description of the data used and the methodology for building the XGBoost model, including the data processing steps, parameter configuration, and the integration of SHAP interpretive analysis. Section 3 focuses on reviewing the existing literature supporting this approach, highlighting similar applications in different contexts, and highlighting the comparative advantages of the selected method. The practical results of the model implementation, along with their interpretation through performance metrics and SHAP values, are analyzed in section 4. The final section of the paper combines the research results with recommendations for additional studies to develop this method for strategic tourism planning in Albania and other countries.

1.1 Artificial Intelligence in Tourism

Artificial intelligence (AI) is a branch of computer science that creates algorithms and methodologies that equip various computer machines with human intelligence to perform functions and reasoning that are currently typical only of the human mind. Kumar and Thakur (2012) define artificial intelligence as an extraordinary testament to human ingenuity, effectively bringing together a multitude of disciplines, including philosophy, mathematics, computer science, psychology, and neuroscience. The concept of artificial intelligence was first used in the summer of 1956. Its first home can be considered the Dartmouth conference in the US, organized by scientists John McCarthy, Marvin Minsky, Nathaniel Rochester and Claude Shannon (Payette and Abdul-Nour, 2023). In 1960, research in the US was funded mainly by the Department of Defense, which established laboratories almost all over the globe. The founders of artificial intelligence hoped that AI would create machines that could do any work that a human could do, such as using natural language, learning, and solving problems. They and their students laid a solid foundation in this field by writing programs so that computers could solve various algebra problems or prove logical theorems that, at the time, seemed incredible to humans. John McCarthy defined AI as "the science and engineering of making intelligent machines". Due to technical challenges and slow progress in some aspects, a long period has been called the "winter of artificial intelligence", with no attention or investment in this field. Nowadays, attention has returned to this important field, where developments in technology and new ways of processing data have raised interest in the development of artificial intelligence again.

AI technology is rapidly transforming various sectors, including tourism, by enhancing customer service, improving operational efficiency, personalizing travel experiences, and supporting sustainability initiatives (Garcia-Madurga and Grillo-Mendez, 2023).

Artificial intelligence can have a significant impact on the labour market: it can create jobs, but at the same time, it is becoming a threat to many jobs, putting us in a dilemma of whether the development of AI is a good thing for humanity or an open threat (Liu, Jiang, Shi and Yang, 2024). Artificial and human intelligence can collaborate, supporting the potential for AI to augment and complement human capabilities, rather than replace them. This could potentially pave the way for a 'hybrid intelligence' ecosystem, where humans and AI collaboratively drive progress (Dellermann, Calma, Lipusch, Weber, Weigel and Ebel, 2019).

With the advancement of artificial intelligence in various fields, the academic community has shown a new interest in the impact of AI on the economy, especially in tourism. Applications of AI in the tourism industry extend to several points, such as:

➢ Using AI models for modelling and forecasting tourism demand, such as:
- Artificial Neuron Network (ANN, CNN, DNN, RNN);
- Gradient Boosting Machines (XGBoost, LightGBM, and CatBoost);
- Fuzzy;
- Facebook Prophet, etc.

➢ The use of intelligent robots to replace tasks performed by tourism staff such as hotel and restaurant robots, mobile navigation, information robots, marketing robots, entertainment robots and library robots, receptionists, doormen, valets, room assistants, bartenders, etc (Garcia-Madurga, Grillo-Mendez, 2023).

➢ Hotel IoT applications have a lot of potential to change and improve operations in the tourism industry. Some of these applications are:
- Smart Room Systems: Guests can use mobile devices to manage the temperature, lights, and electrical appliances in the room.
- Smart Cards: Cards with RFID or NFC technology allow secure and easy access to rooms and other parts of the hotel.
- LoT Security Cameras: The use of security cameras connected to the internet to monitor various hotel environments.
- Energy Sensors: Using sensors to monitor energy usage in hotel rooms and their common areas.

- Lighting and heating: The use of lighting and heating systems that automatically adapt to visitor demands and presence.
- Smart Devices: The use of Smart TVs and internet-connected audio devices to provide additional content and services to visitors.
- Furniture: Using connected kitchen equipment to monitor and control the cooking process and food preparation.

➢ Customized customer requests also have great potential.

- The AI-powered chatbots and virtual assistants function as little multilingual robots that answer customer questions
- Algorithms can analyze customer data to identify customers who are most likely to be interested in a particular travel package or destination and target them with personalized marketing messages (Garcia-Madurga, Grillo-Mendez, 2023).
- Contactless robot services as customer service without any physical contact. The situation requires immediate attention because the COVID-19 pandemic has made social distancing and contact reduction essential for virus containment. Examples of contactless robot services include self-check-in and check-out facilities, facial recognition systems, cleaning robots, and digital key services etc.
- The use of Virtual Reality (VR) allows customers to visually familiarize themselves with the hotel environment and facilities, but it can also provide substitutes for travel experiences by creating virtual experiences that simulate real-life travel experiences.

The use of Artificial Intelligence is not only a practical help for everyone but also affects the protection of the environment by reducing the rampant use of paper and, as a result, massive deforestation, minimizes waste and reduces the movement of cars with a consequence in air pollution. The other side of the coin is that not everyone can embrace its use; clients of different ages may prefer services provided by humans and hesitate to use technology as a result of the difficulty of use, uncertainty or the high cost that these services may have. All of this can lead to the failure of the technology implemented.

These tensions between the potential and acceptability of technology also appear in sectors such as tourism, where the use of advanced modelling to improve decision-making can bring significant benefits for sustainable management. In this context, our study focuses on the application of the XGBoost method, an artificial intelligence method, to model and predict tourist flows in Albania. More specifically, the following section presents the structure of the data used and the methodology for building the model.

2. Data Description and Methodology

This study uses monthly data on non-resident visitors to Albania provided by the Institute of Statistics of Albania (INSTAT), covering the period January 2016 to

December 2024. The data represent the total number of tourist arrivals in the country and are structured in the form of a univariate time series, serving as the basis for building the predictive model.

The number of non-resident visitors to Albania for the period 2016-2024 is reflected in the table below (Breshanaj, Stringa, 2025).

	2016	2017	2018	2019	2020	2021	2022	2023	2024
January	173534	172757	232338	209520	249461	185392	194237	377211	489599
February	169556	185721	190531	201597	228941	158173	200997	309325	480539
March	218858	243462	254020	283910	95321	170279	275976	384028	564975
April	285902	359452	351610	410060	12188	241015	402051	614256	794129
May	358484	360082	394869	401531	16389	328742	604430	705079	973688
June	394361	437820	496137	630334	179594	604381	876056	1007033	1244967
July	864718	864023	1028182	1176810	387716	1158962	1403333	1770724	1818378
August	1124615	1142198	1449952	1556826	575559	1537191	1710041	2022754	2167665
September	406582	459168	664184	591414	377033	494332	761544	1104190	1146090
October	302834	379327	337603	387152	206439	298712	365237	696825	761636
November	210377	256216	246678	268176	148362	244061	358350	547221	604332
December	225690	257474	280699	288708	180815	267409	391565	616994	654342

Table 1. Non-resident tourists in Albania for the period 2016-2024

We have presented a visual representation of these values in the interactive graph, where the increasing trend and seasonality of the data are clearly visible. The graphs were built in the R programming language with the help of the "plotly" package (Breshanaj, Stringa, 2025).

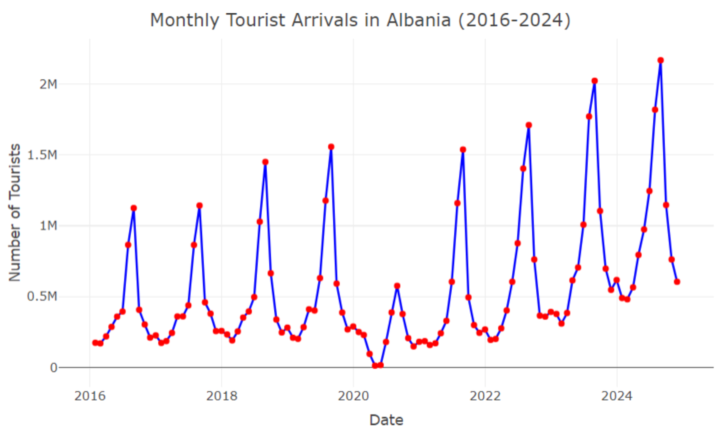

Figure 1. Number of non-resident tourists in Albania (2016-2024) https://rpubs.com/Breshanaj/1265708

In the pre-processing phase, the data were cleaned and transformed to improve the quality and robustness of the model. This included standardizing the date format, filling in missing values through interpolation, and constructing auxiliary variables such as month, year, and lagged values. The elements enable the detection of seasonal and temporal characteristics, which are crucial for tourism applications. The XGBoost algorithm was selected for modelling because it efficiently handles data with intricate temporal patterns. The data was divided into training and testing sets (Odubela, Jiang and Davis, 2020) to evaluate the model's performance, using metrics such as MAE, RMSE, MAPE, and R^2.

In addition to accuracy, the study also aims for transparency and interpretability in the results obtained. This was achieved through SHAP analysis, which helps assess the contribution of each input feature to the final forecast (Lipton, 2018). Thus, in addition to numerical values, the study provides a more in-depth understanding of the factors that influence tourist flow.

The methodology followed provides a clear and tailored approach to the needs of strategic planning in tourism, using modern technologies that can be widely applied in similar sectors of developing economies.

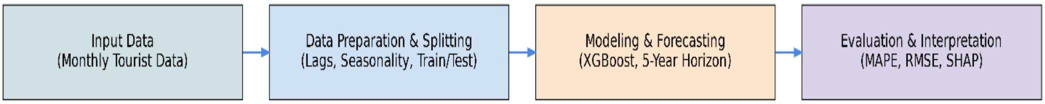

Figure 2. Visual methodology

To more clearly illustrate the steps taken during model building and interpretive analysis, Figure 2 presents a visual summary of the methodology flow followed in this study. The scheme includes the preparation of monthly historical data, the construction of the XGBoost model, the forecasting and estimation process, and the interpretive analysis with SHAP to identify the impact of each feature.

3. Literature Review on the Use of XGBoost and SHAP

The application of XGBoost machine learning algorithms has grown substantially across different fields because they excel at handling intricate data while delivering precise results with minimal resource usage. In the seminal paper "XGBoost: A Scalable Tree Boosting System", the authors proposed a novel sparse data-aware algorithm and a weighted quantile calculation algorithm that helps build trees in an approximate and efficient manner. They present a complete and scalable tree-boosting system called XGBoost, which is widely used by data scientists to achieve top-level results on many machine-learning challenges (Chen and Guestrin, 2016). Most importantly, they say, this method provides insights into cache access, data compression, and sharding to build a boosting system that is highly scalable. By combining these techniques, XGBoost can handle billions of examples using far fewer resources than existing systems (Chen and Guestrin, 2016). Beyond its technical capabilities, XGBoost has found increasingly widespread use in the tourism sector, especially when combined with interpretive methods such as SHAP (Shapley Additive Explanations). An illustrative example comes from the study "Application of

Classification and Word Embedding Techniques ", where a classification model was developed to assess the likelihood of tourists returning to accommodation structures based on content analysis of comments from TripAdvisor. Using natural language processing techniques such as topic modelling and semantic vectors (Word2Vec), the authors built a labelled database, which was used to train the XGBoost model. The interpretability of the model was ensured through Shapley Additive Explanations (SHAP), identifying key themes that influence the decision to return. The results confirmed that factors such as staff professionalism and cleanliness had a differential impact according to the hotel level, proving the validity of the XGBoost–SHAP approach in analyzing unstructured data in tourism (Christodoulou, Gregoriades, Pampaka and Herodotou, 2021). One of the most important developments in increasing the transparency of machine learning models is the use of local interpretive methods such as SHAP (Shapley Additive Explanations). In this regard, Li (2022) which presents an in-depth application of SHAP for interpreting the XGBoost model in a geospatial context, shows that this approach can highlight spatial effects comparable to traditional statistical models such as SLM and MGWR. The importance of this paper lies in the fact that it transforms a "black-box" model into a comprehensible tool for the analysis of spatial and nonlinear complications. Related to this, in our study on the forecasting of tourist flows in Albania, the use of XGBoost together with SHAP analysis aims not only to achieve high predictive performance but also to provide a clear interpretation of the factors that affect the seasonal and regional variation of tourism. Therefore, the approach proposed by Li supports and methodologically justifies the use of the XGBoost–SHAP combination in this analysis.

A further methodological development that demonstrates the extended potential of XGBoost in modelling complex data is presented by Islam et al (2022) where a MESF-XGBoost composite model is proposed for predicting Airbnb rental prices. The authors apply a hybrid approach that combines Latent Dirichlet Allocation (LDA) – to generate synthetic variables from textual property descriptions – with spatial filtering through Moran vectors (MESF) in order to address both semantic content and geospatial dependencies in the data. The results showed that the inclusion of features generated by LDA and MESF spatial components significantly improves the prediction accuracy compared to the basic version of XGBoost while reducing the problems of spatial autocorrelation (Tan, Su, Wu, Cheng and Zheng, 2024). This approach constitutes an important precedent for tourism forecasting studies, especially in cases where the influence of location factors and unstructured descriptions (e.g. reviews, destination descriptions) play a crucial role. In line with our approach using XGBoost and SHAP to analyze tourist flow by travel purpose and geographical distribution in Albania, this study reinforces the importance of integrating semantic and spatial dimensions in advanced forecasting models.

Another successful use of the XGBoost model is presented by Chen and We (2021), who aim to predict freeway travel time using data from tracked vehicles and information such as time of day, day of the week, and atmospheric conditions. This study demonstrates that XGBoost is able to efficiently incorporate temporal and spatial variables, also taking into account correlations between road segments while assessing the relative importance of each factor through model performance analysis. The results show clear advantages of XGBoost over traditional methods, such as Gradient Boosting, both in terms of accuracy and efficiency. This approach demonstrates the broad potential of XGBoost in complex predictive applications and suggests its applicability in other sectors, such as in predicting the tendency of tourists to return to a destination by analyzing similar temporal and spatial variables and the individual experience of users. Another important application of artificial intelligence models in predicting phenomena with social and environmental impact is the problem of predicting air pollution in Macau using five advanced machine learning algorithms, including Artificial Neural Networks (ANN), Random Forest (RF), Support Vector Machine (SVM), Multiple Linear Regression (MLR), and especially XGBoost (Lei, Stanley and Siu, 2023). The authors built 24-hour and 48-hour models to predict CO, PM2.5, and PM10 concentrations and found that XGBoost offered high accuracy and low probability of overfitting. Feature selection was based on SHAP analysis, identifying the most important meteorological factors for each pollutant. The approach enhanced both the model's performance and its interpretability, which has become a critical requirement in artificial intelligence applications. The research results have implications for tourism forecasting because they provide a method to understand how different factors affect the system in a clear way. In this regard, the use of the XGBoost–SHAP combination in our study on tourism forecasting in Albania aims to bring the same powerful analytical approach by accurately identifying the main factors that influence travel motivations and the geographical distribution of tourists.

4. Implementing the XGBoost Model

To estimate and forecast the arrival of non-resident tourists in Albania, the XGBoost (Extreme Gradient Boosting) algorithm, known for its efficiency and ability to model complex nonlinear relationships in temporal data, was applied in this study. Monthly data for the period January 2016 – December 2024, obtained from INSTAT, were processed and structured in order to include important temporal characteristics such as general trend, seasonality and lag features, which are essential for real-time forecasts. Initially, the data were cleaned and sorted chronologically. After the data were normalized and cleaned of missing data, were divided into training and testing sets, where the last 12 months were used for testing. The XGBoost model was built for a regression prediction task using the objective function reg: squared error, which minimizes the mean square error between the predicted and actual values. The learning rate was set to eta = 0.1 to prevent overfitting and ensure consistent learning by making small updates to the model weights at each training step. The maximum depth of the trees was set to max_depth = 6 to limit the complexity of the base models and increase the generalization capacity of the model. The training was performed for 100 rounds (num_round = 100) after a process of parameter calibration through cross-validation. To increase robustness and avoid data overlap, the parameters subsample = 0.8 and colsample_bytree = 0.8 were also used, which control the percentage of data sample and features used in building each tree. The model development process did

not include any tree complexity penalty because it focused on building a model that matches the actual data structure. The configuration generated a robust model which delivered both strong predictive accuracy and straightforward results interpretation. This aspect was further deepened through SHAP analysis, which helped identify the contribution of individual features to the prediction.
Standard regression metrics were used to evaluate the model's performance, which yielded the following results:

- MAPE (Mean Absolute Percentage Error): 15.42%
- MAE (Mean Absolute Error): 174,349.6
- RMSE (Root Mean Square Error): 244,731.4
- R^2 (Coefficient of Determination): 0.7756

These results confirm a satisfactory level of predictive accuracy, demonstrating the suitability of the model to interpret and track seasonal fluctuations and time trends of non-resident tourists in Albania. Figure 3 visually compares historical and modelling data for the year 2024 as a test period for the XGBoost model.

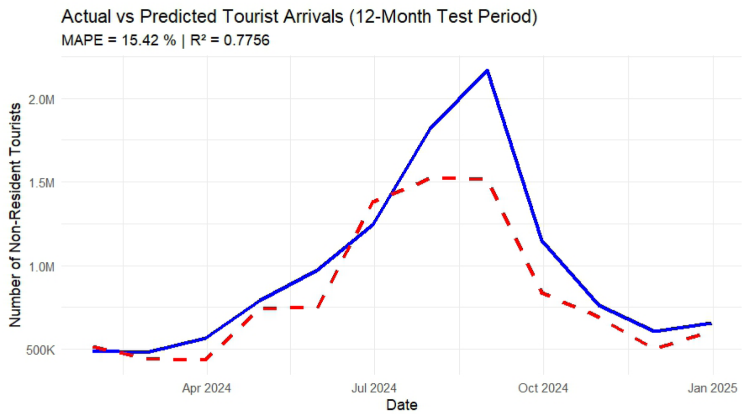

Figure 3. 12-month Test Period

In addition to assessing the accuracy of the test data, a medium-term forecast for a 5-year (60-month) period was also constructed using recursive forecasting. This method has produced a new time series with projected values until the end of 2029, serving as a basis for future tourism scenario-building and planning at the national level.

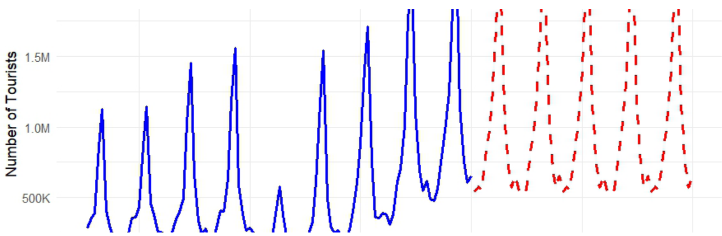

Figure 4. Forecast for the next 5 years according to the XGBoost model

Figure 4 presents an overview of the 5-year forecast of the number of non-resident tourists in Albania based on the XGBoost model. The results show an overall increasing trend, with clear peaks during the summer months, reflecting the strong seasonality of Albanian tourism. The cyclical pattern continues to exist in the data through its repeated waves while the amplitude of the fluctuations shows that seasonal factors have remained stable throughout the historical data. This forecast helps in building development scenarios and optimizing resources for the tourism sector at a national strategic level, especially in the planning of infrastructure and time-oriented marketing campaigns.

4.1 Interpretability of the Model through SHAP

To improve the transparency and understandability of the XGBoost model decisions, the SHAP (SHapley Additive exPlanations) method was applied in this study. SHAP is an advanced interpretive method that, based on game theory, measures the contribution of each input feature to the final result of the model. This approach provides a structured way to analyze the internal behaviour of the algorithm, helping to unravel its decisions even when the model is complex and nonlinear. Figure 5 presents the relative importance of the features used in the model through SHAP values.

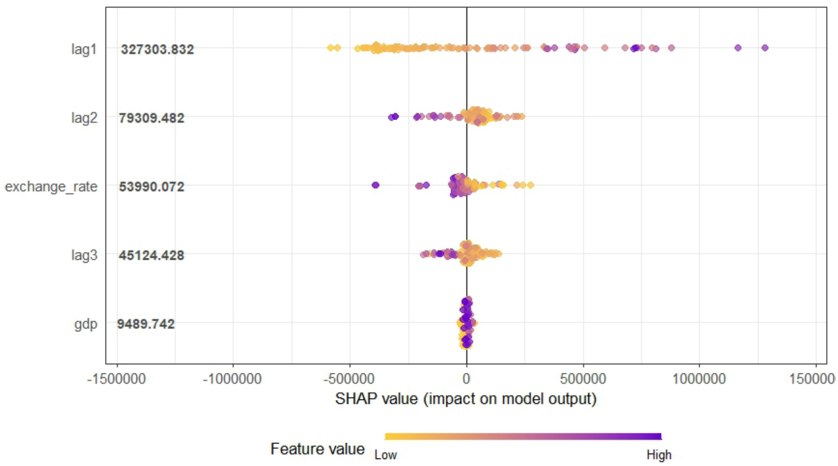

Figure 5. SHAP values

The figure above shows the relative importance of input features in the XGBoost model for predicting the number of non-resident tourists in Albania based on SHAP (Shapley Additive Explanations) values. Each point in the figure represents a SHAP value for a single observation. At the same time, the colour indicates the corresponding value of the variable, from the lowest (yellow) to the highest (purple). The horizontal scale shows the degree of influence of each feature on the model's prediction.

The results clearly show that the internal factors of the time series, specifically lag1, lag2 and lag3, have the greatest impact on the model, with lag1 taking the first place with an average SHAP value of over 327,000. This fact highlights that the immediate dynamics of the preceding month are essential for the forecast of the following month, placing this variable at the centre of the forecasting logic. In contrast, external macroeconomic factors such as the exchange rate and Gross Domestic Product (GDP) exhibit a much more limited impact on the model, with significantly lower average SHAP values (around 54,000 and 9,500 respectively), indicating that their contribution to forecasting accuracy is peripheral.

These results are consistent with the findings of the previous study "Applying Facebook Prophet to forecast the passenger flow in a seaport" from (Breshanaj, Stringa and Ramosacaj, 2025), where a limited impact of external factors such as exchange rate and GDP was observed in the Prophet model, despite their inclusion as external regressors. In both that case and in this analysis with XGBoost, it is clear that models based on internal time components and seasonal characteristics produce higher performance and better interpretability, especially when applied to the field of tourism and transport. This conclusion is of practical importance for policymakers, suggesting that attention should be focused on the analysis of internal trends and seasonal cycles rather than macro-economic indicators, which, although important at the macro level, do not provide a direct contribution to the modeling of monthly tourist behavior.

5. Conclusion

This study explored the use of the XGBoost model in combination with the interpretive SHAP analysis for forecasting the number of non-resident tourists in Albania. The empirical results showed that XGBoost provides high predictive performance (MAPE = 15.42%; RMSE = 244,731; R^2 = 0.7756), reflecting its suitability to capture the complex temporal and seasonal structures that characterize tourist flows in developing countries. Furthermore, the integration of SHAP analysis added significant value by disentangling the relative impact of each feature on the model results. In particular, it was identified that internal factors such as values of previous months (lag features) and seasonal components (sin_month, cos_month) have a much greater impact than macroeconomic indicators, suggesting that models based on historical tourist behavior offer more practical validity for tourism decision-makers. The paper makes its primary contribution through developing a strong explanatory framework for Albanian tourism demand forecasting which addresses a significant research gap while offering a model that other developing nations can apply.

Future Work

Given the limitations of this study, some important directions for further research include:

- **Expanding input features** to include more complex external variables such as special events (festivals, international conferences), accommodation capacities and average seasonal prices;

- **Detailed regional analysis** to model tourism demand at the municipal or county level, integrating spatial dimensions with models such as XGBoost–MESF;
- **Comparison with other AI models**, such as LightGBM, CatBoost or deep neural networks, to evaluate performance in different scenarios.

The implementation of XGBoost and SHAP artificial intelligence methods represent a vital advancement toward smart sustainable tourism management in Albania which supports sufficiently proactive decisions for this important national development sector.

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