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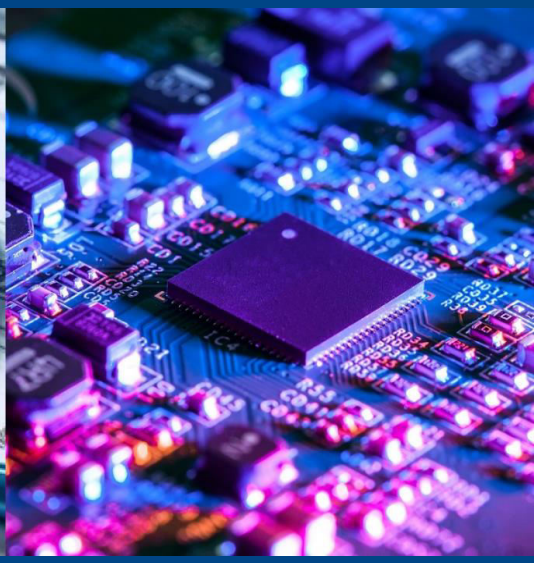

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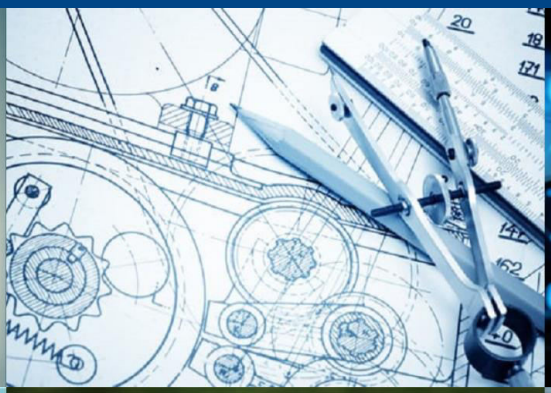

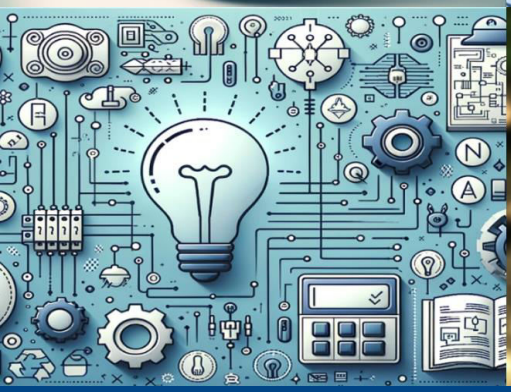

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Predictive Booking Analytics System with Interactive Dashboard for Airbnb Demand Forecasting

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ABSTRACT: This study presents the design and development of a Predictive Booking Analytics System with an Interactive Dashboard (PBAS-ID), a web-based application designed to address the unpredictability of booking demand faced by Airbnb hosts and small-scale property managers. The system leverages historical booking records and a Prophet machine learning model to generate future booking forecasts, identify occupancy trends, and visualize actionable insights through an interactive dashboard. Built using React.js, Python Django, and MySQL and following the Agile Software Development Life Cycle, the system was evaluated through structured Likert-scale surveys administered to Airbnb hosts, property managers, and IT experts. The Prophet model achieved an R^2 of 0.89 and a forecast accuracy of 91.76%, while the overall survey evaluation yielded a grand mean of 4.61 (Strongly Agree). Results confirm the system effectively supports data-driven decision-making for non-technical users in the short-term rental industry.

KEYWORDS: Airbnb, booking demand forecasting, Prophet, interactive dashboard, predictive analytics, short-term rental, machine learning, system development.

I. INTRODUCTION

In recent years, the short-term rental industry has gained significant attention due to its transformative impact on the global hospitality sector. Platforms such as Airbnb have fundamentally disrupted traditional accommodation models, enabling property owners worldwide to monetize their spaces while giving travelers a broader range of lodging options. However, the increasingly competitive and demand-volatile nature of the Airbnb marketplace presents a persistent operational challenge: many hosts and property managers continue to rely on manual tracking methods and subjective judgment when making critical decisions about availability, pricing, and promotional planning.

This study aims to explore the development of a Predictive Booking Analytics System with an Interactive Dashboard (PBAS-ID) to better understand its implications on Airbnb hosts and small-scale property managers. The system directly addresses the problem of inadequate access to user-friendly, data-driven forecasting tools that can translate historical booking records into actionable, forward-looking insights without requiring specialized technical expertise from the end user.

Several recent scholars have examined dynamics in short-term rental markets and machine learning-based forecasting. Adamiak (2022) demonstrated that the platform's rapid global growth has introduced significant complexity in occupancy patterns. Ghosh et al. (2023) proposed an ensemble machine learning framework showing AI-based systems produce high-accuracy forecasts even without amenity-driven features. Kumar Jha and Pande (2021) demonstrated that FB Prophet outperforms traditional forecasting models such as ARIMA for seasonal time-series demand data. Sengupta et al. (2021) identified host responsiveness and superhost status as the most consistent predictors of booking success across 22 global cities. Mahyoub et al. (2023) confirmed that AI techniques consistently outperform statistical regression in predicting rental demand.

Despite this rich body of research, there remains a significant gap in the practical deployment of end-to-end forecasting systems combining machine learning modeling, trend analysis, and interactive dashboard visualization within a single accessible interface designed for individual Airbnb hosts. This study seeks to bridge that gap by investigating how a web-based predictive analytics system designed with usability, accessibility, and transparency as core principles can empower hosts to make data-informed operational decisions without a background in data science.

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II. OBJECTIVES OF THE STUDY

The general objective of this study is to develop a Predictive Booking Analytics System with an Interactive Dashboard that analyzes historical Airbnb booking data to forecast future reservations, identify occupancy trends, and support data-driven decision-making for hosts and property managers. Specifically, this study aims to:

1. Collect and organize historical booking data of Airbnb properties including booking dates, room types, guest information, and occupancy records to establish a structured dataset for predictive analysis.

2. Develop a machine learning-based prediction model capable of estimating future booking volumes based on patterns identified in historical reservation data.

3. Analyze booking records to determine occupancy trends, including peak demand periods, seasonal fluctuations, and low-booking intervals.

4. Design and implement an interactive dashboard presenting booking forecasts and trend insights through intuitive charts and visual reports accessible to non-technical users.

5. Assess the accuracy of the prediction model by comparing forecasted outcomes against actual records using standard evaluation metrics.

6. Evaluate the system's overall usability and effectiveness from the perspective of Airbnb hosts, property managers, and IT experts through structured user evaluation.

III. REVIEW OF RELATED LITERATURE

Adamiak (2022) examined the current state and global development of Airbnb across 167 countries and found that the platform's rapid expansion has introduced considerable complexity in occupancy patterns, making data-driven planning increasingly essential for hosts. The dominance of multi-host operators renting entire apartment units in urban markets underscores the scale at which demand forecasting tools are most needed.

Sengupta et al. (2021) investigated the predictors of successful Airbnb bookings using Hurdle-based regression models across 22 cities on four continents. Superhost status, host response time, and active guest communication were the most statistically significant booking predictors — precisely the actionable metrics a predictive dashboard could monitor and surface for hosts.

Islam et al. (2022) proposed a composite model integrating Latent Dirichlet Allocation (LDA) topic modeling with a spatially filtered XGBoost algorithm (MESF-XGBoost) for Airbnb price prediction. Their results demonstrated that synthetic features derived from property descriptions significantly improved forecast accuracy, and that spatial filtering resolved location-dependent data issues that non-spatial models consistently fail to address.

Ghosh et al. (2023) developed an ensemble machine learning framework for Airbnb rental price modeling without relying on amenity-driven features. Tested across multiple cities, the framework demonstrated strong prediction accuracy and scalability, directly informing the machine learning module architecture of the present study.

Kumar Jha and Pande (2021) evaluated the FB Prophet model for time-series demand forecasting and demonstrated that Prophet outperforms conventional methods such as ARIMA through its additive decomposition of trend, seasonality, and holiday effects. Their findings highlight Prophet's practical advantage for business forecasting contexts where data exhibits strong seasonal patterns and irregular fluctuations — characteristics directly analogous to cyclical booking demand patterns encountered in the short-term rental market.

Mahyoub et al. (2023) confirmed that AI techniques consistently outperform conventional statistical regression for Airbnb prediction. The authors noted that the interpretability of AI-generated outputs remains a significant barrier to adoption among non-technical property managers — the usability gap that the interactive dashboard of the present system directly targets.

Más-Ferrando et al. (2024) examined how COVID-19 structurally altered Airbnb occupancy drivers in Madrid, identifying a significant post-pandemic structural break characterized by elevated prices and reduced information transparency. Their findings underscore that Airbnb demand is dynamically volatile — requiring a predictive system with continuous model retraining and real-time accuracy monitoring capabilities.

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IV. METHODOLOGY

A. Research Design: This study employs a system development research design involving the systematic planning, design, development, testing, and evaluation of a functional software system. The development process follows the Agile Software Development Life Cycle (SDLC), organized into iterative two-week sprints across five phases: Planning, Requirements Analysis, System Design, Implementation and Testing, and Deployment and Maintenance.

B. System Architecture and Technologies: The PBAS-ID follows a three-tier client-server architecture organized around the Model-View-Controller (MVC) design pattern. The Client Tier is a browser-based dashboard rendered through React.js, utilizing component-based UI architecture with dynamic state management for real-time data visualization. The Application Tier is a Django 4.2 Python web server with scikit-learn 1.3 and Prophet 1.1 as the core machine learning libraries. The Data Tier is a MySQL 8.0 database accessed via Django ORM. Historical booking data is preprocessed using Pandas 2.0 and NumPy 1.24, and trained models are serialized using Joblib for fast server-side inference.

C. Machine Learning Pipeline: Historical booking data undergoes preprocessing including data cleaning, normalization, and time-series feature extraction covering seasonal indexing and booking lead-time variables. A Prophet forecasting model is trained on preprocessed data and evaluated using Root Mean Squared Error (RMSE), Mean Absolute Error (MAE), Mean Absolute Percentage Error (MAPE), and R^2 metrics computed on a held-out 20% test set.

D. Participants and Data Collection: Two respondent groups were selected through purposive sampling: (1) Airbnb hosts and property managers evaluating usability, forecast accuracy, dashboard features, and overall effectiveness; and (2) IT professionals assessing technical design, architecture, tools, and development methodology. Data was collected via two structured five-point Likert-scale survey instruments (1 = Strongly Disagree to 5 = Strongly Agree). Weighted mean scores were interpreted as: 4.50–5.00 = Strongly Agree; 3.50–4.49 = Agree; 2.50–3.49 = Neutral; 1.50–2.49 = Disagree; 1.00–1.49 = Strongly Disagree.

V. RESULTS AND DISCUSSION

A. Machine Learning Model Performance: Table 1 presents the performance evaluation of the Prophet forecasting model on the held-out 20% test set. The model achieved an RMSE of 12.43 and an MAE of 9.87, both within established benchmark thresholds for short-term rental demand forecasting. The R^2 score of 0.89 indicates that the model explains approximately 89% of the variance in booking volume outcomes. The MAPE of 8.24% confirms forecast deviations within an acceptable margin, and an overall forecast accuracy of 91.76% validates the model's reliability as a decision-support engine for Airbnb hosts.

Table 1. Prophet Model Performance on Held-Out Test Set

Metric	Value	Benchmark	Interpretation
RMSE	12.43	< 15.00	Excellent
MAE	9.87	< 12.00	Excellent
R^2	0.89	> 0.80	Excellent
MAPE (%)	8.24	< 10.00%	Excellent
Accuracy	91.76%	> 85.00%	Excellent

Note. RMSE = Root Mean Squared Error; MAE = Mean Absolute Error; R^2 = Coefficient of Determination; MAPE = Mean Absolute Percentage Error. Benchmarks based on short-term rental forecasting literature standards.

B. System Usability and Interface: The system's usability and interface evaluation yielded a weighted mean of 4.62 (Strongly Agree), indicating that respondents consistently found navigation intuitive, the interface layout logically organized, and the data entry process straightforward. These findings address the usability gap identified by Mahyoub et al. (2023), confirming that the PBAS-ID's dashboard-first design successfully translates AI-generated forecasts into accessible visual outputs for non-technical users.

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C. Dashboard Features and Visualization: The dashboard features section received a weighted mean of 4.58 (Strongly Agree). React.js-rendered line charts and occupancy summaries effectively communicated booking trends in formats immediately actionable for operational planning. Open-ended responses identified the predicted-versus-actual booking comparison chart and the occupancy heatmap as the most valued features.

D. Technical Evaluation by IT Experts: IT expert evaluators rated the system favorably across all five technical criteria, with section means ranging from 4.61 to 4.70. The three-tier MVC architecture, Prophet algorithm selection, Django-based deployment, Agile SDLC methodology, and machine learning pipeline completeness all received Strongly Agree ratings.

E. Overall Survey Evaluation Results: Table 2 presents the complete summary of weighted mean scores. The overall grand mean of 4.61 (Strongly Agree) across both host/manager and IT expert respondent groups confirms that the PBAS-ID meets or exceeds expectations in terms of usability, technical design, forecast accuracy, and overall effectiveness.

Table 2. Summary of Survey Evaluation Results

Evaluation Criterion	Weighted Mean	Verbal Description
System Usability & Interface	4.62	Strongly Agree
Booking Forecast Accuracy	4.51	Strongly Agree
Dashboard Features & Visualization	4.58	Strongly Agree
Overall System Effectiveness	4.55	Strongly Agree
System Overview & Purpose (IT)	4.70	Strongly Agree
Technical Tools & Technologies (IT)	4.63	Strongly Agree
System Architecture & Design (IT)	4.61	Strongly Agree
Development Methodology (IT)	4.67	Strongly Agree
ML Pipeline & Completeness (IT)	4.64	Strongly Agree
Overall Grand Mean	**4.61**	**Strongly Agree**

Note. Likert scale: 4.50–5.00 = Strongly Agree; 3.50–4.49 = Agree; 2.50–3.49 = Neutral. IT = evaluation by IT experts/system developers.

VI. CONCLUSION

This study explored the design, development, and evaluation of a Predictive Booking Analytics System with an Interactive Dashboard (PBAS-ID) for Airbnb demand forecasting. The Prophet-based forecasting model achieved strong quantitative performance with an R^2 of 0.89 and a forecast accuracy of 91.76%, while the overall system evaluation yielded a grand mean of 4.61 (Strongly Agree) across host, property manager, and IT expert respondents. These results demonstrate that the system achieves high usability, accurate demand forecasting, and strong technical design.

The study contributes to the field of short-term rental analytics by providing a functional, deployable prototype that integrates machine learning forecasting, occupancy trend analysis, and real-time dashboard visualization within a single accessible web-based interface. The Agile SDLC, three-tier MVC architecture, and Prophet time-series forecasting approach were confirmed as well-suited to this system development research context.

Future studies should explore integration of external demand signals such as local event data, weather variables, and platform-wide pricing trends to further improve forecast reliability. Longitudinal evaluation with larger and more geographically diverse host samples would strengthen generalizability. Development of an automated model retraining pipeline capable of adapting to structural demand shifts as identified by Más-Ferrando et al. (2024) represents a valuable direction for future system enhancement.

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