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Optimizing Hotel Room Booking Patterns Using Apriori and FP-Growth Methods: A Case Study at Sapphire Boutique Hotel

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ABSTRACT

The hospitality industry utilizes digital reservation systems that generate substantial volumes of transactional booking data that require structured analytical processing. However, these data are often not optimally analyzed to support data-driven decision making. This study aims to analyze and compare the performance of the Apriori and FP-Growth algorithms in discovering association patterns in hotel room bookings. The research employs a quantitative approach using Association Rule Mining (ARM) techniques and the CRISP-DM framework on booking transaction data from Sapphire Boutique Hotel. The dataset consists of booking transaction data from Sapphire Boutique Hotel, including room type, additional facilities, booking time, and length of stay attributes. Algorithm performance is evaluated based on computation time, the number of generated association rules, and rule quality measured using support, confidence, and lift values. The results indicate that both algorithms are capable of generating relevant booking patterns; however, FP-Growth demonstrates superior performance in terms of computational efficiency and the number of patterns produced compared to Apriori. These findings are expected to support the development of recommendation systems and data-driven marketing strategies in the hospitality industry.

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1. INTRODUCTION

The rapid advancement of information technology has accelerated the adoption of digital reservation systems within the hospitality industry, resulting in the continuous accumulation of large volumes of transactional booking data. These data record detailed information related to room reservations, such as room types, booking periods, facilities selected, and customer characteristics. Despite their potential analytical value, hotel booking transaction data are commonly utilized only for operational and administrative purposes, while deeper analytical exploration to support strategic decision-making remains limited. Consequently, valuable insights regarding booking behavior and customer preferences are often overlooked.

Data mining techniques provide a systematic approach to extracting meaningful knowledge from large and complex datasets. Among these techniques, Association Rule Mining (ARM) has been widely applied to discover hidden relationships and co-occurrence patterns within transactional data [1]. ARM is particularly suitable for analyzing booking transactions, as it can identify frequent combinations of services, facilities, and booking attributes that frequently occur together. Two of the most prominent ARM algorithms are Apriori and FP-Growth, each with distinct operational characteristics. Apriori generates frequent itemsets through iterative candidate generation, while FP-Growth improves efficiency by eliminating candidate generation and utilizing a compact FP-tree structure, making it more scalable for large datasets [2][3].

Numerous studies in transaction-based domains, particularly in retail and sales analytics, have demonstrated the effectiveness of both Apriori and FP-Growth in uncovering consumer behavior patterns. Prior research generally reports that FP-Growth outperforms Apriori in terms of computational efficiency, whereas Apriori offers simpler rule generation and interpretability [4][5]. However, most existing studies are concentrated on retail environments such as supermarkets and minimarkets, with limited empirical evidence regarding their application in the hospitality sector, especially in the context of hotel room booking transactions in Indonesia.

The hospitality industry in Indonesia faces increasing competition and rapidly changing booking behaviors driven by technological innovation and shifting consumer preferences. Sapphire Boutique Hotel represents a strategic segment, as typically manage substantial transaction volumes while operating under more limited analytical and technological resources compared to higher-tier hotels. Although this hotel possesses historical booking data with significant potential to support marketing strategies, room allocation planning, and service optimization, such data are rarely analyzed using advanced data mining techniques, including association rule mining.

Therefore, this study aims to address the existing research gap by conducting a comparative analysis of Apriori and FP-Growth algorithms in identifying booking patterns within hotel room reservation data from Sapphire Boutique Hotel in Kudus City, Indonesia.

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By evaluating both algorithms in terms of rule quality and computational performance, this research contributes empirical evidence on the applicability of association rule mining in the hospitality domain. The findings are expected to provide practical insights for hotel management in optimizing booking strategies and to enrich the academic literature by extending the application of ARM beyond traditional retail-based studies.

2. RESEARCH METHOD

This study employs a quantitative descriptive approach using data mining techniques, specifically Association Rule Mining (ARM), to analyze hotel room booking transaction data. ARM is widely used to extract hidden behavioral relationships and co-occurrence patterns from large transactional datasets [6]. The research focuses on comparing the performance of the Apriori and FP-Growth algorithms in identifying booking patterns at Sapphire Boutique Hotel in Kudus City, Indonesia. The quantitative approach is adopted because the study processes large volumes of numerical and categorical transaction data to discover relationships among booking attributes, such as room type, additional facilities, booking time, and length of stay [7].

The object of this research consists of historical room booking transaction data obtained from Sapphire Boutique Hotel as the single research object. The data used are secondary data in the form of anonymized digital transaction records, collected through documentation techniques and provided in structured formats such as CSV or XLSX files, which are commonly used in behavioral transaction mining studies [8].

The data processing methodology follows the CRISP-DM (Cross Industry Standard Process for Data Mining) framework, which consists of six iterative stages: business understanding, data understanding, data preparation, modeling, evaluation, and deployment. In the business understanding stage, the study identifies the core problem of underutilized booking transaction data for strategic decision-making in Sapphire Boutique Hotel. The data understanding stage involves examining data structure, attribute completeness, and transaction distributions. Subsequently, data preparation includes data cleaning, attribute alignment across hotels, and transformation into transactional basket formats suitable for ARM analysis.

During the modeling stage, the Apriori and FP-Growth algorithms are applied to generate frequent itemsets and association rules. Minimum support and confidence thresholds are determined based on data characteristics, while lift values are used to measure the strength of associations. Apriori identifies frequent patterns through iterative candidate generation, whereas FP-Growth improves efficiency by utilizing an FP-Tree structure and eliminating explicit candidate generation. Both algorithms produce association rules that are further analyzed to assess pattern recurrence, consistency, and changes in support and confidence values. To clarify the operational differences between the algorithms, this study illustrates the processing workflow of Apriori and FP-Growth

using block diagrams. The Apriori workflow emphasizes iterative candidate generation and database scanning, whereas FP-Growth focuses on transaction compression into an FP-Tree followed by pattern growth mining. These diagrams provide conceptual understanding of how each algorithm processes transactional data.

The evaluation stage compares the performance of Apriori and FP-Growth using several metrics, including the number of generated association rules, execution time, support, confidence, lift values, and the relevance of the discovered patterns to hotel business needs. Finally, the deployment stage translates the analytical results into practical insights for hotel management, such as service bundling strategies, promotional package design, reservation planning, and customer segmentation, with findings presented through reports, visualizations, and structured rule tables to support managerial decision-making.

3. RESULTS AND DISCUSSION

3.1. Data Characteristics and Transactional Transformation

The dataset used in this study consists of historical room booking transaction records collected from Sapphire Boutique Hotel in Kudus City. The dataset consists of 2,100 booking transaction records collected between September 2025 and October 2025.The data cover booking transactions within a defined observation period and include attributes such as room type, additional facilities, booking time, and length of stay.

After the data cleaning process, all records were standardized to create a consistent single-hotel dataset to represent a unified population of booking behavior in this hotel. Unlike conventional tabular analysis, these attributes were transformed into transactional baskets in which every booking is represented as a set of items. Therefore, one transaction does not correspond to a single value per column but to a combination of co-occurring booking characteristics.

The transformation significantly increased the analytical dimensionality because one transaction may contain multiple facility items simultaneously. As a result, the dataset became suitable for association analysis rather than statistical aggregation.

This descriptive analysis confirms that the dataset contains sufficient variation and co-occurrence patterns among booking attributes, making it suitable for Association Rule Mining (ARM) implementation.

3.2. Transactional Data Preparation and Transformation Results

The data preparation stage followed the CRISP-DM framework and involved cleaning, transformation, and structuring processes. Incomplete records and duplicate transactions were removed to ensure data consistency.

The preprocessing stage produced a homogeneous dataset by cleaning inconsistent terms and formatting within Sapphire Boutique Hotel's dataset.

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Example transformation:

- Relational format
  TRX-1 → Deluxe Room, TV, Toiletries, Kettle Jug, Water Heater, Woorking Desk, Hair Dryer, Coffee & Tea, Online, 1 Nights, Business
- Transactional format
  TRX-1 → {Deluxe Room, Room, facility TV, facility Toiletries, facility Kettle Jug, facility Woorking Desk, facility Hair Dryer, facility Coffee & Tea, Online, stay_1, guest_Business}

Through this process, each booking record functions as a behavioral basket representing customer preferences. The resulting transactional dataset contains combinations of service attributes rather than isolated variables, enabling the discovery of co-occurrence patterns among booking decisions.

The presence of multiple facility items in a single transaction indicates that customer behavior is multidimensional, where booking choices are influenced by bundled service selections. This transformation ensures that the Apriori and FP-Growth algorithms can process the data efficiently in the form of itemsets.

3.3. Association Rule Mining Using Apriori

3.3.1. Parameter Configuration

The Apriori algorithm was executed using the same minimum support and minimum confidence thresholds applied in the FP-Growth implementation. Only association rules with *Lift* > *1* were retained to ensure meaningful correlations between booking attributes.

3.3.2. Frequent Itemsets Generation

The Apriori process generated 41 association rules, indicating dense relationships among room type and facility attributes.

The dominant frequent items include Deluxe Room, TV, Toiletries, Kettle Jug, and Working Desk. The frequent occurrence of these items shows that guests rarely choose facilities individually; instead, they select a set of complementary amenities simultaneously.

3.3.3. Association Rule Results

Several strong association rules were identified.

- **Rule 1:** If a customer books a Deluxe Room → they also select Kettle Jug Support = 15.8% Confidence = 61% Lift = 1.47. This rule indicates that guests who select Deluxe Room tend to expect beverage preparation facilities as part of their accommodation package.

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- **Rule 2:** If a customer books a Deluxe Room → they select Coffee & Tea Support = 13.5% Confidence = 52.3% Lift = 1.37. This finding suggests that beverage amenities are strongly bundled with premium room selections.
- **Rule 3:** If a customer selects Coffee & Tea → they also select Kettle Jug Support = 19.4% Confidence = 50.7% Lift = 1.22. This rule reflects complementary in-room facility behavior, where customers tend to select related amenities simultaneously.

Overall, Apriori successfully identified meaningful booking behavior patterns. However, the algorithm required iterative candidate generation and database scanning, making it computationally heavier compared to FP-Growth.

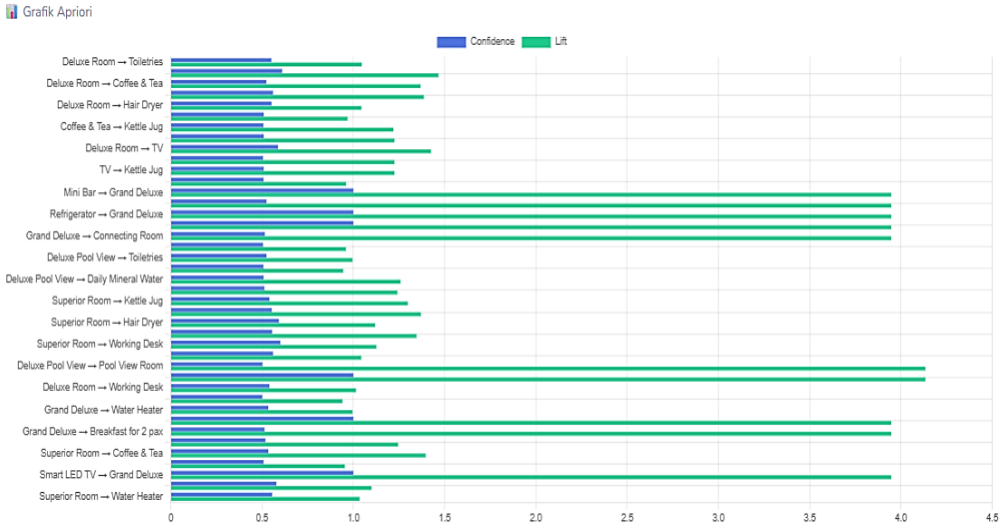

Figure 1. Showing the graphical representation of the Apriori algorithm

3.4. Association Rule Mining Using FP-Growth

3.4.1. Parameter Configuration

The FP-Growth algorithm was executed using predetermined minimum support and confidence thresholds. Only rules with *Lift > 1* were considered meaningful because they indicate positive correlation between booking attributes.

3.4.2. Frequent Itemsets Generation

The mining process produced 41 association rules, indicating dense co-occurrence relationships among facilities and room types.

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The dominant frequent items include Deluxe Room, TV, Toiletries, Kettle Jug, and Working Desk. The frequent occurrence of these items shows that guests rarely choose facilities individually; instead, they select a set of complementary amenities simultaneously.

These items frequently appear together, showing that guests tend to select rooms with complete amenities rather than isolated services.

3.4.3. Association Rule Results

Several strong rules were identified:

- **Rule 1:** If a customer books a Deluxe Room → they also select Kettle Jug. Support = 15.8%. Confidence = 61%. Lift = 1.47. Interpretation: This rule indicates that guests who book a Deluxe Room tend to select a Kettle Jug as part of their accommodation package. The lift value of 1.47 confirms a strong positive association, showing that the co-occurrence is 47% higher than random chance.
- **Rule 2:** If a customer books a Deluxe Room → they select Coffee & Tea. Support = 13.5%. Confidence = 52.3%. Lift = 1.37. Interpretation: This rule suggests that Coffee & Tea are moderately associated with Deluxe Room reservations. The lift value of 1.37 indicates that their co-occurrence is 37% stronger than random chance, reflecting bundled beverage preferences among premium room guests.
- **Rule 3:** If a customer selects Coffee & Tea → they also select Kettle Jug. Support = 19.4%. Confidence = 50.7%. Lift = 1.22. Interpretation: This rule indicates that guests who select Coffee & Tea also tend to choose a Kettle Jug as a complementary facility. The lift value of 1.22 confirms a positive association, showing that their co-occurrence is 22% stronger than random chance and reflects functional bundled usage behavior.

Overall, lift values greater than 1 across rules confirm positive associations between room type and facility preferences.

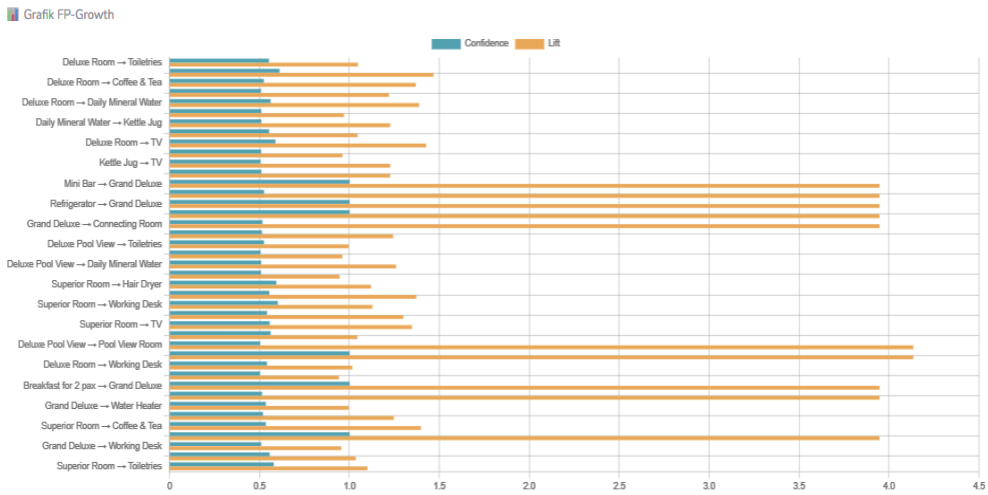

Figure 2. Showing the graphical representation of the FP-Growth algorithm

3.5. Comparative Performance Analysis

The comparative evaluation between Apriori and FP-Growth was conducted based on execution time, number of generated rules, and rule quality metrics.

Metric	Apriori	FP-Growth
Number of Rules	41	41
Average Support	15.1%	15.1%
Average Confidence	60.3%	60.3%
Average Lift	1.85	1.85
Rule Quality (Support, Confidence, Lift)	Identical	Identical
Candidate Generation	Required	Not Required
Database Scanning	Repeated Scans	Compressed FP-Tree
Computational Efficiency	Lower	Higher

Interpretation:

The average support of 15.1% indicates that, on average, each discovered rule represents booking combinations appearing in approximately one-sixth of total transactions.

The average confidence of 60.3% indicates that more than half of the antecedent conditions successfully predict their consequents, reflecting consistent and meaningful booking behavior patterns among hotel guests.

The average lift value of 1.85 confirms strong positive correlations between booking attributes, meaning that the co-occurrence of associated items is 85% stronger than random chance. This demonstrates that the discovered rules represent structured behavioral tendencies rather than incidental combinations.

These findings confirm that both algorithms generate high-quality association rules under the defined thresholds. Although the analytical outputs are identical, FP-Growth remains computationally more efficient due to its FP-Tree-based pattern growth mechanism, making it more suitable for scalable implementation in larger hotel reservation datasets.

3.6. Discussion

Both algorithms produced identical association rules because the dataset consists of 2,100 transactions, which fall into a moderate-scale dataset category for association rule mining experiments.and the minimum support threshold allowed all frequent combinations to be discovered. Therefore, in terms of analytical accuracy, Apriori and FP-Growth provide equivalent knowledge extraction. However, the main difference lies in computational mechanism:

- Apriori repeatedly scans the transaction database to generate candidate itemsets
- FP-Growth compresses transactions into an FP-tree and mines patterns directly

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Consequently, FP-Growth is more scalable for hotel reservation systems containing large-scale transaction records, while Apriori remains suitable for smaller datasets with limited item combinations.

These findings indicate that for hotel booking analytics in Sapphire Boutique Hotel, both algorithms can identify customer behavior patterns accurately, but FP-Growth provides better efficiency for future larger data implementations.

3.7. Design and Implementation of the Data Mining Information System

To operationalize the analysis of booking transactions at Sapphire Boutique Hotel, this study developed a Data Mining Information System (DMIS) implementing both Apriori and FP-Growth algorithms for optimized booking pattern analysis. The system is designed to support data-driven decision making by hotel management by transforming analytical findings into actionable insights. The architecture comprises three tiers:

3.7.1. Presentation Layer

A web-based user interface that allows hotel staff to upload booking transaction data, configure parameters (minimum support, confidence), select analysis algorithm, and view the results of association rule mining. The dashboard visualizes summary metrics such as transaction volume, number of frequent itemsets, and rule quality measures (support, confidence, lift). Association rule mining has proven valuable for revealing hidden patterns from transactional data that inform strategic decisions.

The main dashboard of the developed Data Mining Information System serves as the central navigation interface for users. As illustrated in Figure 3, the home page provides access to dataset management, algorithm selection modules, and analytical summaries, allowing hotel management to initiate the mining process in a structured and user-friendly environment.

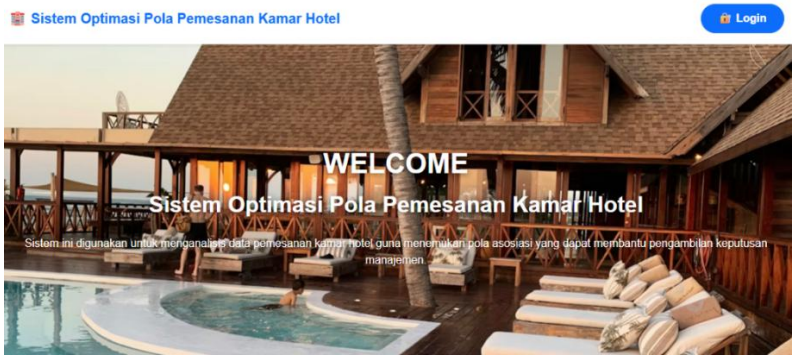

Figure 3. Home Page Interface

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To ensure data security and controlled system access, an authentication module is implemented. Figure 4 presents the login interface, which restricts access to authorized users and protects confidential booking transaction data from unauthorized manipulation.

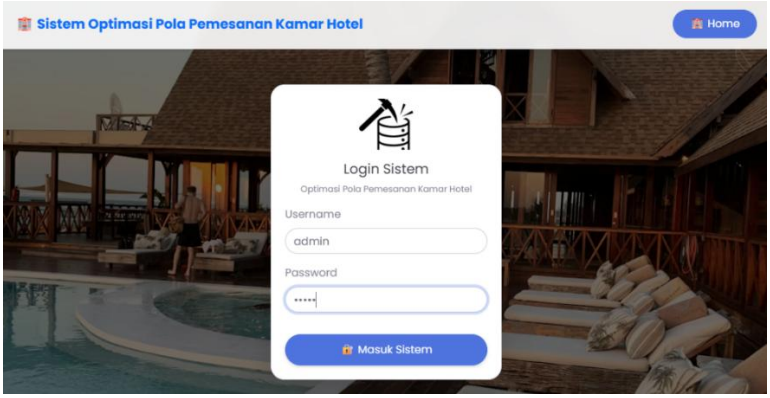

Figure 4. User Login Interface

3.7.2. Application Layer

This layer serves as the analytical engine. It preprocesses structured booking records into transactional basket format, executes the Apriori or FP-Growth algorithm modules, computes evaluation metrics, and filters association rules based on predefined thresholds. The design follows processing steps similar to those employed in retail data mining research.

Prior to analysis, users are required to upload structured booking transaction data into the system. The dataset upload interface is displayed in Figure 5, where users can import transaction files in supported formats before proceeding to preprocessing and transformation stages.

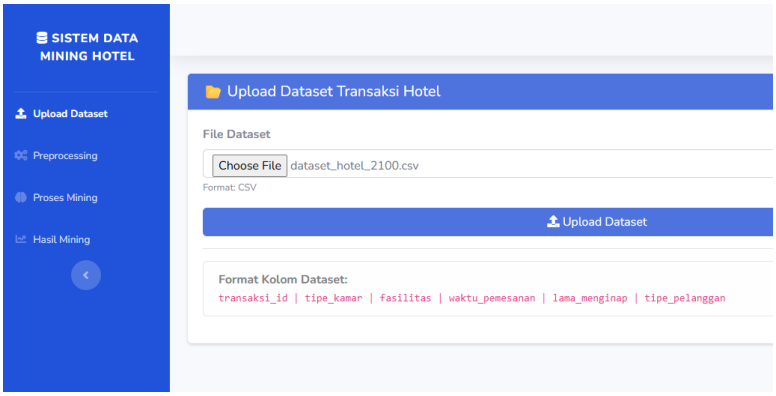

Figure 5. Upload Dataset Interface

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After the dataset is successfully uploaded, the system performs transformation into transactional basket format suitable for association rule mining. Figure 6 illustrates the preprocessing interface, where raw booking attributes are cleaned, standardized, and converted into itemsets to prepare them for algorithmic analysis.

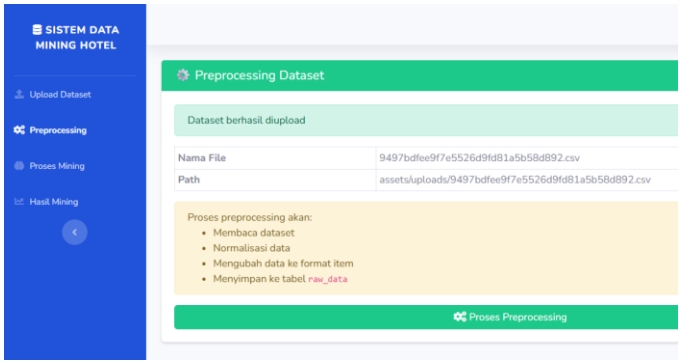

Figure 6. Preprocessing Dataset Interface

The execution of the selected algorithm is conducted through the mining module shown in Figure 7. This interface enables users to configure minimum support and confidence thresholds, select either the Apriori or FP-Growth algorithm, and display the generated association rules along with their evaluation metrics, including support, confidence, and lift values.

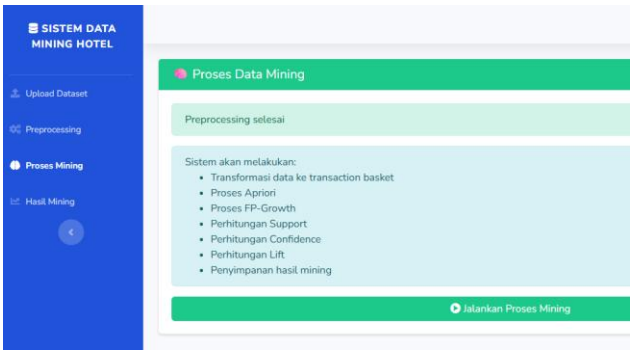

Figure 7. Data Mining Process Interface

3.7.3. Database Layer

A persistent database that records raw transactions, frequent itemsets, generated rules, and configuration settings enabling re-analysis as new booking data become available. The persistent storage structure supporting the analytical system is illustrated in Figure 8. The database layer stores raw transaction data, frequent itemsets, generated association rules, and configuration parameters, ensuring that analyses can be reproduced and extended as new booking data become available.

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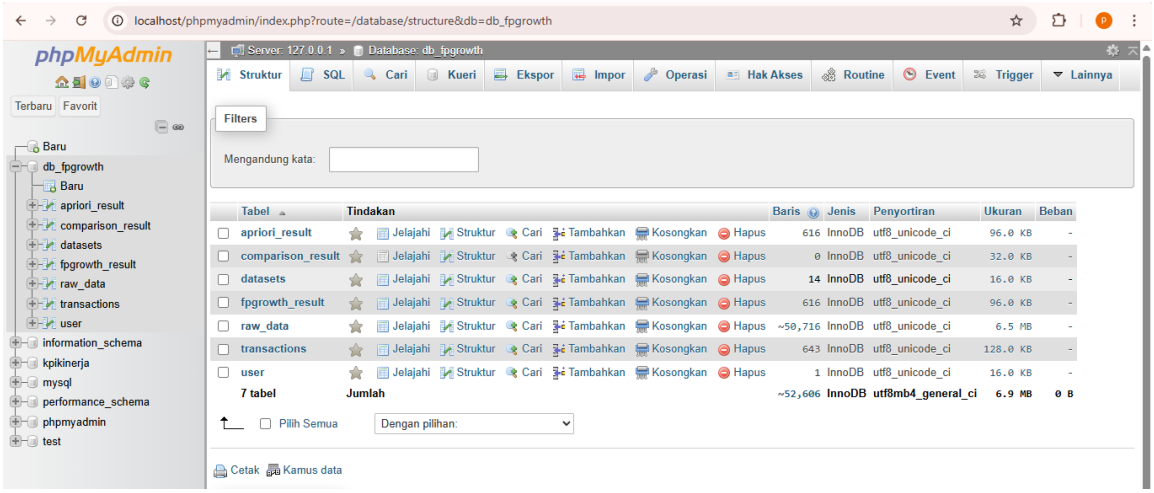

Figure 8. Database Layer

3.8. System Evaluation and Analytical Validation

The implemented system was evaluated in terms of functionality, processing performance, and analytical accuracy. Functionality testing confirms that the system successfully performs data transformation, algorithm execution, and rule visualization without data inconsistency issues.

From a performance perspective, the FP-Growth module consistently demonstrates shorter execution time compared to the Apriori module under identical parameter settings. This result aligns with the experimental findings discussed earlier and validates the decision to prioritize FP-Growth for system integration.

Analytical validation further confirms that the association rules generated through the system are consistent with those obtained during the standalone algorithm testing phase. This indicates that the system implementation does not alter rule quality and maintains analytical reliability.

3.9. Managerial Implications of the Implemented System

The integration of Association Rule Mining into a Data Mining Information System provides several strategic benefits for hotel management. First, the system enables data-driven service bundling strategies. For example, strong associations between weekend bookings and breakfast packages suggest the development of bundled promotional offerings to increase ancillary revenue.

Second, the identification of relationships between length of stay and room type supports customer segmentation and targeted marketing strategies. Long-stay guests may be offered customized promotional packages based on discovered patterns.

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Third, the system contributes to operational planning and demand forecasting. By continuously analysing booking patterns, hotel management can anticipate peak demand periods and optimize room allocation strategies.

Overall, the implementation of the Data Mining Information System enhances the practical contribution of this research. The study not only compares algorithmic performance but also demonstrates how analytical findings can be translated into an operational decision-support tool within the hospitality sector.

4. CONCLUSION

This study has successfully implemented and compared the Apriori and FP-Growth algorithms to analyze hotel room booking transaction data at Sapphire Boutique Hotel using the Association Rule Mining (ARM) approach within the CRISP-DM framework. The transformation of 2,100 booking records into transactional basket format enabled the discovery of meaningful co-occurrence patterns among room types, facilities, booking channels, and length of stay.

The experimental results demonstrate that both algorithms are capable of generating high-quality association rules with identical analytical outputs under the defined minimum support and confidence thresholds. A total of 41 association rules were generated by each algorithm, with an average support of 15.1%, average confidence of 60.3%, and average lift of 1.85. These metrics indicate strong and consistent positive correlations among booking attributes, confirming that guest booking behavior reflects structured service bundling preferences rather than random combinations.

Although the rule quality produced by Apriori and FP-Growth is equivalent for this moderate-scale dataset, FP-Growth shows superior computational efficiency due to its FP-Tree-based pattern growth mechanism, which eliminates repetitive candidate generation and multiple database scans. Therefore, FP-Growth is more scalable and suitable for long-term implementation in hotel reservation systems with larger transaction volumes, while Apriori remains appropriate for smaller datasets and simpler analytical environments.

The development and implementation of the Data Mining Information System (DMIS) further enhance the practical contribution of this research. The system operationalizes the mining process into a decision-support tool that enables hotel management to perform data-driven service bundling, targeted marketing strategies, demand forecasting, and customer segmentation. By integrating ARM into an operational system, this study bridges the gap between theoretical algorithm comparison and practical managerial application within the hospitality sector.

In conclusion, this research confirms that Association Rule Mining, particularly through FP-Growth, provides an effective analytical approach for uncovering hotel booking patterns and supporting strategic decision-making. Future research may extend this study by incorporating larger multi-hotel datasets, dynamic time-based analysis, or hybrid data

mining approaches to further enhance predictive and recommendation capabilities in the hospitality industry.

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