

PERSONALIZED PROPERTY MATCHING USING RAG FOR SPECIAL NEEDS

Data Analysis and Visualization 094295

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Abstract:

In this project we develop a Retrieval-Augmented Generation (RAG) system to improve property recommendations for Airbnb users by leveraging synthetic question-answer (QA) pairs for evaluation. Given the lack of ground truth data in the Airbnb dataset, we generated synthetic QA pairs based on Airbnb property descriptions. This dataset enhances the reliability of the RAG system in retrieving relevant properties. Our system, demonstrated through a prototype application, enables users to query property features like accessibility, infrastructure, and amenities, providing tailored property recommendations. The results confirm the RAG system's efficacy in returning relevant listings, showing promise for application across similar recommendation domains.

Introduction:

In recent years, personalized recommendation systems have become essential for platforms like Airbnb, as users increasingly seek properties that meet unique, specific needs. Beyond standard filters like location, price, and number of rooms, users frequently prefer features tied to accessibility, amenities, or infrastructure—such as wheelchair access, elevators, or essential services like internet and kitchen facilities. Traditional recommendation systems struggle to address these nuanced user preferences, often resulting in generic listings that fail to capture detailed requirements.

This project addresses this gap by developing a Retrieval-Augmented Generation (RAG) system that combines information retrieval with generative capabilities to deliver property recommendations tailored to the needs of users with special requirements. Unlike standalone language models (LLMs), which generate responses based on general data, the RAG approach ensures that responses are grounded in relevant property data, aligning recommendations with user-defined details, such as specific amenities or accessibility features.

To explore the effectiveness of different indexing methods in RAG pipelines, we implemented and compared two models: one using FAISS and the other using Pinecone. Each model follows the core RAG stages: (1) embedding and indexing property descriptions, (2) retrieving relevant listings based on user queries, (3) using a language model to generate responses incorporating these listings, and (4) presenting recommendations through an interactive demo application. For evaluation, we generated synthetic question-answer pairs using an LLM, which serve as ground truth data to assess the models' retrieval and generative performance.

Ultimately, this project aims to improve user satisfaction by delivering tailored recommendations. By comparing the FAISS and Pinecone-based RAG models against a baseline LLM model, we gain insights into how different indexing methods impact

recommendation quality, establishing a scalable approach applicable across platforms requiring personalized, context-aware recommendations.

Methodology:

[Dataset and Preprocessing:](#)

The Airbnb dataset included property descriptions, amenities, and numerical attributes such as price, guest capacity, and number of reviews. Preprocessing ensured compatibility with the RAG pipeline and enhanced the dataset's quality for analysis:

1. **Exploration:** The dataset's structure, missing values, and data types were analyzed. Nested fields (e.g., amenities) were parsed into lists, and irrelevant columns (weekly_price, monthly_price) were removed.
2. **Handling Missing Values:** Missing values in numeric fields (bedrooms, beds, security_deposit, cleaning_fee) were imputed with averages, while date fields (first_review, last_review) were standardized, with missing entries set to NaT.
3. **Outlier Detection and Cleanup:** Non-numeric entries in numeric fields were identified and replaced with placeholders or averages.
4. **Dataset Sampling:** A stratified sample (~25 MB) was extracted to maintain diversity while reducing dataset size.
5. **Data Enrichment:** New features, such as parsed amenities and derived availability, were added to enhance filtering capabilities.
6. **Visualization and EDA:** Histograms and scatterplots (e.g., Price vs. Number of Reviews) revealed patterns in key attributes, guiding feature selection and modeling steps (see Appendix for visuals).

[Pipeline and System Development:](#)

Our RAG pipeline provided personalized property recommendations through the following steps:

1. **Data Embedding and Indexing:** Property descriptions were embedded using all-MiniLM-L6-v2 and indexed in both FAISS and Pinecone to enable efficient similarity-based retrieval.
2. **Query Retrieval:** User queries were embedded and matched against indexed data to retrieve the top-K relevant properties. Retrieval rankings were evaluated using metrics like Recall at K and MRR.
3. **Generative Responses:** Retrieved descriptions were summarized into concise recommendations using the distilgpt2 generative language model, providing contextually relevant answers to user queries.

4. **Demo Integration:** A demo application combining a FastAPI backend with a Streamlit front-end enabled users to:
 - Submit personalized queries and preferences (e.g., “wheelchair-accessible property with an elevator”).
 - Explore ranked property recommendations through an intuitive interface.
 - FastAPI Highlights:
 - **Asynchronous Request Handling:** Efficiently managed multiple concurrent user sessions without delays or conflicts.
 - **Thread Safety:** Ensured independent processing of user queries, avoiding data overwrites or interference.
 - **Scalability:** Adaptable to handle growing user loads, making it suitable for larger-scale deployment.

This integration showcased the RAG pipeline’s practical application through a responsive and user-friendly system.

[QA Dataset Creation and Evaluation:](#)

To address the absence of labeled ground truth, a synthetic QA dataset was generated using Cohere’s LLM:

1. **Sample Selection:** Approximately 750 Airbnb listings were selected to ensure feature diversity.
2. **Attribute-Based Prompting:** Prompts targeted accessibility, amenities, and infrastructure to create realistic QA pairs.
3. **Validation and Refinement:** QA pairs were refined to maintain consistency in format (Q: [Question] A: [Answer]).

The dataset (synthetic_qa_pairs_expanded.csv) enabled the evaluation of RAG-generated responses. Metrics such as BLEU, ROUGE, and BERTScore measured generative quality, while retrieval performance was assessed using Recall at K and MRR.

Experiments:

[Experimental Setup:](#)

Our experiments evaluated the performance of two RAG implementations (FAISS and Pinecone) in generating property recommendations tailored to specific user needs. We focused on retrieval accuracy, response relevance, and system limitations in handling complex queries. Additionally, a demo application was used to simulate real-world interactions and assess the system's usability and performance.

1. Synthetic Queries: Synthetic queries were created to test the models ability to handle detailed requirements. Examples included “wheelchair-accessible property with an elevator”

and “quiet neighborhood with fast internet access.” These queries covered diverse topics such as accessibility, amenities, and infrastructure.

2. Evaluation Metrics:

- BLEU, ROUGE, and BERTScore: These metrics assessed the generative quality of responses. BLEU and ROUGE scores were generally low due to differences in phrasing between generated and reference answers.

- Precision, Recall, and F1-Score: Both systems performed well in precision but showed lower recall, reflecting limitations in retrieving all relevant items.

- Recall at K and MRR: Both FAISS and Pinecone had low Recall at 5 and MRR scores, indicating difficulties in ranking highly specific listings within the top-K results.

3. Synthetic QA Dataset as Ground Truth: A synthetic QA dataset generated using Cohere’s LLM served as ground truth for evaluation. This dataset captured common user questions and answers, providing a foundation for comparing generated responses. However, traditional metrics like BLEU and ROUGE struggled to fully capture recommendation quality due to phrasing differences.

4. User Interaction Simulations via Demo Application:

A FastAPI backend and Streamlit front-end powered the demo application. Users provided preferences and queries, and the system returned ranked recommendations. The app revealed the system's strengths in handling standard queries but highlighted challenges with rare or unique features.

[Summary of Results:](#)

Experiments demonstrated comparable performance across FAISS and Pinecone-based RAG systems. Key findings include:

- **Comparable Retrieval Quality:** Both implementations achieved similar scores across BLEU, ROUGE, and BERTScore, underscoring their effectiveness in retrieving relevant descriptions. Metrics included:
 - LLM Model Performance: BLEU: 0.04, ROUGE-1: 0.21, BERTScore F1: 0.85
 - RAG Model Performance: BLEU: 0.01, ROUGE-1: 0.08, BERTScore F1: 0.81
- **Recall and Ranking Challenges:** Both systems exhibited low Recall at K and MRR scores (0.00 in some cases), suggesting potential gaps in ranking highly relevant items among the top results. Enhancing retrieval strategies or dataset coverage could mitigate these issues.

- Consistent Generation Quality: Generated responses were coherent and relevant across both implementations, suggesting that differences in indexing did not affect the language model's output.

Comparison of FAISS and Pinecone:

The minimal performance differences between FAISS and Pinecone likely reflect redundancy in the dataset and similar embedding handling. Both systems use similarity-based retrieval, yielding comparable outcomes when applied to embeddings from the same model.

By integrating the demo application into our experiments, we highlighted the RAG system's practical usability and its ability to adapt to diverse user needs, offering a comprehensive evaluation framework.

Discussion:

This project highlights the potential of a Retrieval-Augmented Generation (RAG) system to enhance personalized property recommendations in the Airbnb domain. By using both FAISS and Pinecone implementations with a synthetic QA dataset as ground truth, we addressed some limitations of traditional recommendation models in meeting specific user needs, such as accessibility and amenities. The addition of Cohere-based QA generation allowed us to construct relevant ground truth data, while both FAISS and Pinecone proved effective for large-scale data retrieval.

Our key insights demonstrate that while the RAG system delivered high precision in retrieving relevant properties, recall rates were limited, particularly for queries requiring niche or rare features. This may stem from challenges in ranking specificity within the top-K results. Additionally, generative quality metrics such as BLEU and ROUGE did not fully capture the contextual relevance of recommendations, underestimating the system's true performance when assessed using BERTScore.

A unique aspect of this project was the development of an interactive demo application, where users could input specific property requirements and receive ranked, tailored recommendations. This interface demonstrates the system's practical applications, offering an intuitive experience for users with diverse needs.

Key Findings and Future Improvements:

- Synthetic QA Generation: The QA dataset provided a useful evaluation framework, but limitations in the volume of generated pairs, due to API constraints, impacted system coverage. Future work could benefit from exploring self-hosted LLMs to increase scalability and control costs.
- Enhanced Relevance and Ranking: The close performance results between FAISS and Pinecone suggest that indexing choice may have a limited effect on retrieval relevance. Future

improvements could focus on re-ranking models that better capture niche preferences and on tuning the retrieval models with domain-specific embeddings.

- Expansion of QA Coverage: Extending the synthetic QA dataset to encompass a broader array of user scenarios and property features could improve system robustness. This enhancement could increase response accuracy for diverse and nuanced queries, making the RAG system more adaptable across different recommendation-based platforms.

Overall, the RAG system effectively delivered precise, contextually relevant responses, though with room for improvement in recall and niche feature recognition. These refinements would allow the system to better support complex, user-specific queries in the hospitality and other recommendation-intensive domains.

Appendix:

1. GitHub Repository:

<https://github.com/ItayBachar1/DataAnalysisLab.git>

2. Demo Application Screenshots

This appendix showcases the functionality and user interface of the demo application designed for personalized property recommendations using the RAG system. The screenshots illustrate key steps in the user interaction process, from providing user information to querying the system and receiving results.

Figure 1: User Information Input Page

A screenshot of a web form titled "User Information". The form contains four input fields: a text field for "Name", a numeric field for "Max Price per Night" with a value of "0.00" and minus/plus buttons, a numeric field for "Number of Guests" with a value of "1" and minus/plus buttons, and a dropdown menu for "Select accessibility amenities (must select at least one):" with the text "Choose an option" and a downward arrow. Below these fields is a "Submit Information" button.

User Information

Name

Max Price per Night

0.00

Number of Guests

1

Select accessibility amenities (must select at least one):

Choose an option

Submit Information

This page allows users to input essential information such as their name, maximum price per night, number of guests, and specific accessibility amenities. This information is used to filter and personalize property recommendations.

Figure 2: Completed User Information Form

User Information

Name

Gal Levy

Max Price per Night

300.00 - +

Number of Guests

3 - +

Select accessibility amenities (must select at least one):

Elevator x Wheelchair acce... x

Submit Information

An example of a completed form with inputs for name, price range, guest count, and selected accessibility amenities. The system validates user inputs before proceeding.

Figure 3: Main Query Interface

Choose Language / בחר שפה

English

Hello, Gal!

Max Price per Night: 300.0

Number of Guests: 3

Accessibility Amenities: Elevator, Wheelchair accessible

Airbnb Property Search System

Enter your question about Airbnb listings

Search Listings

Once user information is submitted, the main query interface allows users to type specific questions about their property preferences (e.g., “Looking for a wheelchair-accessible property with an elevator”).

Figure 4: Search Results

Airbnb Property Search System

Enter your question about Airbnb listings

i want a 3 beds apartment with pool

Search Listings

Top Recommended Listings

Listing: Water View 2 Bedroom Apartment

ID: 23171144

URL: [View Listing](#)

Description: This is a fully self contained two bedroom apartment with water views, located right in the heart of the Sydney business district and in close proximity to Darling Harbour and Town Hall. Our clean, modern two bedroom and two bathroom apartment would suit individuals, couples, families, friends to share or business. It is fully furnished with linen and towels included. - The main bedroom has flexible bedding option - You can choose either two king single beds or one king size, with water views and a walk through wardrobe. - The main bathroom has a ensuite with a shower over bath tub. -the second bedroom has a Queen size bed and water views and a big wardrobe. -Also has main bathroom with walk in shower and toilet facilities. - Large open plan living / dining space and entertaining balcony that overlooks to Darling Harbour. - Kitchen has gas cooking with dishwasher and a separate laundry. - 42 inch TV Security access to building Outdoor heated resort style swimming pool and Gy

Listing: 3 bedrooms, luxury condominium

ID: 1661373

URL: [View Listing](#)

Description: New and modern condominium with 24/7 security. Swimming pools, soccer courts, playing room, gym and much more. Air conditioning, Wifi Internet and Cable TV. Restaurants in your door. New and comfortable apartment modern and luxury condominium. What the condominium offers: * 5 swimming pools (adults and children) * 2 saunas * Movie theater for children * Movie theater for adults * Gaming room (table tennis, snooker, air hockey, PS3) * Lan house * Beauty coiffeur * Gym Wifi broadband internet included, no extra cost. Cable TV with over 150 channels. Rooms' layout: * Living room Sofá for 3 people Dinning table with chairs for 4 people Ceiling fan TV LCD 42 Cable TV (over 150 channels) 4 foam mattresses * Bedroom 1 (suite) 1 couple bed + 2 foam mattresses Air conditioning * Bedroom 2 2 single beds (can be merged and become one couple bed) Air conditioning * Bedroom 3 2 single beds Air conditioning We provide additional foam/inflatable mattresses for the additional occupants. * Kitchen Duplex

Listing: Delightful Downtown with View★Parking★Jacuzzi★Pool

ID: 22148252

A list of top-recommended properties matching the user's query is displayed, including key details such as property name, description, and a link to view the listing.

Figure 5: Detailed View of Multiple Listings

Airbnb Property Search System

Enter your question about Airbnb listings

I want a 3 beds apartment with pool

[Search Listings](#)

Top Recommended Listings

Listing: Water View 2 Bedroom Apartment

ID: 23871144

[View Listing](#)

Description: This is a fully refitted and two bedroom apartment with water views, located right in the heart of the Sydney business district and in close proximity to Darling Harbour and Town Hall. Our clean, modern two bedroom and two bathroom apartment would suit individuals, couples, families, friends, friends, share or business. It is fully furnished with linen and towels included. The main bedroom has flexible bedding option - You can choose either two king single beds or one king size, with water views and a walk through wardrobe. The main bathroom has a ensuite with a shower over bath tub, the second bedroom has a Queen size bed and water views and a big wardrobe. Also has main bathroom with walk in shower and toilet facilities. Large open plan living / dining space and entertaining balcony that overlooks to Darling Harbour. Kitchen has gas cooking with dishwasher and a separate laundry. - 42 inch TV Security access to building Outdoor heated resort style swimming pool and Gym

Listing: 3 bedrooms, luxury condominium

ID: 9464273

[View Listing](#)

Description: New and modern condominium with 24/7 security, swimming pool, racquet courts, playing room, gym and much more. Air conditioning, WiFi internet and Cable TV. Restaurants in your door. New and comfortable apartment modern and luxury condominium. What the condominium offers: * 5 swimming pools (adults and children) * 2 courts * Housewater for children * Movie theater for adults * Gaming room (table tennis, snooker, air hockey, PS2) * Gymnasium * Security coffee * Gym WiFi broadband internet included, no extra cost. Cable TV with over 100 channels. Room layout: * Living room (suit for 3 people) * Living table with chairs for 4 people * Cable box TV LCD 42 Cable TV (over 100 channels) * 4 foam mattresses * Bedroom 1 (suite) 1 couple bed + 3 foam mattresses Air conditioning * Bedroom 2 2 single beds (can be merged and become one couple bed) Air conditioning * Bedroom 3 2 single beds Air conditioning We provide additional foam mattresses for the additional occupants. * Kitchen Duplex

Listing: Delightful Downtown with View★Parking★Jacuzzi★Pool

ID: 2244833

[View Listing](#)

Description: (Basking Downtown to Honolulu Honolulu March Events) Enjoy 650 sqft (large) spacious condo with floor to ceiling windows on 4th floor. Jacuzzi tub, washer and dryer in unit. Pool and hot tub in building. Secured and designated free parking spot. Fully equipped kitchen. Walk to the best restaurants and bars and visit historic island Plaza. Book now! "I have stayed in Airbnb in Shanghai, Denver, New York, Los Angeles, etc. This is as far the best Airbnb I have ever had!" - Jo Stephanie This stunning one-bedroom condo is most requested for birthdays and anniversaries. Enjoy breathtaking view, beautifully renovated interior, spa and organic amenities. Gaze 622-42 in night with free parking. Enjoy building pool & hot tub 7 days a week, 24-hour doorman. Doorman/laundry/laundry to ground floor for your daily needs. "Great value for the price especially due to its central location and amenities (including a full and new kitchen, washer and dryer). The parking space is an adjacent garage was a hit"

Listing: Spacious NOMAD 1 BR for 4

ID: 7463623

[View Listing](#)

Description: If you, your relatives, or friends want to wake up in a quiet, clean and spacious apartment as opposed to a cramped NYC hotel room, we believe our centrally-located apartment will delight you. A clean, spacious apartment with high ceilings, a separate bedroom, bathroom, kitchen and dining area. The apartment is on the fifth floor of a full service senior elevator building with a 24 hr doorman and laundry facilities in the basement. The apartment is ideal for those on temporary assignment, contract professionals, parents visiting children, wedding guests and relocating executives. It is equipped with (linen, sheets, blankets, television, secure WiFi internet, coffee maker, refrigerator, stove, microwave, dishwasher (and other kitchen appliances), and includes utilities. We do not have local phone service available. No smoking is permitted and pets cannot be accommodated. The space is suitable for two people on the double bed and two on our L shape couch. Our friends have said:

Listing: PRIVATE Room in Spacious, Quiet Apt

ID: 470888

[View Listing](#)

Description: Come stay on Historic Sugar Hill in Manhattan. Spacious room in clean, quiet, apartment (and main elevator building) in safe, historic neighborhood. Centrally located to major attractions. Here is on the same block as the apartment, half a block away! Complimentary breakfast. Only three blocks away from Times Square! Private Room in spacious quiet apartment. Apartment overlooks a large stretch of gorgeous park, on a quiet, quiet and intimate street. Please read below for convenience items the room is equipped with and amenities. Rates variable. Accommodates: One to four persons. New QUEEN bed PLUS, Queen, or Twin size Sets (inflatable, with settings for firm, medium, or plush). 700 capacity swimming pool right in front of the apartment and amphitheater-free outdoor jazz concerts, featuring world renowned artists, part of NYC Summer Stage and Summer in the City...June-September. Apartment is newly renovated. Spacious, 1.5 baths. Very clean, well maintained, quiet and peaceful.

An extended view of multiple property recommendations, showcasing detailed descriptions for each result, helping users make informed decisions.

3. Visualizations:

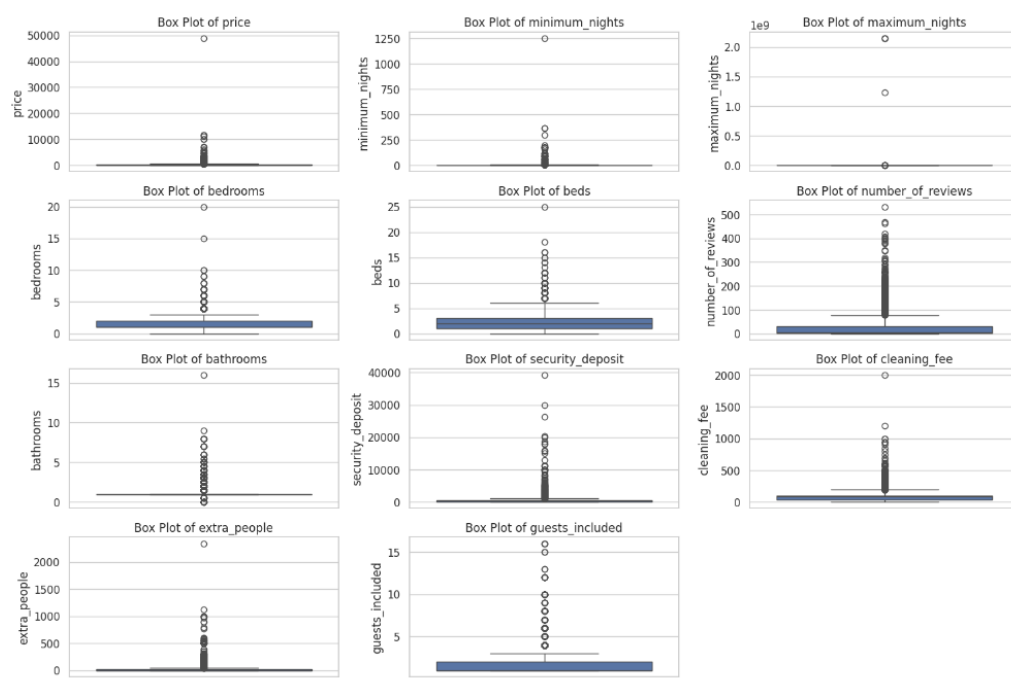
Figure 1:



Description: This scatter plot shows the relationship between the number of reviews and the price per night for Airbnb listings. Each point represents a listing, plotted by its number of reviews and price.

Insight: The scatter plot helps determine if there is a correlation between a listing's popularity (based on review count) and its pricing. For example, popular listings with low prices could suggest high demand due to affordability.

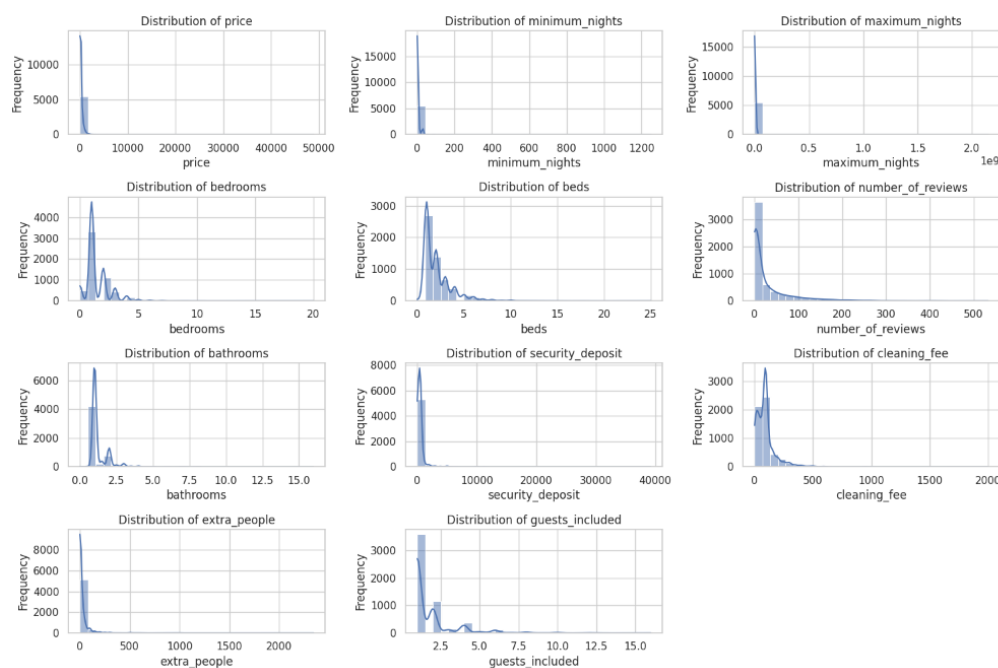
Figure 2:



Description: This box plot displays the variation in prices across different property types (e.g., apartment, villa, condo). Each box represents the interquartile range of prices within a property type, with whiskers indicating variability outside the upper and lower quartiles.

Insight: By showing the distribution of prices within each property type, this plot enables a direct comparison across categories, revealing which types tend to be priced higher or lower, and highlighting any outliers.

Figure 3:



Description: The distributions illustrate various features of Airbnb listings, including price, minimum and maximum stay nights, and characteristics like the number of bedrooms, beds, and bathrooms. Most distributions are right-skewed, with the majority of listings having low values for price, minimum nights, and fees, as well as fewer bedrooms and bathrooms.

Insight: The dataset predominantly represents affordable, smaller accommodations suitable for short-term stays and small groups. This suggests that Airbnb caters largely to budget-conscious travelers or small families. Features like low cleaning fees, minimal security deposits, and flexible occupancy options further enhance accessibility and affordability, which could be important for recommendations and search filtering.

3. References:

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