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FACULTY OF APPLIED & COMPUTER SCIENCES

COMPUTER SCIENCE DEPARTMENT

SUBJECT : BUSINESS ANALYSIS 3.2

SUBJECT CODE : AIBUY3A

ASSESSMENT : GROUP ASSIGNMENT

NAME OF GROUP : FUTURE SHAPERS

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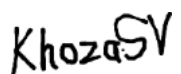**SUBMISSION DATE** : 13 OCTOBER 2025

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AI Solution - THEORETICAL ASPECT

Shortage of staff impacts the quality of service, reviews, and manual check-in delay. AI can help by taking on responsibilities. For example, it could manage reservation changes, update guest profiles, or even schedule housekeeping tasks based on real-time room availability by offloading these administrative burdens. Use of a biometric system to be implemented for customers' possessions to be secured or safe. Use AI to help customize suites in accordance with the customer's needs or preferences.

Business Objectives

- High Occupancy Rates: Keep a high percentage of booked rooms throughout the year.
- Increase Guest Satisfaction: Deliver good customer service to boost reviews, and referrals and repeat bookings.
- Improve Operational Efficiency: Reduce costs without compromising service quality through technology and staff training.
- Strengthen Brand Reputation: Build trust and loyalty through consistent quality, environmental responsibility, and community involvement.
- Promote Sustainability: Implement eco-friendly practices like waste reduction, energy conservation, and local sourcing.

Business Success Criteria

- Occupancy rate of over 75% year-round.
- Guest satisfaction rating of 4.5-5 on review platforms.
- Revenue growth of at least 10% annually.
- Operational cost savings of around 5–10% per year through efficiency measures.
- Repeat guest rate of over 30%.

Business Background

Hotels are an important component of the hospitality industry, offering paid accommodations, food, and a range of guest services. They cater to a diverse clientele, including tourists, business travelers, and local guests. The success of a hotel depends heavily on its ability to deliver a consistently positive guest experience. This is influenced

by several external factors, such as economic conditions, travel trends, and evolving consumer technology, particularly the rise of online booking platforms and review websites. In this competitive environment, operational efficiency and customer satisfaction are essential to maintaining high occupancy rates and profitability.

AI Hotel Management System: Requirements, Constraints, and Risks

To address the persistent staff shortages and operational inefficiencies affecting service quality in regional hotels, the implementation of an AI-powered hotel management system is proposed. For the system to be effective, several **functional** and **non-functional requirements** must be met, while also considering existing **constraints** and potential **risks** that could impact successful deployment.

Requirements

Functional Requirements:

- **Reservation   Management:**
  The AI system must efficiently handle room reservations, including processing changes, cancellations, and upgrades. It should allow for personalized room or suite configurations tailored to each guest's preferences.

- **Guest   Profile   Updates:**
  Automatically maintain and update guest history, loyalty status, and personal preferences to enhance personalization and service consistency.

- **Housekeeping   Scheduling:**
  Dynamically assign housekeeping tasks based on real-time room availability and guest occupancy. The system should align staff assignments with customer preferences and service needs.

- **Automated   Check-In/Check-Out:**
  Enable self-service options through kiosks or mobile applications. Use biometric authentication (e.g., fingerprint or facial recognition) to ensure secure room access, valid from check-in to check-out.

- **Operational   Insights:**
  Provide real-time analytics and dashboards covering occupancy rates,

housekeeping status, guest feedback, and service efficiency to aid in decision-making and operational improvements.

Non-Functional Requirements:

- **Reliability:**
  The system must function 24/7 with minimal downtime to support round-the-clock hotel operations.

- **Data   Security:**
  Protect sensitive guest data in compliance with international data protection regulations such as the GDPR, ensuring encryption, access control, and secure storage.

- **User-Friendly   Design:**
  Interfaces must be intuitive and easy to use for both hotel staff and guests, minimizing the learning curve and encouraging adoption.

- **Scalability:**
  The platform must be scalable to support integration across multiple hotels or chains, allowing for centralized control and standardized services.

- **Multi-language   Support:**
  Enable seamless communication with international guests through AI-powered translation features and localized interfaces, supporting a variety of languages for faster, more accurate service.

Constraints

- **Budget   Limitations:**
  Financial resources may limit the scope, speed, or features available during initial development and deployment phases.

- **Legacy   Systems:**
  Existing hotel management systems may not be fully compatible with new AI tools, potentially requiring costly upgrades or middleware solutions.

- **Regulatory   Compliance:**
  The system must comply with local labor laws, health and safety regulations, and international data privacy standards, which may influence design decisions or

operational procedures.

Risks

Technical Risks:

- **AI**   **Mismanagement:**
  Potential for AI to misinterpret guest requests, mishandle bookings, or assign rooms incorrectly, which could result in guest dissatisfaction.

- **Data**   **Breaches**   **or**   **Misuse:**
  Risk of unauthorized access to personal guest data, leading to privacy violations, loss of trust, and potential legal action.

- **System**   **Failures:**
  Downtime or bugs in the system could delay check-ins, block room access via biometric errors, or disrupt housekeeping operations.

- **Integration**   **Challenges:**
  Difficulties may arise when integrating AI tools with outdated or proprietary hotel systems, causing delays or performance issues.

- **Staff**   **Adaptability:**
  Employees unfamiliar with AI technology may struggle with the new system, leading to productivity dips, time mismanagement, or user errors during the transition phase.

Initial Assessment of Tools and Techniques

The successful development and implementation of the AI hotel management system will rely on a carefully selected stack of tools and techniques. This initial assessment identifies key technologies that can address the project's requirements and challenges.

AI Tools and Techniques

- **Natural Language Processing (NLP):** This will be a core component for developing conversational AI. It will enable the system to understand and respond to guest inquiries via chatbots on the website, mobile apps, and through email. This approach will significantly reduce the workload on the front desk staff, allowing them to focus on high-value, in-person guest interactions.

- **Robotic Process Automation (RPA):** RPA will be used to automate repetitive and administrative tasks that do not require complex decision-making. Examples include sending automated booking confirmations, generating daily reports, and processing check-in and check-out emails. This will reduce manual errors and improve overall operational efficiency.
- **Computer Vision:** To enhance the guest experience and security, computer vision will be used for two main purposes:
  - **Self-Service Check-in:** The system can use computer vision to verify guest identity through ID scanning or facial recognition, streamlining the check-in process and reducing waiting times.
  - **Biometric Access:** This technology will be crucial for the biometric system, ensuring secure and seamless room access for guests for the duration of their stay.
- **Sentiment Analysis Tools:** These tools will be vital for monitoring and improving guest satisfaction. By analyzing online reviews, social media comments, and direct guest feedback, the system can automatically detect service issues or common complaints. This allows the management to proactively address problems and protect the hotel's reputation.

Integration and Data Management Tools

- **Database Management Systems (MySQL):** A reliable database management system is essential for storing and organizing critical guest data. This includes guest profiles, reservation details, preferences, and loyalty status. The database will serve as the central repository of information, enabling the AI to provide personalized services and make data-driven decisions.

Problem Definition

Hotels in our region are currently facing a significant challenge: persistent staff shortages. This issue has created serious operational inefficiencies, such as slower check-in processes, delays in housekeeping, and reduced responsiveness to guest needs. As a

result, guest satisfaction is declining, often reflected in negative online reviews, which can deter future bookings. This not only harms the hotel's reputation but also leads to lower occupancy rates and declining revenue. If left unaddressed, this issue could threaten the long-term sustainability of local hospitality businesses, making it critical to find effective staffing and operational solutions.

How is it relevant to the project's theme?

This problem is a perfect fit for the theme "AI Solution for Industries." The core issue, a shortage of human labor for repetitive, time-consuming tasks, can be directly addressed by AI automation. The AI system will manage routine operations such as reservations, guest profile updates, housekeeping schedules, and guest queries. This will free up staff to focus on more complex, human-centric tasks that are critical for maintaining a high-quality guest experience.

How beneficial will the solution be?

- For Hotels: The system will allow hotels to maintain and even enhance service quality despite staff limitations. This will directly lead to improved guest satisfaction, a stronger brand reputation, and an increase in revenue through higher occupancy rates and repeat business. The solution will also increase operational efficiency and provide valuable insights into strategic decision-making.
- For Staff: By automating repetitive tasks, the AI tool will support local employment stability by allowing existing staff to be more effective and productive. Employees will be able to focus on direct guest service and engagement, and they will have clear, AI-assisted schedules, enabling better work-life balance and planning.
- For the Community: The local municipality will benefit from a robust and thriving tourism sector. Sustained tourism will increase visitor spending in local businesses and contribute to a stable tax base, supporting the overall economic growth of the community.

Machine Learning Approach

The machine learning approach for this solution is designed to be comprehensive, utilizing a variety of algorithms to address different aspects of hotel operations. The primary goal is to predict, optimize, and automate tasks with high accuracy.

- Predictive Analytics: We will use Gradient Boosting Machines (GBM), such as Boost, to predict guest no-shows, optimal room rates, and future occupancy. GBMs are excellent for structured data and can handle complex relationships between features like booking date, room type, seasonality, and competitor pricing.

- Classification: For tasks like identifying high-value guests or classifying customer feedback, a Support Vector Machine (SVM) or Random Forest algorithm will be employed. These models can effectively categorize data points and are robust to noisy data.

- Clustering: To segment guests based on behavior and preferences for targeted marketing, we will use K-Means Clustering. This unsupervised learning algorithm will group guests with similar booking patterns, service requests, and spending habits, allowing the system to offer personalized recommendations.

Data

The system will rely on a diverse set of data, both structured and unstructured, to function effectively. The quality and variety of this data are crucial for training accurate models.

- Structured Data: The provided hotel_bookings.csv dataset is an excellent example of the type of structured data that will be utilized. It contains a wealth of information, including:
  - Guest Profile Data: Columns such as is_repeated_guest, customer_type, children, and adults provide insights into guest demographics and loyalty.
  - Reservation Data: Information like lead_time, arrival_date_year, arrival_date_month, arrival_date_day_of_month, and total_of_special_requests are essential for predicting booking patterns and managing inventory.
  - Operational Data: The assigned_room_type and booking_changes

columns reflect operational decisions and guest behavior.

- o Financial Data: The adr (average daily rate) column is a key financial metric used for revenue optimization.

- **Unstructured Data:** This category will be sourced from other systems and APIs.

  - o Guest Feedback: Text from online reviews, surveys, and direct messages.
  - o Chatbot Transcripts: Conversations with the AI assistant.
  - o Biometric Data: Facial or fingerprint scans for secure access (stored as templates, not raw images, for privacy).
  - o Image Data: Scans of guest IDs for verification.

Model

The AI model's accuracy will be evaluated using a combination of metrics tailored to each specific function.

- **For Predictive Models** (e.g., occupancy prediction):

  - o Mean Absolute Error (MAE): This measures the average absolute difference between predicted values ($\hat{y}_i$) and actual values (y_i). Lower MAE indicates better accuracy. Formula: MAE = (1/n) * Σ |$\hat{y}_i$ – y_i|
  - o Root Mean Squared Error (RMSE): This is the square root of the MSE. It brings the error metric back to the same unit as the target variable and is more sensitive to large errors than MAE. Formula: RMSE = sqrt((1/n) * Σ ($\hat{y}_i$ – y_i)²) RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n} (\hat{y}_i - y_i) ^2}

- **For Classification Models** (e.g., guest segmentation):

  - o F1-Score:
    The harmonic mean of precision and recall. It provides a single score that balances the ability of the model to correctly identify positive cases (precision) and its ability to find all relevant cases (recall).
  - o Confusion Matrix:
    A table that visually summarizes the performance of a classification model, showing true positives, true negatives, false positives, and false negatives.

Time Series Analysis on Data

Time series analysis is crucial for forecasting future trends based on historical data.

- Sample   Description:

  The system will analyze time series data of daily occupancy rates over the past five years. This data will be segmented by month, day of the week, and special events (e.g., holidays, local festivals).

- Methodology:

  We will use the ARIMA (Autoregressive Integrated Moving Average) model for short-term forecasting of occupancy and room demand. This model captures seasonality and trends in the data to provide an accurate prediction for a specific future   period.
  For instance, the model can predict the likely occupancy for a specific Saturday in the upcoming month based on historical data from similar periods.

Solution Techniques

- Continuous Learning**:** The AI model will be designed to improve its accuracy through a continuous feedback loop. When a prediction is made (e.g., a room rate forecast), the actual outcome is recorded. This new data is then fed back into the model to refine its parameters and improve future predictions. This is known as **online learning** or **transfer learning**.

- Technique for Accuracy Improvement**:** For the sentiment analysis tool, **Active Learning** will be used. This technique involves having the model identify instances of guest feedback that it is most uncertain about. These "uncertain" samples are then sent to a human staff member to be manually labeled, and the new, corrected data is used to retrain the model. This is a highly efficient way to improve accuracy with minimal manual effort.

Natural Language Processing (NLP)

NLP is a cornerstone of the system's human-AI interaction capabilities. It is highly relevant to the solution's theme of improving service quality.

- **Relevance:** The NLP component will power the chatbot and email response system, allowing guests to communicate in natural language. It will handle a wide range of inquiries, from basic questions ("What time is check-in?") to complex requests ("I need extra towels for room 305 and a reservation for dinner tonight.").

- **Achievability:** This is achievable through pre-trained models like transformer-based architectures (e.g., BERT or GPT), which can be fine-tuned with hotel-specific data.

Deep Learning

Deep learning techniques will be used for the more complex and nuanced tasks within the system.

- **Computer Vision:** A **Convolutional Neural Network (CNN)** will be used for the biometric and ID verification system. CNNs are highly effective at image recognition and classification, enabling a fast and secure check-in process.

Mean Squared Error (MSE): This calculates the average of the squared differences between predicted and actual values. Because errors are squared, larger mistakes are penalized more strongly. Formula: $MSE = (1/n) * \Sigma (\hat{y}_i - y_i)^2$

Data Sources

• Hotel Bookings Dataset: Sourced from Kaggle (https://www.kaggle.com). This dataset contains structured information such as guest demographics, reservation details, and financial data

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