AI-DRIVEN LABOR OPTIMIZATION AND DYNAMIC STAFF SCHEDULING

A Project Report

Submitted to the APJ Abdul Kalam Technological University

in partial fulfillment of requirements for the award of degree

Bachelor of Technology

in

Computer Science and Engineering

by

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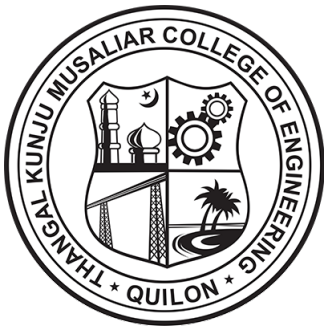

DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING

TKM COLLEGE OF ENGINEERING KOLLAM

KERALA

MAY 2024

DECLARATION

We hereby declare that the project report **AI-DRIVEN LABOR OPTIMIZATION AND DYNAMIC STAFF SCHEDULING** , submitted for partial fulfillment of the requirements for the award of degree of Bachelor of Technology of the APJ Abdul Kalam Technological University, Kerala is a bonafide work done by us under supervision of Prof. Reena Mary George

This submission represents our ideas in our own words and where ideas or words of others have been included, we have adequately and accurately cited and referenced the original sources.

We also declare that we have adhered to ethics of academic honesty and integrity and have not misrepresented or fabricated any data or idea or fact or source in my submission. We understand that any violation of the above will be a cause for disciplinary action by the institute and/or the University and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been obtained. This report has not been previously formed the basis for the award of any degree, diploma or similar title of any other University.

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CERTIFICATE

This is to certify that the report entitled **AI-DRIVEN LABOR OPTIMIZATION AND DYNAMIC STAFF SCHEDULING** submitted by **CATHERIN JOY** (TKM20CS040), **FATHIMA FIYA K M** (TKM20CS051), **SHIKHA PILLAI** (TKM20CS120) & **THESLIN SEBASTIAN** (TKM20CS133) to the APJ Abdul Kalam Technological University in partial fulfillment of the B.Tech. degree in Computer Science and Engineering is a bonafide record of the project work carried out by him under our guidance and supervision. This report in any form has not been submitted to any other University or Institute for any purpose.

Internal Supervisor **Head of Department**

Project Coordinator **External Supervisor**

Abstract

The project addresses the optimization of sales forecasting, scheduling, and employee management through advanced data analytics and predictive modeling techniques. By collecting detailed employee skillset and availability information alongside three years of daily sales data, the project uses models such as LSTM and XGBoost to predict future sales, identifying LSTM as the most precise approach. The forecasted sales are converted into labor demand, incorporating role-specific factors, day-of-week variations, and average labor hours per unit. These labor demand predictions facilitate the automation of scheduling, utilizing heuristic techniques and Bayesian inference. This combination allows the system to account for employee availability constraints and role-specific requirements, offering dynamic adjustments to schedules based on probabilistic reasoning. The system integrates a user-friendly interface developed with Streamlit, providing functionalities such as sales forecasting, automated scheduling, and employee management. This interface empowers users to make data-driven decisions, efficiently manage their workforce, and enhance operational efficiency.

Keywords: LSTM, XGBoost, Heuristic, Bayesian, Streamlit

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Contents

List of Figures

List of Tables

Chapter 1

Introduction

In the dynamic landscape of the hospitality industry, the effective management of human resources is paramount for the success of dining establishments. Addressing the challenge of optimizing labor costs, minimizing employee overtime, and ensuring an optimal workforce to meet varying sales demand is pivotal in achieving operational excellence. To navigate this complex task, there is a need for an advanced AI-driven solution that leverages historical and real-time data to make informed decisions in employee scheduling.

This endeavor involves the development of an intelligent system capable of analyzing diverse datasets, including employee work hours, historical staff scheduling, sales trends, real-time demand fluctuations, seasonal patterns, and skill set requirements. The overarching goal is to identify opportunities for reducing overtime without compromising service quality and implement an efficient scheduling mechanism that aligns staff allocation with sales demand, employee availability, and skill sets. The resulting system aims not only to optimize labor costs but also to enhance the overall dining experience for guests.

By addressing these challenges, the proposed solution seeks to usher in a new era of operational efficiency in the hospitality sector. The integration of advanced AI algorithms promises adaptability to evolving trends, a reduction in labor costs, improved staff satisfaction through thoughtful scheduling, and ultimately, an elevated standard of service that resonates with the ever-changing demands of the industry.

1.1 Background information

Traditionally, staffing in dining establishments has relied on manual methods, leading to inefficiencies in scheduling and increased labor costs. Recognizing the need for improvement, our project focuses on leveraging AI-driven technologies to optimize workforce management. By analyzing historical and real-time data, we aim to streamline scheduling processes, minimize overtime, and ensure optimal staffing levels to meet fluctuating sales demand. This innovative approach promises to enhance operational efficiency and deliver superior guest experiences within the hospitality industry.

1.2 Problem statement

The challenge at hand involves addressing critical issues within the hospitality industry, particularly in dining establishments, where the efficient management of human resources plays a pivotal role. The overarching problem revolves around the need to optimize labor costs, reduce employee overtime, and ensure an ideal staffing level that aligns seamlessly with fluctuating sales demand. The complexity arises from the multitude of factors influencing staff allocation, including historical employee work hours, past scheduling patterns, real-time demand variations, seasonal trends, and the diverse skill sets required for different roles. The objective is twofold: first, to develop an AI-driven model capable of identifying instances where employee overtime can be minimized without compromising service quality; and second, to implement an intelligent scheduling system that optimally allocates Back-of-House (BOH) kitchen staff, and front-of-house staff based on a nuanced understanding of sales demand, employee availability, and skillset requisites. This problem statement encapsulates the intricate challenges faced by dining establishments in balancing operational efficiency, cost-effectiveness, and an enhanced customer experience, calling for a sophisticated AI solution to revolutionize the way workforce management is approached in this dynamic industry.

1.3 Objectives

The project aims to revolutionize workforce management in the hospitality industry through several key objectives. Firstly, it seeks to enhance sales forecasting accuracy by integrating various factors

like seasonal trends and special events into a machine learning model. Secondly, it aims to translate sales forecasts into precise labor requirements by considering employee skill sets and real-time demand fluctuations. Thirdly, optimizing staff allocation using Bayesian Deep Networks aims to improve operational efficiency. Additionally, the project will integrate skillset matching into scheduling, reduce overtime, adapt to seasonal variations, and enhance customer experience. Finally, the project will evaluate scheduling models and provide a user-friendly interface for end-users. These objectives collectively strive to streamline operations, reduce costs, and elevate the overall quality of service in the hospitality sector.

- Reduction of Employee Overtime

  This objective focuses on minimizing instances of employee overtime by implementing intelligent scheduling practices. By analyzing historical data and real-time conditions, the aim is to identify opportunities to optimize shifts and workload distribution, ultimately reducing overtime costs while ensuring adequate coverage.

- Intelligent Scheduling System

  This objective entails the development and implementation of an advanced scheduling system that leverages AI and data analytics. The system will consider various factors such as sales forecasts, employee availability, skill sets, and customer demand patterns to generate optimized schedules. The goal is to streamline operations, improve resource allocation, and enhance overall efficiency.

- Cost Optimization

  This objective centers on optimizing costs associated with workforce management. By implementing intelligent scheduling practices, identifying opportunities to reduce overtime, and aligning staffing levels with demand, the aim is to minimize labor costs while maintaining service quality. This includes strategies to improve efficiency, reduce waste, and maximize productivity.

- Employee Satisfaction

  This objective emphasizes the importance of employee well-being and satisfaction. By implementing fair and balanced scheduling practices, considering employee preferences and work-life balance, the aim is to foster a positive work environment. This not only

improves employee morale and retention but also contributes to overall operational success and customer satisfaction.

1.4 Motivation

The motivation for developing an AI-driven solution to optimize labor costs, reduce employee overtime, and ensure optimal staff allocation in the hospitality sector stems from the overarching goal of achieving operational excellence and sustainable profitability. In an industry where customer satisfaction is paramount, the need for an intelligent scheduling system becomes imperative to streamline operations, minimize inefficiencies, and elevate the overall dining experience. By harnessing the power of AI to analyze a myriad of data, from historical staff scheduling and sales trends and employee skill sets, establishments can not only achieve significant cost savings but also enhance service quality. The desire to stay adaptable to industry trends and ensure employee satisfaction further propels the development of this solution. Ultimately, the integration of advanced technology aims to position businesses as innovative leaders, providing them with a competitive edge and strategic resource management capabilities essential for long-term success in the dynamic landscape of the hospitality sector.

1.5 Organization of the report

Chapter 1 : Introduction, a comprehensive overview of the project scope, objectives, and background to establish context and purpose.

Chapter 2: Literature Review, a critical examination and synthesis of existing research and relevant literature, providing a foundation for the project's theoretical framework.

Chapter 3: Requirement Analysis, an overview of different functional, non functional and environmental requirements which are to be considered in achieving project goals.

Chapter 4: Proposed Methodology, a presentation of the chosen approach and methods to be employed in addressing the research questions or achieving project goals. And a detailed description of the practical execution and application of the proposed methodology.

Chapter 5: Result, provides a systematic presentation of the findings obtained from the implementation of the proposed methodology.

Chapter 6: Conclusion and Future Scope, a summary of key findings, insights, and the overall

impact of the project, concluding with reflections on its significance and potential future developments.

Chapter 2

Literature Survey

2.1 Related Works

In the realm of labor optimization and scheduling in the hospitality industry, the need for efficiency has become paramount, necessitating innovative solutions to navigate the complexities of workforce management. Struggling with the delicate balance between cost optimization and service quality, the hospitality sector faces ongoing challenges in labor management. The intricate dynamics of this industry require a nuanced approach to workforce management, considering factors such as fluctuating customer demand, diverse skill requirements, and legal constraints.

To address these challenges, this project employs advanced machine learning and optimization techniques, presenting a novel solution for predicting future sales, translating them into precise labor requirements, and intelligently scheduling staff. This literature survey explores recent advancements in artificial intelligence (AI) and optimization techniques that have been applied to tackle these challenges.

One prominent approach involves the use of tree boosting models, with XGBoost being a notable development for computational speed and model performance [1]. The characteristics of XGBoost, such as algorithmic optimizations and distributed computing, make it well-suited for hospitality demand forecasting. By leveraging the computational efficiencies and predictive accuracies of XGBoost models, the project aims to produce more accurate and scalable demand forecasts to drive workforce planning.

Hybrid intelligent systems, combining machine learning and optimization techniques, have also shown promise in retail sales forecasting [2]. The integration of Ensemble Empirical Mode

Decomposition (EEMD) and XGBoost, followed by an optimization model, enhances prediction accuracy over traditional methods. This hybrid system provides useful insights for hospitality demand forecasting and aligns with the overarching goals of the project.

Algorithms for employee scheduling, categorized into exact methods, heuristic rules-based techniques, and metaheuristics, are explored in a comprehensive review [3]. Metaheuristics, in particular, are identified as compatible algorithms for integration with the optimization modules in hospitality workforce scheduling.

Drawing inspiration from evolutionary optimization techniques applied to nurse rostering problems, the survey suggests that concepts around constraint handling and weighted objective functions from these techniques can be leveraged for hospitality workforce planning [4].

Reinforcement learning approaches, such as Sparse Cooperative Q-learning (SCQL), are investigated for sequential decision-making problems in workforce scheduling [5]. The factored state space approach and tree policy learning through SCQL provide an efficient reinforcement learning framework that can be applied to workforce scheduling challenges in hospitality.

Beyond the hospitality sector, insights from the application of reinforcement learning techniques in supply chain optimization and decision-making processes are explored [6]. The comprehensive examination of diverse machine learning applications in supply chain management highlights the potential of ML in addressing various challenges within the supply chain.

Real-time business intelligence and its intersection with decision management are discussed, emphasizing the significance of real-time BI in enabling timely and informed decision-making processes within organizations [7]. The paper contributes valuable insights for leveraging real-time BI in decision management, with implications for optimizing workforce scheduling in the hospitality industry.

Specifically tailored to the hospitality industry, advancements in forecasting techniques are proposed, including a hybrid deep learning approach for hotel room demand prediction [8]. The study focuses on the dynamic nature of the industry, providing insights for optimizing resource allocation, pricing strategies, and overall operational efficiency.

A detailed exploration of artificial neural networks for hotel room demand forecasting is presented [9], aligning with the intelligent labor optimization project's goal of accurately forecasting sales demand for efficient scheduling.

While not directly related to the hospitality industry, a decision support system for personnel scheduling using Bayesian networks in healthcare institutions is introduced [10]. The methodology

and insights from this study can be adapted for the development of an intelligent scheduling system for the hospitality sector, emphasizing the importance of Bayesian networks.

Skill management within the hotel industry is comprehensively examined [12], reviewing literature on skill development, acquisition, and utilization. The study underscores the importance of considering skill sets in scheduling and optimization processes to enhance overall service quality and operational efficiency in the hospitality sector.

An intelligent skill-based approach to employee scheduling in the hospitality industry is introduced [13], considering both the skillsets and preferences of employees. By incorporating these factors into the scheduling system, the authors aim to enhance overall employee satisfaction and operational efficiency, aligning with the goals of the proposed intelligent labor optimization project.

The impact of interface design on user acceptance of workforce management systems in the hospitality sector is investigated [14]. Emphasizing the significance of user-friendly interfaces, the study highlights the importance of successful adoption and utilization of the scheduling system within the hospitality industry.

Insights from the healthcare sector contribute to understanding the design considerations for workforce management systems in complex service-oriented environments [15]. While not directly related to the hospitality industry, the findings may offer transferable insights for the development of user interfaces in the proposed project, catering to the specific needs and workflows within the hospitality sector.

[18] utilize a Long Short-Term Memory Recurrent Neural Network (LSTM-RNN) model to forecast crop yields, taking into account various climatic factors. The research was presented at the 5th International Conference on Computing Methodologies and Communication (ICCMC) held in Erode, India, in 2021. The paper discusses the methodology and results of applying the LSTM-RNN model to predict crop yields, highlighting the importance of considering climatic conditions in agricultural forecasting. The study contributes to the field of agricultural science by offering a novel approach to crop yield prediction that leverages advanced machine learning techniques.

2.2 Limitations

The reviewed literature lays a solid groundwork for our project, but there's room for improvement. Current research on demand forecasting might not fully capture the intricacies of restaurant operations, where factors like reservations and weather can significantly impact customer flow.

Additionally, existing optimization algorithms need to consider the specific skill sets and preferences of restaurant staff for a truly efficient schedule. While real-time data integration shows promise, its application to dynamic scheduling within restaurants requires further exploration. Insights from other industries, while valuable, might not directly translate to the unique needs of restaurants, where factors like table turnover and split shifts need consideration. Finally, user interface design needs to be tailored to the specific workflows and needs of restaurant managers and staff for successful adoption within the industry. By addressing these limitations, our project has the potential to develop a more accurate, efficient, dynamic, and user-friendly employee scheduling system, ultimately benefiting both the restaurant and its workforce.

Chapter 3

Requirement Analysis

- **Functional Requirements:** The project necessitates the creation of an AI-driven model capable of identifying instances to minimize employee overtime without compromising service quality. Furthermore, it mandates the development of an intelligent scheduling system that optimally assigns BOH kitchen staff and front-of-house personnel based on dynamic factors like real-time sales data, employee availability, and skill matching. This system should offer customizable parameters, allowing users to adjust staffing levels and monitor performance effectively, ensuring continual refinement and improvement.

- **Non-Functional Requirements:** The system's primary objective is accuracy, crucial for precise sales forecasting and staff allocation. It must also demonstrate scalability, reliability, and usability, accommodating diverse establishments and maintaining consistent operation under varying conditions. Robust security measures are essential to safeguard sensitive data, while efficient performance in processing data and generating recommendations is vital for seamless operation.

- **Environmental Requirements:** The system's integration with existing infrastructure must be seamless, ensuring compatibility across devices and platforms. Accessibility is key, allowing authorized users to access the system from various locations and devices. Regulatory compliance is paramount, necessitating adherence to industry standards and regulations governing data privacy and labor laws. Additionally, the system should seamlessly integrate with other hospitality systems like POS, while regular updates ensure adaptability to evolving business needs and industry trends.

Chapter 4

Proposed Methodology

4.1 Formulation & Presentation of Problem

In many industries, especially in sectors such as hospitality, retail, and other service-oriented businesses, efficient workforce management is critical for operational success and profitability. An ongoing challenge is balancing labor costs with service quality. Businesses must meet varying sales demands and fluctuations in customer traffic, which can significantly affect staffing needs. Overstaffing leads to high labor costs, while understaffing can result in poor customer service, staff burnout, and increased employee turnover due to overtime.

The problem involves optimizing labor costs and reducing employee overtime while maintaining the optimal number of staff to meet varying sales demands. This requires a detailed understanding of historical and real-time sales data, customer traffic, and employee availability and skill sets.

Challenges Identification

- Data Quality and Integrity: Ensuring that the sales data, employee information, and other relevant datasets are accurate, complete, and up-to-date is crucial. Inaccurate or missing data can lead to unreliable forecasts and scheduling.
- Model Selection: Identifying the most suitable predictive models for sales forecasting and evaluating their performance..
- Model Accuracy: Ensuring that the chosen models provide accurate and reliable sales forecasts, especially considering seasonal trends and demand fluctuations.

- Balancing Constraints: Managing multiple constraints, such as employee availability, skill set requirements, role-specific demands, legal requirements, and business objectives.
- Dynamic Scheduling: Handling real-time changes in demand and staff availability while maintaining optimal scheduling.
- User-Friendly Design: Creating an intuitive and user-friendly interface that provides all necessary functionalities and information.

Project Goal

The primary goal of the project is to optimize labor costs while reducing employee overtime and maintaining high service quality. This involves developing an intelligent scheduling system that aligns with sales demand and employee availability to efficiently allocate staff in different roles, including BOH (back-of-house or kitchen), bar, and FOH (front-of-house) staff. The project aims to leverage AI models for sales forecasting and a combination of heuristic and Bayesian approaches for scheduling optimization. Additionally, the system should accommodate varying sales demands, customer traffic trends, and seasonal fluctuations. A user-friendly interface built will allow users to analyze sales forecasts, manage schedules, and oversee employee management seamlessly. By achieving these objectives, the project seeks to streamline operations, improve workforce management, enhance the overall dining experience for guests, and ultimately empower data-driven decision-making for better business outcomes.

4.2 Solution Approach

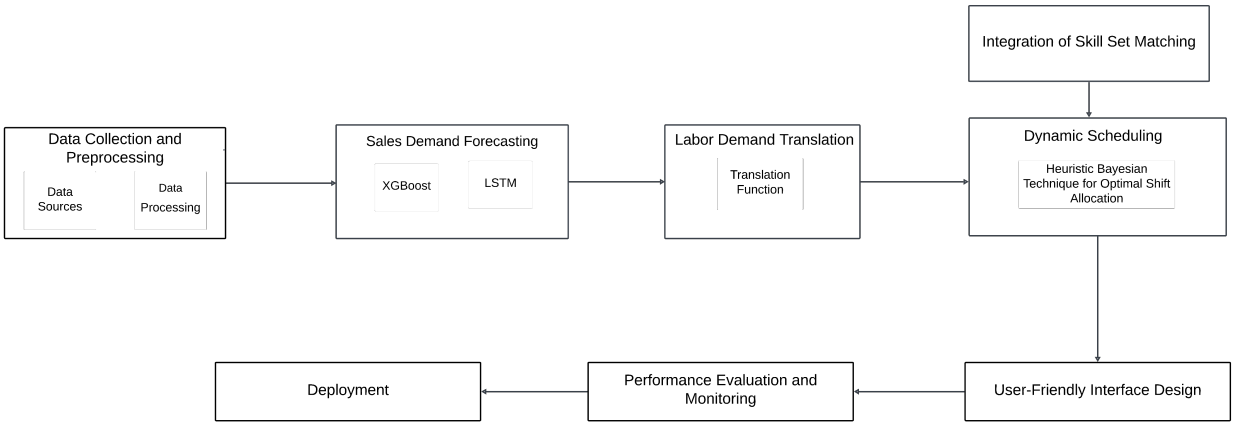

Figure 1: Architecture Diagram

As ahown in Figure 1, the solution approach for this project involves developing a comprehensive system that combines AI-driven sales forecasting, intelligent scheduling optimization, and a user-friendly interface for managing labor costs and employee scheduling efficiently. The following steps outline the approach:

1. Data Collection and Preparation: Three years of daily sales data, employee work hours, skill sets, employee details and availability information are gathered and integrated. The data is then cleaned and preprocessed to ensure its quality and suitability for use in modeling and analysis.

2. Sales Forecasting: Machine learning models such as LSTM (Long Short-Term Memory) and XGBoost are utilized to forecast future sales based on historical data. Model performance is compared, and the most accurate model is selected for predicting sales, taking into account seasonality and demand fluctuations.

3. Convert Sales Forecasts to Labor Demand: Predicted sales figures are converted into equivalent labor demand for each role (BOH, FOH, and bar staff) using factors such as average labor hours per unit and role-specific requirements. Labor demand forecasts are adjusted based on historical patterns and trends to account for peak and off-peak times.

4. Intelligent Scheduling : Heuristic techniques are applied to handle constraints such as employee availability, skill sets, and role-specific demands during different hours or days. Bayesian inference is used to evaluate the likelihood of employee availability for specific shifts, incorporating historical data and probabilities. Optimized schedules are generated to minimize employee overtime while ensuring optimal staffing levels and coverage.

5. Develop User Interface: A user-friendly application is designed and built using Streamlit, offering functionalities such as sales forecasts, scheduling, and employee management. The interface is designed to be intuitive, allowing users to interact with and benefit from the system with ease.

6. Continuous Monitoring: Model performance and scheduling efficiency are continuously monitored to identify areas for improvement.

4.3 Software/Hardware Requirements and Specifications

4.3.1 Software Requirements

- Python programming language suitable for machine learning and data processing tasks.
- Data analysis libraries (Pandas, NumPy).
- Machine learning frameworks such as TensorFlow, Scikit-Learn and PyTorch for model development and training.chine learning frameworks.
- Visualization tools (Matplotlib).
- Data processing libraries, Pandas for efficient handling and manipulation of datasets.
- Jupyter Notebooks for interactive development and visualization of predictive models.

4.3.2 Hardware Requirements

- Adequate RAM is essential, especially when working with large datasets or training complex models.
- Ample storage capacity for storing historical data, model parameters, and any additional resources.
- A stable and high-speed network infrastructure is crucial for accessing and processing real-time data, especially in applications where data is streamed.

4.4 Implementation

4.4.1 Data Collection Module

In the data collection module, various types of data belonging to the restaurant Chicking were successfully gathered and managed to support labor cost optimization and employee scheduling. A retrospective analysis of the module's performance highlights its achievements in implementing effective data collection strategies that ensured data integrity and accuracy.

The module meticulously captured historical sales data over the past three years, including date and sales amount for each day. This extensive dataset provided a solid foundation for subsequent analyses and modeling. Additionally, the module collected detailed employee data, including employee IDs, roles, skills, and availability. This comprehensive database of employee information was essential for understanding staff capabilities and constraints.

Skillset data collection was another key aspect of the module's success. The module identified and documented specific skills required for each task or role within the workforce, creating a skill requirement database for various roles. This data was crucial for aligning employee skill sets with role requirements during scheduling.

Furthermore, the module effectively recorded historic schedule data, which included shift assignments, employee roles, and scheduling patterns. This historical data provided valuable insights into past workforce utilization and allowed for informed decision-making in optimizing future scheduling.

4.4.2 Data Preprocessing Module

- Missing Values Handling

  The identification and handling of missing values within the datasets were meticulously executed in the data collection module. Robust strategies such as imputation, removal, and interpolation were employed to detect and address missing values, ensuring the completeness and reliability of the data for subsequent analyses. By using imputation techniques, missing values were replaced with estimated values based on other data points. Removal of rows with excessive missing data and interpolation methods provided additional ways to maintain data integrity and consistency.

- Outlier Detection and Treatment

  An effective approach was implemented for outlier detection and treatment, involving the application of appropriate strategies such as normalization, transformation, or removal to address outliers. This process contributed to the refinement of the datasets, enhancing their suitability for accurate and reliable analyses.

- Data Consistency Checks

  To maintain the integrity and accuracy of the datasets, thorough consistency checks were established. These checks systematically identified and resolved discrepancies or errors within the datasets, ensuring a high level of uniformity and reliability in the recorded information.

4.4.3 Sales Forecasting Module

- Data Loading and Preparation

  Historical sales data and related features such as date and sales amount are loaded from a data source, such as a CSV file. The data is preprocessed, including normalization and scaling to improve the model's training performance and consistency.

- Feature Engineering and Selection

  Time-based features such as hour, day of the week, quarter, and month are created using the data to capture temporal relationships.

- LSTM Model Development

  The development of the LSTM model was implemented to forecast future sales using historical sales data. Data loading and preprocessing began with extracting the sales data and normalizing it using a StandardScaler to ensure improved training performance. The function 'prepare_data' structured the data into sequences and targets, using a time steps parameter to construct sequences of data points and corresponding targets for future sales. The data was then split into training and testing sets for evaluating the model's performance on unseen data. The LSTM model was built using two layers with 50 units each, followed by a dense layer with one unit representing the output prediction. The model was compiled with the Adam optimizer and Mean Squared Error loss function. An Early Stopping callback

monitored the validation loss and stopped training if there was no improvement over 10 epochs, helping avoid over fitting. Once trained, the model generated predictions for both the training and testing sets, which were transformed back to the original scale using the scaler. The visualization of actual sales data alongside predicted sales data provided insight into the model's performance and how well the predictions aligned with actual sales trends.

- XGBoost Model Development

  The XGBoost model was developed to forecast future sales using historical sales data. The dataset was loaded and indexed by date for time-series analysis, with data visualizations providing insights into trends and outliers. The data was then split into training and testing sets to assess the model's performance on unseen data. A feature engineering function, create_features, generated time-series features such as hour, day of the week, quarter, and other temporal attributes to enhance the model's ability to capture patterns. TimeSeriesSplit was applied to create multiple training and validation sets for model evaluation. An XGBoost regressor was initialized with parameters such as base score, booster type, number of estimators, early stopping rounds, objective, maximum depth, and learning rate. The model was trained on the training set and evaluated on the testing set, using early stopping rounds to prevent overfitting. The model's predictions on the test set were used to calculate root mean squared error (RMSE), providing an assessment of its accuracy and effectiveness in forecasting sales trends.

- Model Evaluation and Selection

  Performance metrics such as Mean Squared Error (MSE), Root Mean Squared Error (RMSE), Mean Absolute Error(MAE) and R-squared(R^2) are calculated to quantify the models' prediction errors. Lower values indicate better model accuracy and performance. Ultimately, the model with the best performance according to these metrics and validation techniques is selected for future sales forecasting. This selection process ensures that the chosen model can provide reliable and accurate predictions for effective operational planning.

- . Forecasting and Exporting Predictions

  Once trained, the models forecast future sales using unseen data. If necessary, the predictions are transformed back to their original scale. These predictions are then be exported for use in downstream processes, such as labor scheduling, allowing for efficient operational planning.

4.4.4 Translation of Sales Predictions to Labor Demand Module

This module in this project transforms sales predictions into labor demand in hours for various roles within the restaurant. Once the model is trained, users can input a start and end date for the prediction period. The module then iterates through the specified date range, making predictions for each day based on the model.

For each date in the range, the module calculates labor demand for different roles using the predicted sales figures and pre-defined average labor hours per unit. Role-specific and day-of-week factors are applied to adjust the labor demand for each role, ensuring it reflects the expected workload.

The calculated labor demand for each role is stored in a dictionary, along with the date. This data is then appended to a list to accumulate the demand data for the specified date range. The accumulated demand data is used to create a DataFrame, which is then saved to a CSV file with appropriately named columns. The output of the module provides insights into the labor demand for different roles over a specified date range, enabling data-driven decision-making for optimal workforce allocation.

4.4.5 Intelligent Scheduling Module

- **Data Preparation**

  The module generates a workforce schedule by utilizing predicted labor demand, employee details, and role-specific skills. Data is loaded from CSV files containing information about labor demand, employee details, and role-specific skills. The employee data, including each individual's primary role, skills, and availability, is organized into a dictionary for streamlined processing. Similarly, role-specific skills are compiled into a dictionary that maps roles to the skills they require. This organized data forms the foundation for creating an efficient schedule that balances operational needs with labor availability and employee skillsets.

- **Constraints**

  This module operates under a set of constraints to ensure that the generated workforce schedule adheres to operational requirements and optimizes labor allocation. One key constraint is the maximum working hours: each employee can work up to 9 hours per day. This limitation guides the calculation of how many employees are needed for a particular role

based on predicted labor demand.

It also considers a specific shift structure with three shifts throughout the day: 10 am to 2 pm, 2 pm to 11 pm, and 6 pm to 11 pm. To prevent excessive working hours or fatigue, employees cannot be scheduled for two consecutive shifts (e.g., 10-2 and 2-11 or 2-11 and 6-11) within the same day. However, employees may work the shifts 10-2 and 6-11 on the same day.

Role-based shifts provide stability for managers and assistant managers, who have consistent shifts every day regardless of labor demand. Managers work shifts 10-2 and 6-11, while assistant managers work the shift 2-11. This consistency ensures the presence of leadership across all shifts.

To maintain balance in staffing, the number of shifts in the morning (10-2) and evening (6-11) should be equal in a day. Additionally, shift assignment constraints mandate the presence of at least one employee during the morning shift (10-2) and another during the afternoon shift (2-11).

When there is a shortage of staff for a role, the module employs a skillset matching mechanism. Employees with the necessary skills can be reassigned from other roles if their primary role's demand is already satisfied. This allows for flexibility in workforce management and ensures that all roles are adequately staffed based on their skill requirements.

- **Schedule Generation**

  The schedule generation process begins with the creation of a schedule based on predicted labor demand. To start, it automatically assigns fixed shifts for managers and assistant managers. Managers are scheduled for shifts from 10 am to 2 pm and from 6 pm to 11 pm, while assistant managers are assigned to the shift from 2 pm to 11 pm. This consistency provides the necessary leadership presence across all shifts.

  When it comes to assigning other employees to shifts, the module employs a heuristic approach that considers factors such as employee availability, primary role, and skills. This approach ensures that employees are scheduled for shifts they are suited for, based on their primary role and skills.

  In the event of a staff shortage for a particular role, the module can reassign employees with the required skills from other roles, provided their primary role's demand has been met. This matching of employee skills to roles helps address staffing gaps and maintain smooth operations.

Finally, the module strives to balance the number of morning (10 am to 2 pm) and evening (6 pm to 11 pm) shifts in a day. This shift balancing ensures equitable distribution of shifts throughout the day and avoids overloading employees with excessive work hours during specific time periods. By managing labor demand and employee availability efficiently, the module helps create an optimal workforce.

- **Integration**

  The schedule is saved as a CSV file for easy access and further use. Once the schedule is saved, the CSV file is integrated into a user interface (UI) for easy visualization and management. This integration allows users to access and interact with the schedule, providing a clear view of daily workforce allocations and ensuring that shifts meet the constraints and operational requirements of the organization.

4.4.6 User Interface Module

The user interface (UI) module of the scheduling application is created using Streamlit, a popular Python library for building interactive web applications. The UI module provides a comprehensive and user-friendly platform for interacting with various features and modules within the application, such as sales forecasting, automated staff scheduling, employee management, and more. Here's an overview of the UI module and its features:

- Login Page

  The login page serves as the authentication gateway to the scheduling application, enabling users to access the application's features upon successful verification. Users are required to enter their username and password to authenticate their identity. If the credentials are valid, the application grants access to the user's account and the various functionalities of the application. This process ensures that only authorized users specifically manager and assistant manager of the restaurant can interact with the application, enhancing security and protecting sensitive data. Through a straightforward and secure authentication process, the login page establishes a secure entry point to the application.

- Home Page

  The home page of the scheduling application offers a welcoming introduction for users as they enter the application. It greets them with a clear title and a message that invites them to

explore the various features of the application. The page serves as a central hub from which users can navigate to other sections using the sidebar menu. The straightforward layout and welcoming message set the stage for an intuitive user experience, guiding users to choose the options they need for managing schedules, forecasting sales, and handling employee data.

- Sidebar Navigation

  The sidebar navigation in the scheduling application provides a user-friendly and efficient way for users to move between different pages within the application. The sidebar menu offers various options, including home, sales forecast, automated staff scheduling, employee management, settings, and logout, giving users access to all the application's functionalities. Each option in the menu is accompanied by icons and descriptive text, making it easy for users to identify and select the desired section. This intuitive design streamlines navigation and enhances the overall user experience, allowing users to quickly find and access the features they need for managing scheduling, forecasting, and other tasks.

- Sales Forecast and Analysis Page

  The sales forecast and analysis page enables users to generate sales predictions and analyze sales trends for given date ranges. By inputting start and end dates, users can obtain sales predictions based on a trained machine learning model. The page provides visualizations in the form of charts, allowing users to see how predicted sales fluctuate over time and identify any notable trends. Additionally, the page offers analysis reports, such as total predicted sales, monthly and weekly forecasts, and periods of maximum sales. These features give users valuable insights into sales performance, helping them make data-driven decisions and optimize operations.

- Automated Staff Scheduling Page

  The automated staff scheduling page provides users with the ability to generate a workforce schedule for a specified date range. By selecting a start and end date, users can request a schedule that aligns with their chosen time frame. Using sales predictions, the application calculates labor demand for different roles within the organization and utilizes this information to construct an optimized schedule. Once the schedule is generated, it is displayed in a data table format that includes essential details such as the date, employee ID, shift start and end times, and the assigned role for each employee. This clear and organized presentation allows

users to easily review and manage staff scheduling based on predicted sales and operational needs.

- Employee Management Page

  The employee management page allows users to efficiently manage the organization's employee database. The page features an employee directory where users can view a data table containing employee details such as ID, role, skills, and availability. This comprehensive overview enables users to quickly assess the workforce and its capabilities. Additionally, the page provides options to manage employees, including adding new employee records, deleting existing records, and editing employee details. These features allow users to maintain an up-to-date and accurate database, ensuring that the organization has access to reliable employee information for scheduling and operational planning.

- Settings Page

  The settings page in the scheduling application provides users with the ability to manage their personal account information and security. Logged-in users can view their personal details, including name, email, and contact information, offering them a clear overview of their account profile. In addition, the page allows users to change their password by entering their current password and the new one they wish to use. Users are required to confirm the new password to ensure accuracy and avoid errors. This functionality helps users maintain account security and provides them with control over their personal information within the application.

- Session Management and State Handling

  The session management and state handling features in the user interface module ensure a seamless and personalized user experience. The application keeps track of the user's session state, such as whether they are logged in and which modules they have accessed. This allows the application to provide a consistent and tailored experience throughout the user's session. State persistence is achieved through functions that load and save state data, maintaining user preferences and information across different sessions. This means that when a user returns to the application, their settings and preferences are preserved, allowing them to pick up where they left off and making their interactions with the application more efficient and user-friendly.

Chapter 5

Results

Sales Forecasting

The accuracy of sales forecasting is crucial for efficient resource allocation. To achieve this, we employed two machine learning models: XGBoost and LSTM (Long Short-Term Memory). Figure 2 and Figure 3 presents a visual comparison of the sales predictions generated by both the XGBoost and LSTM models alongside the actual sales amount over a designated timeframe respectively. The plot illustrates the remarkable accuracy of the LSTM model, as its predicted values closely mirror the actual sales figures, outperforming the predictions generated by the XGBoost model.

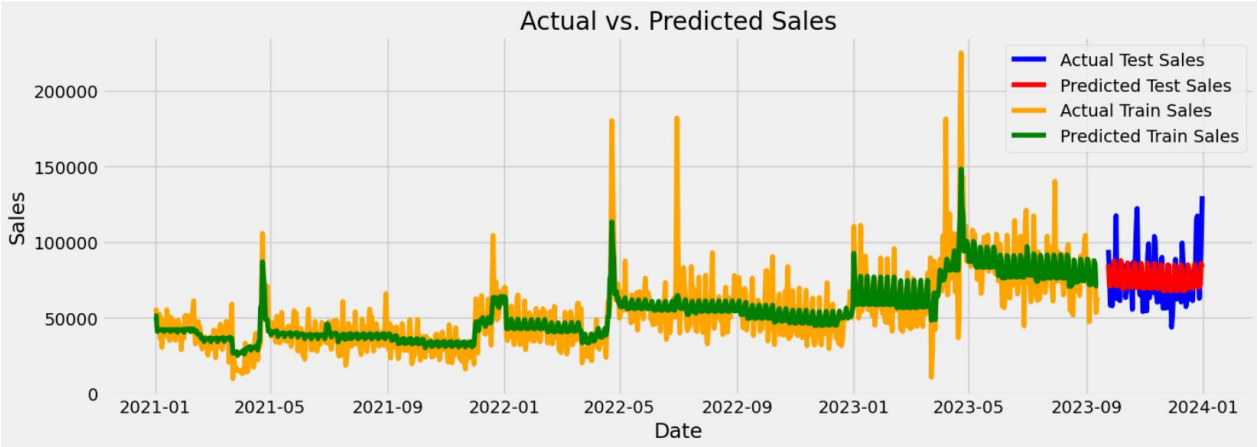

Figure 2: XGBoost training plot

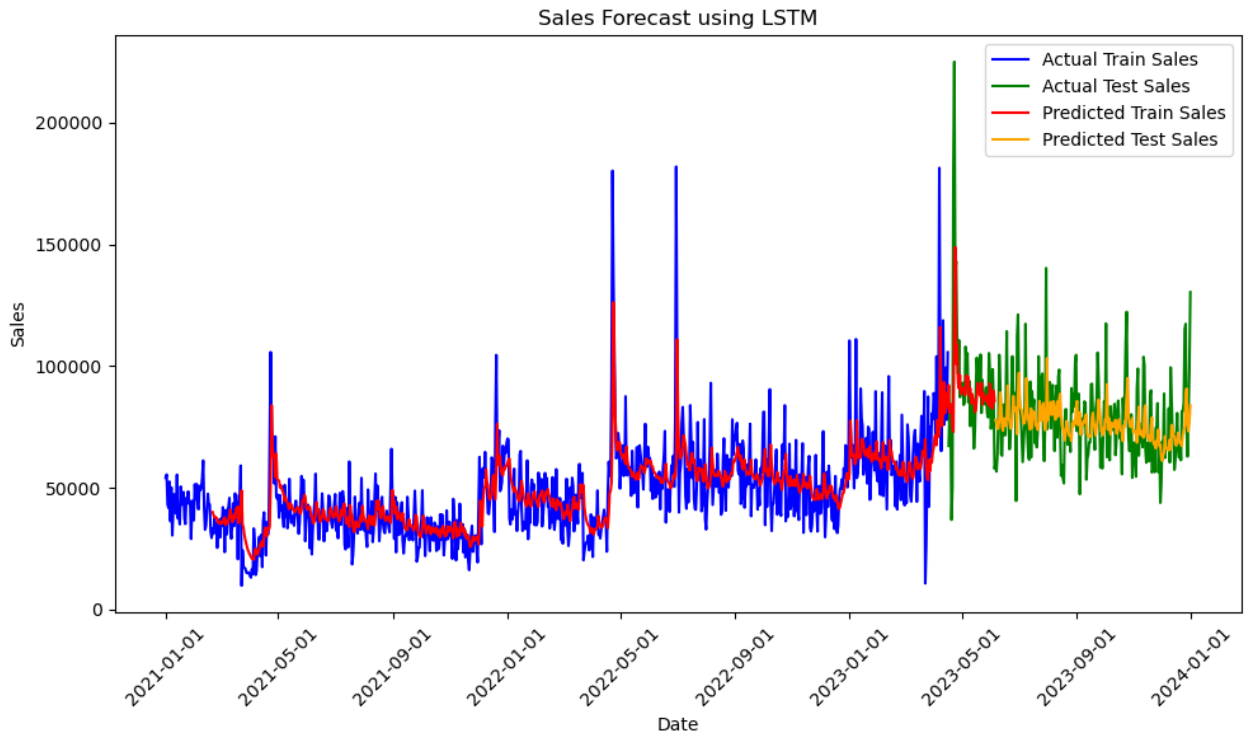

Figure 3: LSTM training plot

Table 1 offers a side-by-side comparison of the performance evaluation metrics between the XGBoost and LSTM models. The tabulated data further underscores the LSTM model's dominance, as it consistently achieves lower error rates and higher R-squared values across all evaluated metrics, reaffirming its effectiveness in accurately forecasting restaurant sales.

Model	Metrics			
	MAE	MSE	RMSE	R^2
XGBoost	1.417	2.82	1.681	0.254
LSTM	0.412	0.512	0.714	0.865

Table 1: Result Of Prediction

Labor Demand Translation

Figure 4 illustrates the derived labor demand based on the predicted sales amounts generated by the LSTM model. It depicts the projected staffing requirements in hours over the specified day, derived from the translational function linking predicted sales to labor demand.

date	manager	assistant_r	cook	cashier	server
6/20/2024	8.869593	8.869593	46.11075	18.19796	27.52066
6/21/2024	9.10346	9.10346	47.32657	18.67779	28.2463
6/22/2024	10.98164	10.98164	57.09074	22.5313	34.07393
6/23/2024	11.58147	11.58147	60.20911	23.76198	35.93509
6/24/2024	9.262896	9.262896	48.15543	19.00491	28.741
6/25/2024	9.928873	9.928873	51.61768	20.37131	30.8074
6/26/2024	10.69587	10.69587	55.60507	21.94497	33.18723
6/27/2024	8.70891	8.70891	45.27541	17.86828	27.02209
6/28/2024	9.492893	9.492893	49.35113	19.4768	29.45464
6/29/2024	11.04574	11.04574	57.42399	22.66282	34.27283
6/30/2024	11.14492	11.14492	57.93959	22.8663	34.58056
7/1/2024	10.13124	10.13124	52.66972	20.78651	31.4353
7/2/2024	9.466463	9.466463	49.21373	19.42257	29.37263
7/3/2024	8.783716	8.783716	45.6643	18.02177	27.2542
7/4/2024	9.336697	9.336697	48.53911	19.15633	28.96999
7/5/2024	9.911463	9.911463	51.52717	20.33559	30.75338
7/6/2024	10.08997	10.08997	52.4552	20.70185	31.30726
7/7/2024	10.38601	10.38601	53.99423	21.30924	32.22582
7/8/2024	9.480676	9.480676	49.28762	19.45173	29.41673
7/9/2024	8.362619	8.362619	43.47512	17.15779	25.94761
7/10/2024	9.223863	9.223863	47.95251	18.92482	28.61989
7/11/2024	9.08447	9.08447	47.22784	18.63883	28.18738
7/12/2024	9.218798	9.218798	47.92617	18.91443	28.60417
7/13/2024	9.755566	9.755566	50.7167	20.01573	30.26966
7/14/2024	9.5632	9.5632	49.71664	19.62105	29.67279
7/15/2024	9.03203	9.03203	46.95522	18.53124	28.02467
7/16/2024	9.400879	9.400879	48.87277	19.28801	29.16913
7/17/2024	8.935606	8.935606	46.45393	18.3334	27.72548

Figure 4: Labour Demand

Staff Scheduling

Figure 5 showcases the results of applying the Heuristic Bayesian Technique for Optimal Shift Allocation to the derived labor demand from Figure 4. It provides the optimized employee scheduling across the specified roles.

Date	Employee	Shift Start Time	Shift End Time	Role
5/2/2024	1796	10:00	14:00	manager
5/2/2024	1796	18:00	23:00	manager
5/2/2024	1730	14:00	23:00	assistant_manager
5/2/2024	1695	10:00	14:00	cook
5/2/2024	1695	18:00	23:00	cook
5/2/2024	1673	10:00	14:00	cook
5/2/2024	1673	18:00	23:00	cook
5/2/2024	1668	10:00	14:00	cook
5/2/2024	1668	18:00	23:00	cook
5/2/2024	1654	14:00	23:00	cook
5/2/2024	1632	14:00	23:00	cook
5/2/2024	1647	14:00	23:00	cook
5/2/2024	1587	10:00	14:00	cashier
5/2/2024	1587	18:00	23:00	cashier
5/2/2024	1555	14:00	23:00	cashier
5/2/2024	1487	10:00	14:00	server
5/2/2024	1487	18:00	23:00	server
5/2/2024	1465	10:00	14:00	server
5/2/2024	1465	18:00	23:00	server

Figure 5: Staff Scheduling

User Interface

The user interface (UI) encompasses several key features designed to enhance usability and efficiency within the restaurant management system. It begins with a user-friendly login page (Figure 6), ensuring secure access to the platform. The home page (Figure 7), serves as a central hub, providing an overview of functionalities and quick access to essential features. The sales analysis page (Figure 8), offers comprehensive insights into sales performance. The automated staff scheduling page (Figure 9), generate optimized schedules based on various factors, optimizing workforce allocation. The employee management page (Figure 10), facilitates the administration of employee details, including adding, deleting, and editing employee information, while the settings page (Figure 11), allows users to customize preferences and configurations according to their needs.

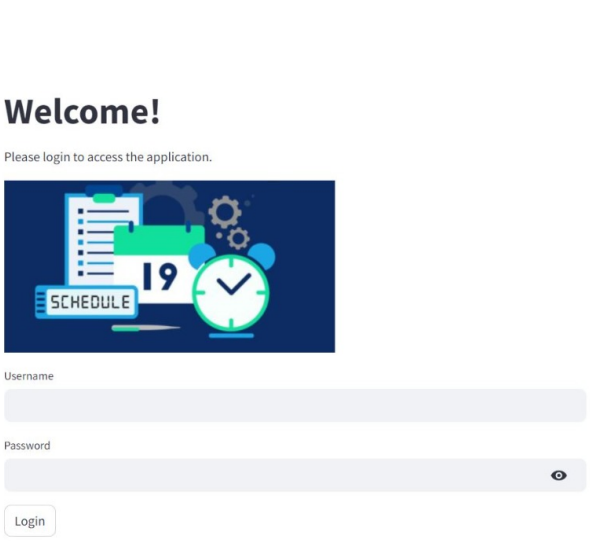

Figure 6: Login Page

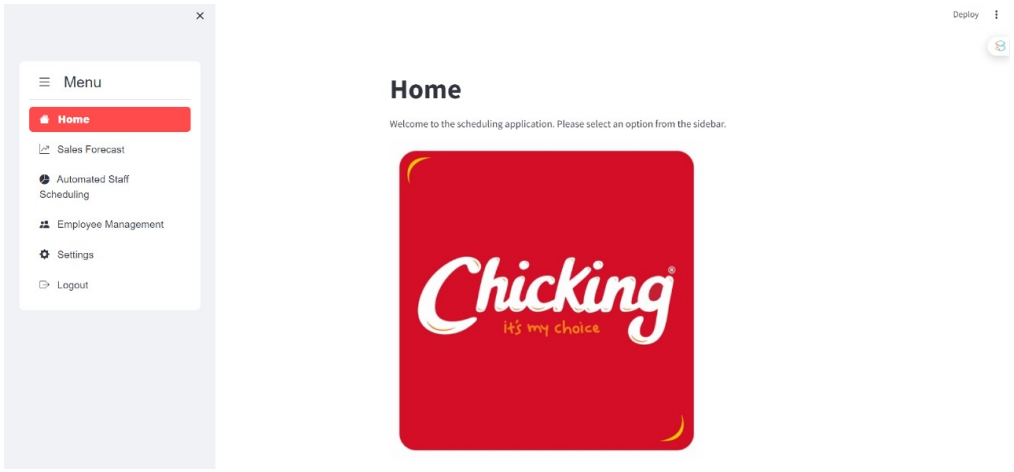

Figure 7: Home Page

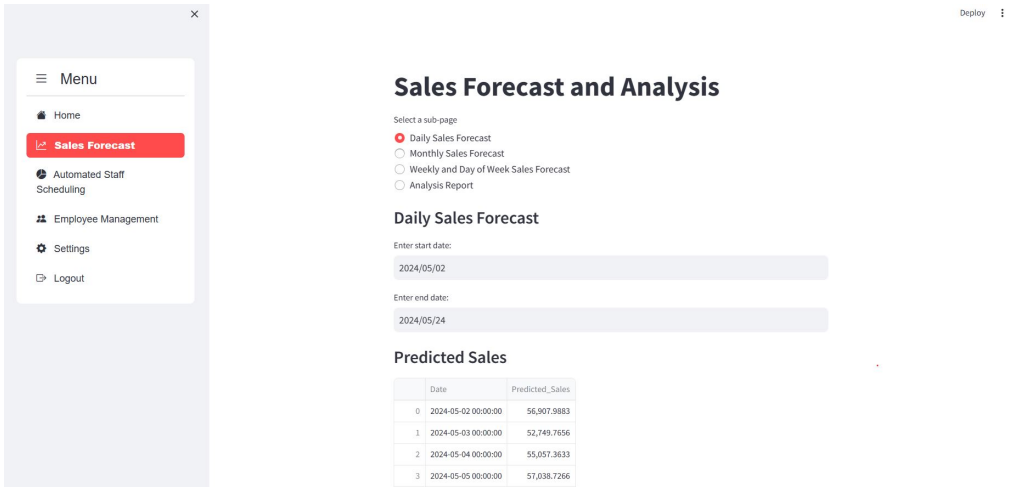

Figure 8: Sales Forecast and Analysis Page

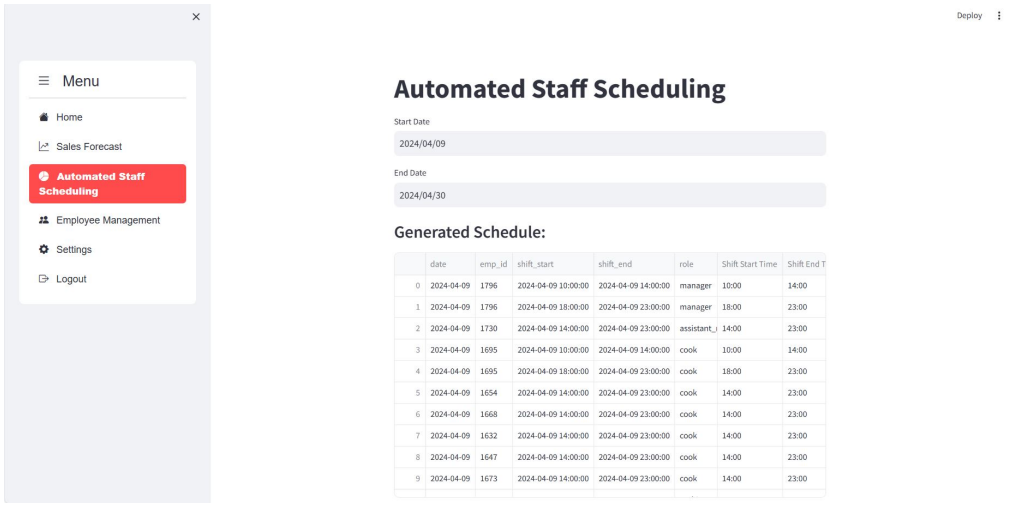

Figure 9: Automated Staff Scheduling

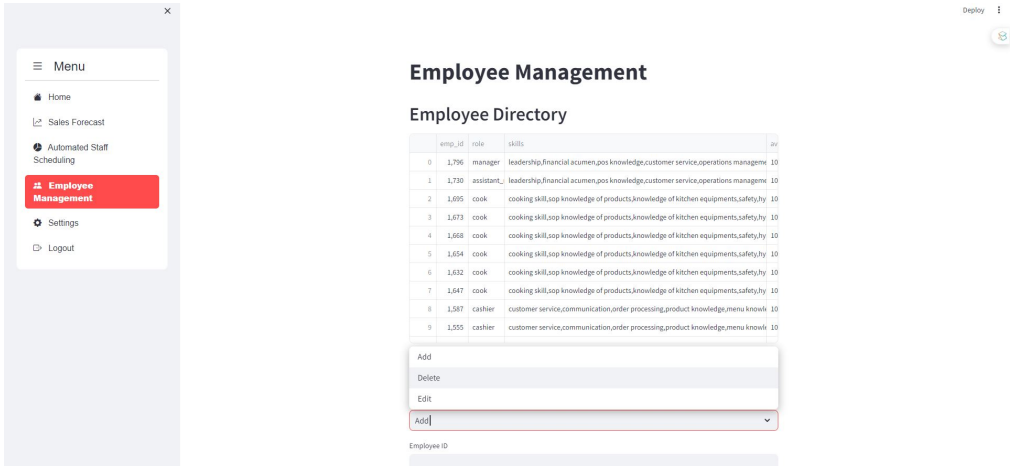

Figure 10: Employee Management Page

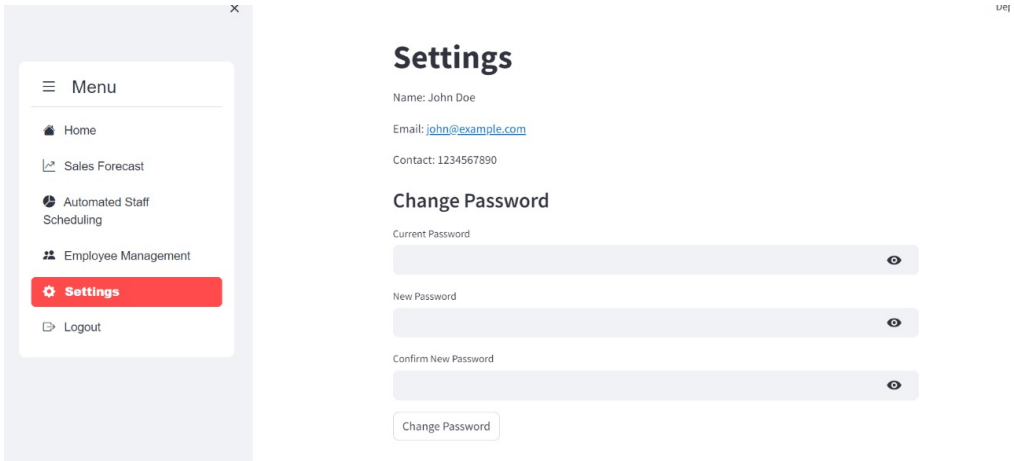

Figure 11: Settings Page

Chapter 6

Conclusion and Future Works

In conclusion, the challenges faced by dining establishments in managing human resources are multifaceted, requiring a holistic approach that integrates advanced technologies and data-driven strategies. The problem statement highlights the critical need to optimize labor costs, minimize employee overtime, and align staffing levels with fluctuating sales demand. To address these challenges, the development of an AI-driven model for minimizing overtime and an intelligent scheduling system for optimal staff allocation is proposed.

The project successfully developed a comprehensive system to optimize labor costs and reduce employee overtime while ensuring optimal staffing levels to meet varying sales demand. By utilizing AI-driven sales forecasting models such as LSTM and XGBoost, and intelligent scheduling optimization with heuristic and Bayesian techniques, the project achieved efficient resource allocation across BOH, FOH, and bar staff roles. The user-friendly Streamlit interface provided intuitive functionalities for sales forecasting, scheduling, and employee management. The system's continuous monitoring and feedback mechanisms enabled ongoing improvements, and the seamless integration with existing business systems like payroll and POS systems facilitated smooth operations.

The future works for the project involve several key enhancements aimed at improving the system's performance and adaptability. One such enhancement includes incorporating real-time data sources, such as current sales figures, temperature, and events, into the model and scheduling system. This integration will enable the system to adapt dynamically to real-time changes in demand and external factors, thereby enhancing its accuracy and responsiveness to fluctuations.

Moving forward, several avenues for future work present themselves. Firstly, continuous refinement and optimization of the AI-driven models and scheduling algorithms are essential to adapt to evolving business needs and industry trends. This includes integrating additional data sources, such as customer feedback and external factors (e.g., weather conditions), to further enhance predictive accuracy.

Secondly, the development of a user-friendly interface for the scheduling system would facilitate seamless implementation and adoption by dining establishments. Incorporating features such as real-time monitoring, shift swapping, and employee feedback mechanisms can improve transparency and communication within the workforce.

Furthermore, exploring the potential of emerging technologies, such as machine learning and natural language processing, to automate administrative tasks and improve decision-making processes could unlock new possibilities for workforce management optimization.

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Appendix

Attained Program Outcomes

PO 1: Engineering Knowledge :

The challenge at hand underscores the critical importance of engineering knowledge in addressing complex issues within the hospitality industry. Engineers are tasked with leveraging their expertise to develop innovative solutions for optimizing labor management in dining establishments. This requires a deep understanding of data analytics, machine learning algorithms, and predictive modeling techniques to effectively tackle the multifaceted challenges of labor optimization, cost reduction, and staffing alignment with sales demand.

PO 2: Problem Analysis:

The problem statement highlights the necessity for rigorous problem analysis in identifying and understanding the intricate challenges faced by dining establishments. Engineers must conduct a comprehensive analysis of historical employee data, past scheduling patterns, and real-time demand variations to uncover underlying issues and opportunities for improvement. By conducting thorough problem analysis, engineers can develop targeted strategies and solutions that address the root causes of inefficiencies in labor management.

PO 3: Design and Development of Solutions:

The objective of developing an AI-driven model and intelligent scheduling system underscores the importance of designing and developing innovative solutions to complex problems. Engineers are tasked with designing robust algorithms and software systems

capable of optimizing labor allocation, minimizing overtime, and enhancing operational efficiency in dining establishments. Through iterative design and development processes, engineers can create solutions that effectively address the unique challenges of workforce management in the hospitality industry.

PO 4: Conduct Investigations of Complex Problems:

Engineers are responsible for conducting in-depth investigations of complex problems related to labor management in dining establishments. This involves analyzing vast amounts of data, identifying patterns and trends, and uncovering insights that inform decision-making processes. By conducting thorough investigations, engineers can gain a deeper understanding of the factors influencing staff allocation, sales demand, and operational efficiency, ultimately leading to the development of effective solutions.

PO 5: Modern Tool Usage:

The utilization of modern tools and technologies, such as Behavioral Decision Networks (BDN) for scheduling and Long Short-Term Memory (LSTM) models for prediction, is essential in addressing the challenges of labor management in the hospitality industry. Engineers must leverage these advanced tools to analyze data, develop predictive models, and design intelligent systems that optimize workforce management and enhance operational efficiency in dining establishments.

PO 6: The Engineer and Society :

Engineers play a crucial role in addressing societal challenges, such as the efficient management of human resources in dining establishments. By developing AI-driven solutions that minimize labor costs, reduce overtime, and enhance customer experiences, engineers contribute to the overall well-being and sustainability of the hospitality industry. Their efforts help to create more efficient and customer-centric dining experiences while supporting the economic viability of restaurants and other dining establishments.

PO 7: Environment and Sustainability:

While the primary focus of the problem statement is on labor management in dining establishments, engineers must also consider the environmental and sustainability implications of their solutions. By optimizing labor allocation and reducing unnecessary overtime, engineers can help minimize energy consumption, waste generation, and environmental impact within dining establishments. Additionally, by promoting operational efficiency and cost-effectiveness, engineers contribute to the long-term sustainability of the hospitality industry as a whole.

PO 8: Ethics:

Ethical considerations are paramount in the development and implementation of AI-driven solutions for labor management in dining establishments. Engineers must ensure that their solutions prioritize fairness, transparency, and accountability in decision-making processes. This includes addressing potential biases in predictive algorithms, protecting employee privacy rights, and upholding ethical standards in workforce management practices. By adhering to ethical principles, engineers can build trust and confidence in their solutions while safeguarding the rights and well-being of employees.

PO 9: Individual and Teamwork:

Addressing the complex challenges of labor management in dining establishments requires a collaborative effort among individual engineers and multidisciplinary teams. Engineers must work together to analyze data, develop algorithms, and design solutions that effectively address the diverse needs of stakeholders. By fostering a culture of collaboration and teamwork, engineers can leverage their collective expertise to develop innovative and impactful solutions that drive positive change in the hospitality industry.

PO 10: Communication:

Effective communication is essential in ensuring the successful development and implementation of AI-driven solutions for labor management in dining establishments. Engineers must communicate effectively with stakeholders, including restaurant owners, managers, employees, and customers, to understand their needs, gather feedback, and address

concerns. By fostering open and transparent communication channels, engineers can ensure that their solutions are aligned with the needs and expectations of all stakeholders, ultimately leading to greater acceptance and adoption.

PO 11: Project Management and Finance:

Engineers are responsible for effectively managing projects and resources to deliver successful outcomes in labor management for dining establishments. This involves developing project plans, setting timelines, allocating resources, and managing budgets to ensure the timely and cost-effective delivery of solutions. By employing sound project management and financial principles, engineers can maximize the impact of their solutions while minimizing risks and optimizing return on investment for stakeholders.

PO 12: Lifelong Learning:

Lifelong learning is essential for engineers to stay abreast of the latest developments in AI, data analytics, and workforce management practices. Engineers must continuously update their skills and knowledge through ongoing education, training, and professional development opportunities. By embracing lifelong learning, engineers can adapt to evolving technologies and industry trends, ensuring that they remain at the forefront of innovation and capable of addressing the ever-changing challenges of labor management in the hospitality industry.