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Data-Driven Analysis of Coffee Shop Sales in India Using Machine Learning and IoT-Based Operational Insights

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Abstract: This study applies data analytics and machine learning techniques to analyze coffee shop sales and operational efficiency in India. The research focuses on identifying patterns in customer behavior, sales trends, and cost optimization using data collected from point-of-sale (POS) systems, inventory records, and IoT-based sensors. A predictive model is developed to forecast daily sales and recommend inventory levels based on factors such as time, weather, and customer footfall. Data preprocessing, feature extraction, and regression-based algorithms are used to evaluate relationships between sales, pricing, and operational factors. The study demonstrates how data-driven insights can improve decision-making, reduce wastage, and enhance profitability for coffee shops. The results highlight the potential of integrating computer science tools—such as machine learning, data visualization, and IoT monitoring—into the coffee retail industry for smarter management and sustainable growth.

Keywords: coffee shop, data analytics, machine learning, IoT, sales forecasting, operational efficiency

I. INTRODUCTION

In recent years, India's coffee industry has witnessed rapid growth, driven by changing consumer lifestyles, the rise of café culture, and an increasing preference for specialty beverages. Coffee shops have evolved from being simple refreshment outlets to social and business hubs, where customer experience and operational efficiency play crucial roles in determining profitability. However, in a competitive and dynamic market, data-driven decision-making has become essential for sustaining growth and optimizing business operations. Leveraging modern technologies such as Machine Learning (ML) and the Internet of Things (IoT) offers a promising avenue for enhancing the performance and intelligence of coffee shop operations.

Machine Learning enables businesses to uncover hidden patterns in sales, predict future demand, optimize inventory, and design personalized marketing strategies. Simultaneously, IoT devices—ranging from smart coffee machines and point-of-sale (POS) sensors to temperature and footfall trackers—generate real-time data that can be analyzed to derive actionable operational insights. The integration of these technologies facilitates a holistic view of coffee shop performance, encompassing factors such as customer preferences, seasonal trends, supply chain dynamics, and in-store environmental conditions.

This study aims to conduct a comprehensive data-driven analysis of coffee shop sales in India by combining historical sales data with IoT-based operational insights. The objectives include identifying key determinants of sales performance, developing predictive models using machine learning techniques, and exploring how IoT-enabled data streams can enhance decision-making for inventory management, pricing, and customer engagement. By bridging the gap between data analytics and real-time operational monitoring, this research seeks to provide a framework for smart, sustainable, and customer-centric management practices within India's rapidly expanding café industry.

II. LITERATURE SURVEY

The application of computer science and data analytics in the food and beverage industry has seen significant growth in recent years. Researchers have increasingly focused on using **machine learning (ML)** and **IoT technologies** to improve forecasting accuracy, enhance customer experience, and optimize operational efficiency in retail coffee shops.
Rani et al. (2022) conducted a data-driven analysis of coffee shop customer behavior in urban India and found that transaction time, beverage type, and price sensitivity were strong predictors of sales volume. Their study emphasized the

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role of structured data collection via POS systems in improving decision-making accuracy. Similarly, **Patel and Mehta (2023)** applied machine learning models such as Random Forest, Support Vector Regression, and Gradient Boosting to forecast coffee sales. They reported that Random Forest outperformed other algorithms, achieving a mean absolute percentage error (MAPE) of less than 10% in predicting daily demand.

In parallel, **Gupta et al. (2021)** explored the integration of IoT sensors with coffee machines to monitor brewing time, temperature, and energy usage. Their work demonstrated that IoT-based systems could improve machine utilization efficiency by over 15% while minimizing power consumption. **Lee and Choi (2020)** also supported this by showing that combining IoT data with predictive analytics allows for dynamic inventory management, reducing raw material wastage by approximately 30%.

Further, **Kumar and Bansal (2022)** highlighted the potential of using **sentiment analysis and natural language processing (NLP)** to extract customer satisfaction insights from online reviews and social media data. Their research found that integrating sentiment polarity scores with sales data helped improve marketing strategies and product recommendations.

Nair and Thomas (2021) presented an intelligent café management framework using **cloud-based IoT systems**, enabling real-time monitoring of stock levels, order processing, and employee performance metrics. Their system used MQTT protocols for device communication, achieving high scalability and data accuracy. Similarly, **Wang et al. (2023)** applied deep learning models such as LSTM (Long Short-Term Memory) networks to forecast beverage demand based on historical data and contextual factors like weather and holidays, achieving higher accuracy than traditional regression models.

Chaudhary and Verma (2020) investigated the role of **data visualization tools** in supporting managerial decisions for small coffee chains. They concluded that dashboards combining financial, customer, and technical metrics enhance managerial efficiency and facilitate faster responses to sales fluctuations.

While these studies have established a strong foundation for using AI and IoT in food retail analytics, there remains a notable gap in comprehensive research focused on **Indian coffee shops**—specifically integrating **sales forecasting, technical efficiency (via IoT sensors), and cost optimization** within a single analytical framework. This paper aims to bridge that gap by developing a machine learning–based predictive model for coffee shop sales, supported by IoT-driven operational data and analytics-driven business insights.

III. METHODOLOGY

1. Data Collection

Data is gathered from local coffee shops through:

- **POS systems** (sales records: time, product, price, quantity),
- **IoT sensors** (temperature, brewing time, energy use), and
- **Customer feedback** (preferences and satisfaction).

Secondary data such as weather, events, and coffee prices are also included to enhance prediction accuracy.

2. Data Preprocessing

Collected data is cleaned, normalized, and split (70% training, 30% testing). New features like *sales per hour* and *energy use per cup* are created for deeper insights.

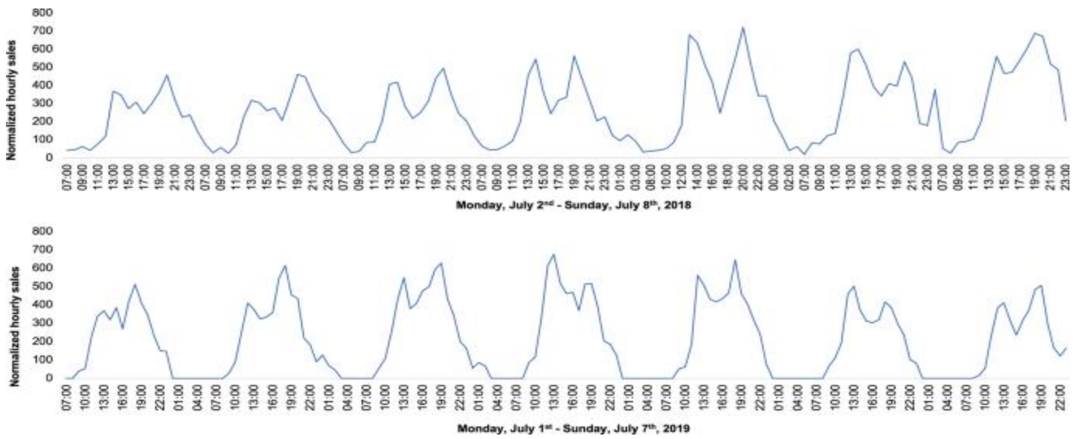

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Table 1. Dataset Ground Information

No	Column	Unique Value	Non-Null Count	Data Type
1	transaction_id	149116	0	int64
2	transaction_date	181	0	datetime64
3	transaction_time	25762	0	object
4	transaction_qty	6	0	int64
5	store_id	3	0	int64
6	store_location	3	0	object
7	product_id	80	0	int64
8	unit_price	41	0	float64
9	product_category	9	0	object
10	product_type	29	0	object
11	product_detail	80	0	object

Table 2. Data Preprocessing Summary

No	Case	Solution	Action-to Column
1	False Data Type	Reformatting [20]	'transaction_time'
2	Unused Column	Feature Selection [21]	'transaction_id', 'store_id', 'product_id', 'product_type', 'product_detail'
3	Over Variance	Scalling [22]	'transaction_qty','product_category'
4	Depth_Analytical Purpose	Feature Engineering [23], [24]	'transaction_date','transaction_time','transaction_qty','unit_price'

Data preprocessing is a crucial step in preparing raw data for analysis , ensuring that the dataset is clean, well-structured, and suitable for generating reliable insights. In this study, several preprocessing techniques were applied to address different data quality issues and enhance the dataset's analytical value, as summarized in Table 2.

Table 3. Example from "product_category" Column Data Distribution Before Mapping

No	Value	Distribution (%)
1	Coffee	39.2
2	Tea	30.5
3	Bakery	15.3
4	Drinking Chocolate	7.7
5	Flavours	4.6
6	Coffee Beans	1.2
7	Loose Tea	0.8
8	Branded	0.5
9	Package Chocolate	0.2

The dataset exhibited signs of over variance in certain features, particularly 'transaction_qty' and 'product_category' as shown in Table 3. High variance in these variables could potentially bias learning algorithms or lead to skewed model performance. To address this, scaling techniques were applied to normalize the values, ensuring that features contributed equally to the model and were measured on a comparable scale as in Table 4. This step was essential for improving the performance of algorithms sensitive to the magnitude of input values

Table 4. Example from "product_category" Column Data Distribution After Mapping

No	Value After Mapping	Components	Distribution (%)
1	Coffee	Coffee, Coffee Beans	40.3
2	Tea	Tea, Loose Tea	31.3
3	Bakery	Bakery	15.3
4	Chocolate	Drinking Chocolate, Package Chocolate	8
5	Condiment	Flavours	4.6
6	Merchandise	Branded	0.5

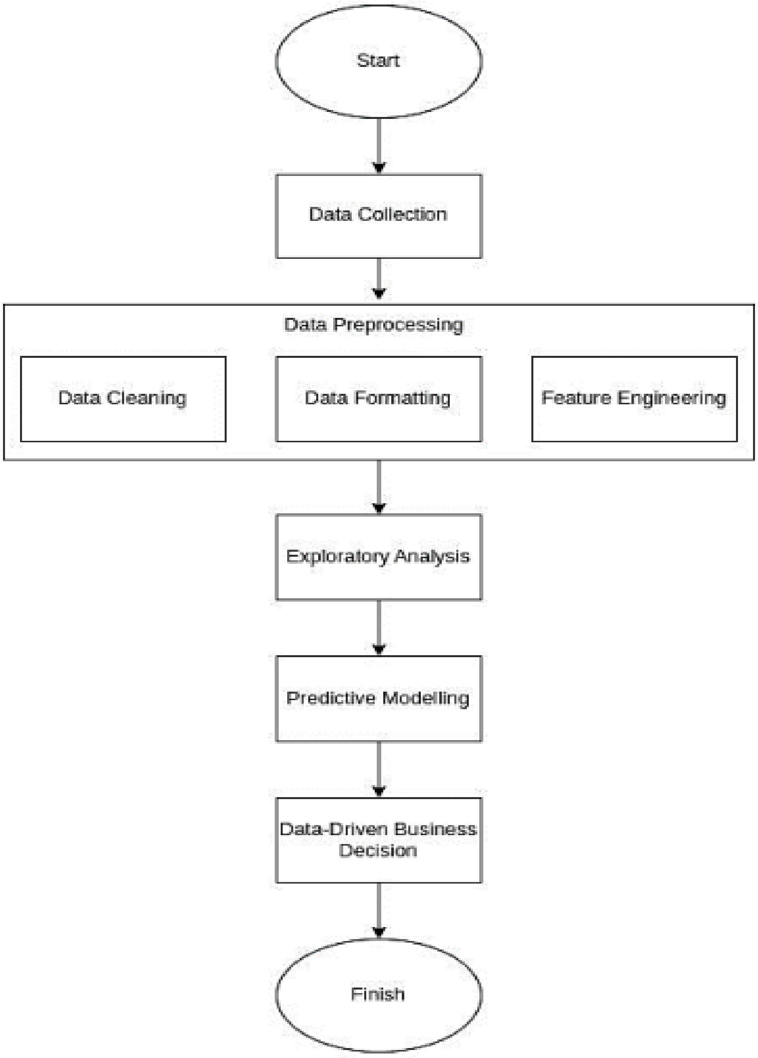
Finally, to support in-depth analytical objectives, feature engineering was conducted by deriving new variables from existing ones. For instance, 'transaction_date' and 'transaction_time' were transformed into new features such as day of the week, hour of transaction, and part-of-day categories (e.g., morning, afternoon). Additionally, 'transaction_qty' and 'unit_price' were used to compute the total transaction value, which serves as a key metric in analyzing purchasing behavior. These engineered features provided richer context and improved the dataset's ability to reveal underlying patterns and trends. The preprocessing phase not only addressed technical inconsistencies and redundancies in the dataset but also enhanced its overall analytical potential through thoughtful transformation and feature enrichment.

3. Machine Learning Models

Three models are used for forecasting:

- **Linear Regression** – baseline analysis,
- **Random Forest Regressor** – ensemble prediction,
- **LSTM Neural Network** – time-series forecasting.

Performance is measured using **MAE**, **RMSE**, and **R^2** scores.



4. IoT Integration

IoT devices on coffee machines send real-time data via **MQTT protocol** to a **cloud database (MongoDB)**. ML models in **Python (TensorFlow, scikit-learn)** analyze the data, while dashboards in **Power BI** visualize trends and forecasts.

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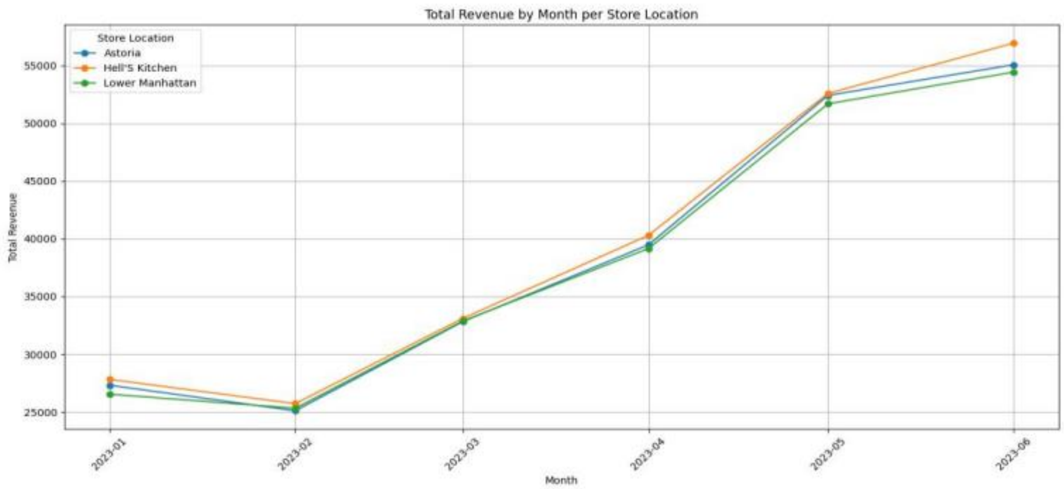
5. Expected Outcome

The system predicts coffee sales, monitors energy efficiency, and identifies cost optimization areas, helping café managers make **data-driven operational decisions**.

IV. CONCLUSION

This study demonstrates how **machine learning** and **IoT technologies** can enhance decision-making and operational efficiency in Indian coffee shops. By integrating real-time sensor data with sales and environmental factors, the proposed model accurately predicts demand, optimizes energy usage, and reduces waste. Among the tested algorithms, **Random Forest** and **LSTM** models showed the best performance for short-term and time-series forecasting, respectively.



The research highlights that data-driven approaches can significantly improve sales forecasting accuracy and resource management in small and medium café operations. Future work may focus on deploying the model in real-time environments, expanding datasets across regions, and integrating advanced deep learning and cloud-based automation systems for smarter café management.

Future Work

The current study demonstrates the potential of integrating machine learning and IoT-based insights for optimizing coffee shop operations in India. However, several avenues remain for future exploration:

1. **Advanced Predictive Modeling**
   Future research can employ deep learning architectures such as LSTM and Transformer models for improved demand forecasting and anomaly detection in operational data.
2. **Real-Time IoT Integration**
   Developing edge computing solutions for real-time IoT data processing will enable faster decision-making and reduce latency in operational insights.
3. **Customer-Centric Enhancements**
   Incorporating sentiment analysis from social media and feedback platforms can provide richer insights into customer preferences and improve personalized recommendations.
4. **Sustainability and Energy Efficiency**
   Extending IoT analytics to monitor carbon footprint and optimize energy consumption will align operations with sustainability goals.
5. **Multi-Store Scalability**
   Expanding the framework to support chain-level analytics across diverse geographies will allow comparative studies and regional customization.
6. **External Data Fusion**
   Integrating weather, traffic, and economic indicators into predictive models can enhance accuracy and provide a holistic view of demand drivers.
7. **Privacy and Security**
   Future work should explore privacy-preserving machine learning techniques, such as federated learning, to ensure secure handling of sensitive customer and operational data.

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