ISSN: 2582 - 6379
IJISEA Publications
International Journal for Interdisciplinary Sciences and Engineering Applications
IJISEA - An International Peer- Reviewed Journal
2026, Volume 7 Issue 2
www.ijisea.org

Article Info

Date Received: 15/03/2026
Date Revised: 05/04/2026
Available Online: 27/04/2026

Intelligent Customer Segmentation And Lifetime Value Prediction Using Rfm Analysis And Machine Learning with KPI Dashboard Visualization

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DOI: 10.64264/ijisea/0742

ABSTARCT

In today's competitive business environment, understanding customer behavior and predicting customer value are essential for effective marketing and business growth. This project focuses on Customer Segmentation and Customer Lifetime Value (CLTV) Prediction using data modelling techniques. The system analyzes customer transactional data using Recency, Frequency, and Monetary (RFM) analysis to evaluate customer purchasing behavior. Based on these features, K-Means clustering is applied to segment customers into different groups according to their value and activity patterns. Furthermore, a regression-based predictive model is developed to estimate the Customer Lifetime Value, enabling businesses to identify high-value customers and plan targeted marketing strategies. The system also includes an interactive dashboard developed using Streamlit, which allows users to visualize customer segments, analyze patterns, and predict CLTV efficiently. This approach helps organizations make data-driven decisions, improve customer retention, and maximize long-term profitability.

Key words: Customer Lifetime Value (CLTV), Customer Segmentation, RFM Analysis, K-Means Clustering, Machine Learning, Predictive Modelling, Streamlit Dashboard

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1. INTRODUCTION

In the modern digital economy, businesses generate large volumes of customer data through transactions, online interactions, and purchasing activities. Analyzing this data effectively is crucial for organizations to understand customer behavior, improve marketing strategies, and maximize profitability. One of the key techniques used in customer analytics is customer segmentation, which divides customers into meaningful groups based on similar behavioral characteristics. By identifying these segments, businesses can develop targeted marketing campaigns, improve customer engagement, and enhance long-term customer relationships.

Traditional marketing approaches often treat customers as a homogeneous group, ignoring differences in purchasing behavior and value contribution. Such methods limit the ability of businesses to identify high-value customers and allocate resources efficiently. Another critical challenge for organizations is estimating Customer Lifetime Value (CLV), which represents the total revenue a business can expect from a customer over the entire duration of their relationship. Without proper analytical tools, predicting lifetime value and identifying valuable customers becomes difficult, resulting in ineffective marketing strategies and reduced business growth.

To address these challenges, data-driven techniques such as Recency, Frequency, and Monetary (RFM) analysis and machine learning algorithms have gained significant attention in customer analytics. RFM analysis evaluates customer behavior based on how recently a customer made a purchase, how frequently they purchase, and how much money they spend. Machine learning models, such as K-Means clustering, can further enhance segmentation by identifying patterns in customer data and grouping customers with similar behavioral attributes. These approaches enable organizations to better understand customer value and predict future purchasing potential.

In this paper, we propose an Intelligent Customer Segmentation and Lifetime Value Prediction system using RFM Analysis and Machine Learning with KPI Dashboard Visualization. The proposed system utilizes RFM metrics to analyze customer transaction data and applies clustering techniques to categorize customers into different segments. Additionally, predictive modeling is used to estimate customer lifetime value, enabling businesses to identify high-value customers. To improve decision-making and accessibility of insights, an interactive KPI dashboard is developed to visualize key performance indicators, customer segments, and predicted lifetime values. This approach enables businesses to make data-driven marketing decisions, improve customer retention strategies, and enhance overall business performance.

2. LITERATURE REVIEW

Customer segmentation and customer lifetime value prediction have become important research areas in marketing analytics and data science. Many researchers have proposed data-driven approaches to analyze customer behavior and improve business decision-making.

Several studies have applied Recency, Frequency, and Monetary (RFM) analysis as an effective method for evaluating customer purchasing behavior. RFM analysis allows businesses to categorize customers based on their transaction history and spending patterns. Research has shown that RFM-based segmentation helps organizations identify loyal customers, inactive customers, and potential high-value customers, enabling more targeted marketing strategies.

Machine learning techniques have further enhanced customer segmentation by identifying hidden patterns in large datasets. Clustering algorithms such as K-Means clustering are widely used to group customers with similar behavioral characteristics. Previous studies have demonstrated that clustering methods can effectively segment customers into meaningful groups, allowing companies to design personalized marketing campaigns and improve customer retention.

In addition to segmentation, predicting Customer Lifetime Value (CLV) has received significant attention in recent years. Various predictive modeling techniques such as regression models, decision trees, and ensemble learning methods have been used to estimate the long-term value of customers. Accurate CLV prediction enables businesses to allocate resources efficiently and focus on retaining high-value customers.

Recent advancements in business analytics have also introduced data visualization and dashboard systems to support decision-making. KPI dashboards provide interactive visual representations of key metrics such as customer segments, purchasing trends, and revenue distribution. These dashboards help businesses interpret complex data more effectively and make data-driven strategic decisions.

Despite these advancements, many existing systems focus either on customer segmentation or lifetime value prediction independently, without integrating both analytical techniques into a single framework. Moreover, limited emphasis has been placed on combining machine learning models with interactive visualization tools that can assist business users in understanding customer insights.

To address these limitations, the proposed system integrates RFM-based customer segmentation, machine learning-based lifetime value prediction, and KPI dashboard visualization into a unified framework. This approach provides businesses with a comprehensive platform for analyzing customer behavior, predicting future value, and supporting strategic marketing decisions.

3. METHODOLOGY

The proposed system aims to analyze customer transaction data to perform customer segmentation and predict customer lifetime value using machine learning techniques. The overall methodology consists of multiple stages, including data collection, preprocessing, feature

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extraction using RFM analysis, customer segmentation through clustering algorithms, lifetime value prediction using predictive models, and visualization through a KPI dashboard.

3.1 Data Collection

The dataset used in this study consists of customer transactional data containing information such as customer ID, purchase date, number of transactions, and transaction amount. This data serves as the foundation for analyzing customer purchasing behavior and identifying patterns that influence customer value. The collected dataset is used to compute behavioral metrics required for further analysis.

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1	InvoiceNo	StockCode	Descriptio	Quantity	InvoiceDat	UnitPrice	Customerl	Country
2	536365	85123A	WHITE HA	6	########	2.55	17850	United Kingdom
3	536365	71053	WHITE ME	6	########	3.39	17850	United Kingdom
4	536365	84406B	CREAM CL	8	########	2.75	17850	United Kingdom
5	536365	84029G	KNITTED L	6	########	3.39	17850	United Kingdom
6	536365	84029E	RED WOO	6	########	3.39	17850	United Kingdom
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22	536367	48187	DOORMAT	4	########	7.95	13047	United Kingdom
23	536368	22960	JAM MAKI	6	########	4.25	13047	United Kingdom

Fig 1: Sample Dataset

3.2 Data Preprocessing

Data preprocessing is an essential step to ensure the quality and reliability of the dataset. In this stage, missing values, duplicate records, and inconsistent entries are identified and removed. The data is then transformed into a structured format suitable for analysis. Additionally, relevant features such as purchase frequency, transaction dates, and monetary values are extracted to support customer behavior analysis.

3.3 RFM Analysis

Recency, Frequency, and Monetary (RFM) analysis is used to evaluate customer purchasing behavior. The three RFM parameters are defined as follows:

- Recency (R): Measures how recently a customer made a purchase.
- Frequency (F): Indicates how often a customer makes purchases.
- Monetary (M): Represents the total amount spent by a customer.

These metrics are calculated for each customer and used to generate RFM scores. The RFM scores help in identifying customer engagement levels and provide meaningful features for segmentation.

3.4 Customer Segmentation using K-Means Clustering

Customer segmentation is performed using the K-Means clustering algorithm, which groups customers based on similarities in their RFM values. The algorithm partitions customers into multiple clusters where each cluster represents a specific customer category such as high-value customers, loyal customers, or low-engagement customers. This segmentation helps businesses better understand customer behavior and design targeted marketing strategies.

3.5 Customer Lifetime Value (CLTV) Prediction

To estimate the long-term value of customers, a predictive model is developed using machine learning techniques. The model analyzes historical transaction data and RFM features to predict the potential lifetime value of each customer. Predicting CLTV enables businesses to identify high-value customers and allocate marketing resources more efficiently.

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3.6 KPI Dashboard Visualization

To improve accessibility and usability of the analytical results, an interactive KPI dashboard is developed using Streamlit. The dashboard presents key performance indicators such as customer segmentation distribution, predicted lifetime value, purchase trends, and revenue insights. The visualization helps businesses interpret complex analytical results and supports data-driven decision-making.

4. RESULTS AND OUTPUTS

The proposed system was implemented to analyze customer transaction data and generate meaningful insights through customer segmentation and lifetime value prediction.

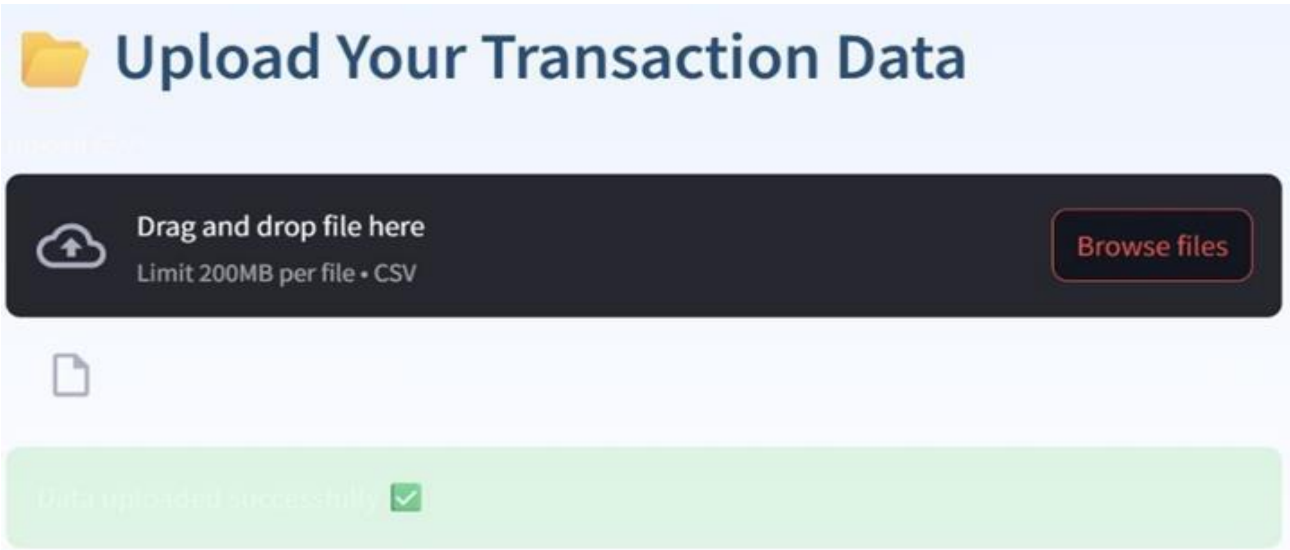

Fig 2: Customer Life Time Value App – Upload Data

The results demonstrate the effectiveness of using RFM analysis and machine learning techniques to identify different customer categories and estimate their long-term value.

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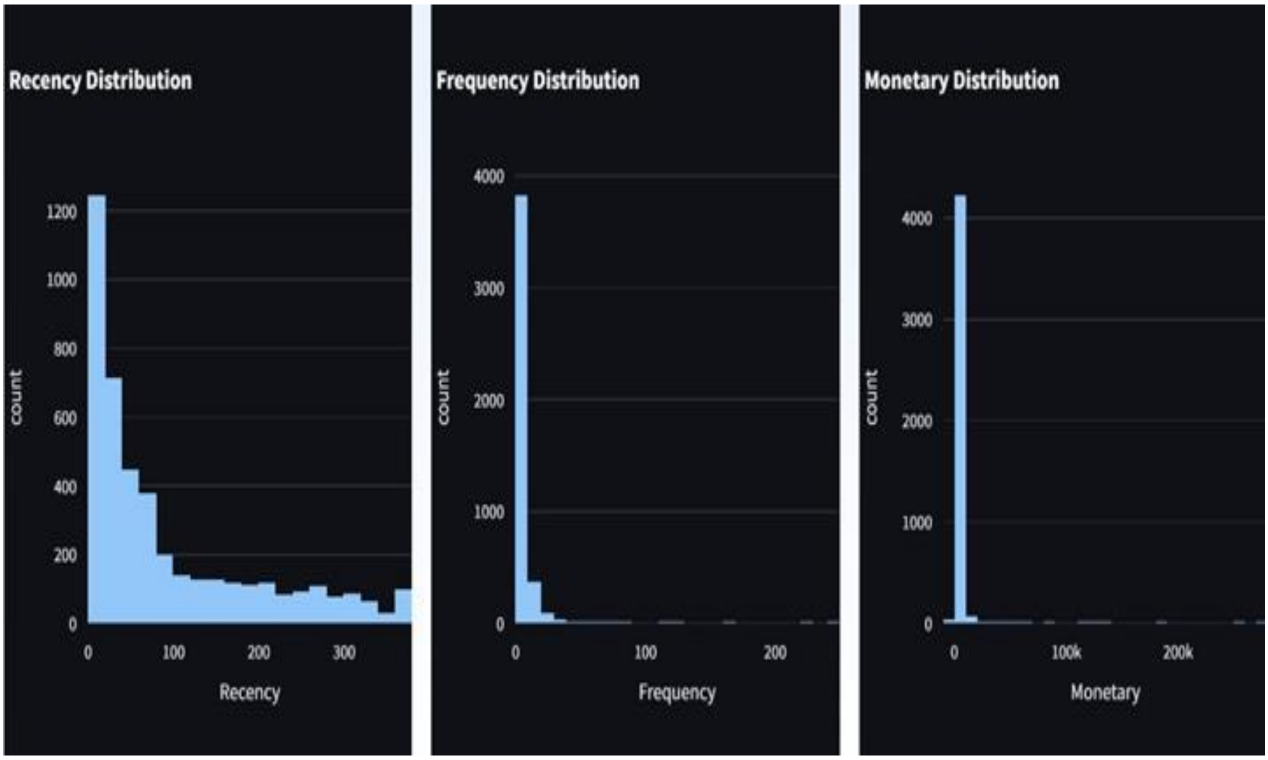

Fig 3 : RFM Score Distribution

Initially, the dataset was processed to calculate the Recency, Frequency, and Monetary (RFM) values for each customer. These metrics helped in evaluating customer purchasing behavior and identifying variations in customer engagement and spending patterns. The computed RFM features served as the input for the clustering model.

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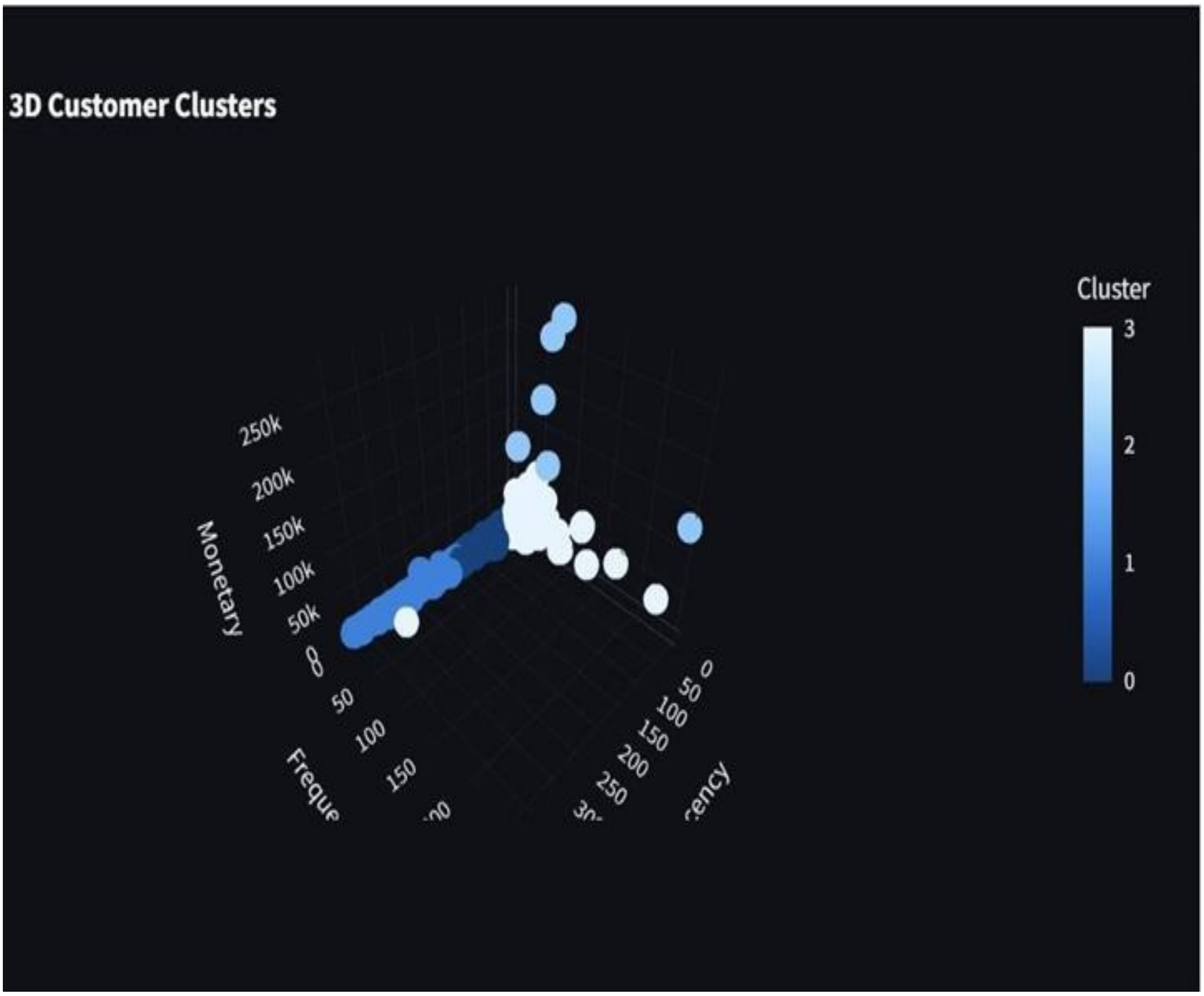

Fig 4 : K-Means Customer Segmentation Clusters

The K-Means clustering algorithm was applied to segment customers based on their RFM scores. The clustering process grouped customers into distinct segments representing different behavioral categories such as high-value customers, loyal customers, regular customers, and low-engagement customers. This segmentation enables businesses to better understand customer characteristics and design personalized marketing strategies.

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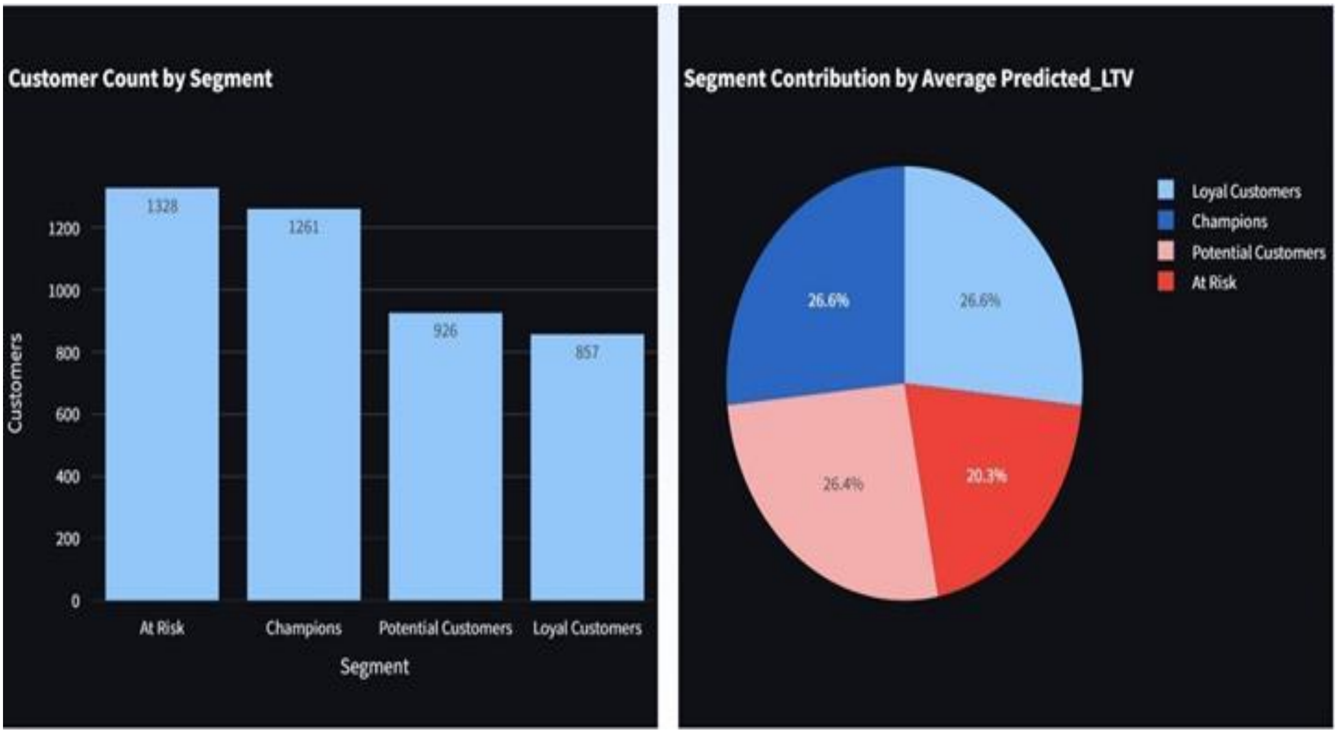

Fig 5 : KPI Dashboard — Revenue and Trend Analysis0

Furthermore, the predictive model was used to estimate Customer Lifetime Value (CLTV) based on historical purchasing patterns and RFM features. The model successfully identified customers with high revenue potential, allowing organizations to prioritize these customers for retention and targeted promotions.

Fig 6: KPI Dashboard — Segment Overview

To improve interpretability and usability of the analytical results, an interactive KPI dashboard was developed. The dashboard visualizes key metrics such as customer segmentation distribution, predicted lifetime value, and purchasing trends. Through these visualizations, business users can easily monitor customer performance indicators and gain insights into revenue contribution from different customer groups.

Overall, the experimental results demonstrate that combining RFM analysis, machine learning clustering, and predictive modeling with KPI visualization provides a powerful framework for customer analytics. The system enables organizations to better understand customer behavior, improve marketing strategies, and make data-driven business decisions.

5. CONCLUSION

In this study, an intelligent framework for customer segmentation and customer lifetime value prediction was developed using RFM analysis and machine learning techniques. The proposed system analyzes customer transaction data to understand purchasing behavior and classify customers into meaningful segments. By applying RFM metrics and the K-Means clustering algorithm, customers were effectively grouped based on their recency, frequency, and monetary spending patterns.

In addition to segmentation, a predictive model was utilized to estimate Customer Lifetime Value (CLTV), enabling businesses to identify high-value customers and prioritize them for targeted marketing and retention strategies. The integration of an interactive KPI dashboard further enhances the usability of the system by providing clear visualizations of customer insights, segmentation results, and revenue patterns.

The results demonstrate that combining data analytics, machine learning, and visualization tools can significantly improve customer understanding and support data-driven decision-making. The proposed approach provides a scalable solution that can assist businesses in optimizing marketing strategies, improving customer retention, and maximizing long-term profitability.

Future work can further enhance the system by incorporating advanced machine learning models such as deep learning and ensemble methods to improve prediction accuracy. Real-time customer analytics can be integrated to enable dynamic segmentation and lifetime value updates. More sophisticated visualization techniques and natural language interfaces can be added for deeper business insights. The system can also be extended to support cross-industry applications and deployed on cloud platforms for broader scalability and accessibility. Incorporating Explainable

AI (XAI) techniques will improve the transparency and interpretability of the predictive models, increasing trust among business users.

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