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AN INTELLIGENT REAL-TIME MARKET DAY IDENTIFICATION FRAMEWORK USING MACHINE LEARNING FOR SOCIOECONOMIC ANALYSIS OF TRADITIONAL MARKETS IN KOGI STATE

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Abstract

Periodic markets play a critical role in rural socioeconomic systems. Yet, their operations are often constrained by limited access to accurate market-day information and a lack of data-driven insights into their economic impacts. This study presents an integrated framework for identifying real-time market days and modeling the socioeconomic impact of periodic markets in Kogi State, Nigeria. To realize this objective, an application was developed to digitally identify and disseminate market-day information for major markets operating in the state. This will greatly improve accessibility and planning for market participation. To measure the impact of such a system, machine learning and data analysis techniques were applied in modeling the socioeconomic viability of the day-to-day activities in the markets using market-related dataset with 53 instances and market-related indicators like population density, transportation cost variations, market location,

Keywords: Periodic Markets, Real-time Market-Day Tracking, Socioeconomic Impact Modeling, Machine Learning Analytics, Decision Tree Model.

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establishment type, and environmental conditions. Decision Tree–based models were employed to capture nonlinear relationships and assess the relative importance of these factors in explaining commodity price reduction during market days. The results indicate that population density, market location, and market establishment type are the most influential determinants of price behavior, while environmental and institutional factors also play meaningful roles. The study demonstrates that integrating real-time market information systems with machine learning analytics provides actionable insights for traders, consumers, and policymakers. This approach contributes to improved market efficiency, informed decision-making, and sustainable planning of periodic markets in developing economies.

INTRODUCTION

Traditional open markets remain a central pillar of socioeconomic life in many developing economies, particularly in Nigeria, where periodic market days structure trade, mobility, pricing behavior, and social interaction (Gbarawae et al., 2025; Joshua et al., 2024). Market days function as organized temporal systems rather than isolated commercial events, influencing commodity price fluctuations, transportation demand, population concentration, and exposure to infrastructural and environmental constraints (Enefola et al., 2024; Ochiche et al., 2021). Despite their importance, the scheduling, identification, and analysis of market-day activities have largely remained informal, static, and experience-driven, limiting their usefulness for systematic planning, forecasting, and evidence-based policymaking (Khan et al., 2018; Ochiche et al., 2021).

Across other application domains, advances in digital technologies and intelligent systems have significantly improved the management of recurring, time-based events. Studies on real-time Islamic prayer time computation demonstrate how algorithmic modeling grounded in astronomy and mathematics improves accuracy over static, manually prepared schedules (Rojak et al., 2022). Similarly, social event tracking platforms integrating real-time analytics have enhanced event coordination, personalization, and stakeholder engagement beyond traditional ticketing-focused systems (Nazir et al., 2024). In agriculture and climate-related domains, intelligent monitoring systems and machine learning models have been successfully applied to manage cyclical processes, predict environmental conditions, and support precision decision-making (Math & Dharwadkar, 2020). Collectively, these studies reflect a broader transition toward intelligent temporal analytics, where recurring events are dynamically monitored and analyzed using data-driven techniques. However, the extension of such approaches to

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traditional market-day systems—particularly for integrated socioeconomic impact assessment—remains underexplored.

Existing literature on periodic markets has established their critical economic and social roles. Spatial and temporal studies of Nigerian rural markets reveal that market-day arrangements influence accessibility, trader participation, commodity diversity, and overall market efficiency, with poor spatial–temporal coordination often leading to inefficiencies (Ochiche et al., 2021). Empirical evidence from Kogi State further shows that periodic markets contribute significantly to livelihoods through economic exchange, social integration, political organization, physical aggregation of goods, and informal learning (Adedayo et al., 2023; Enefola et al., 2024). Historical and qualitative analyses of major markets in Nigeria illustrate how structured market systems sustain economic activity and demonstrate resilience even under adverse conditions such as public health crises (Alazor et al., 2024; Liman, 2024). Beyond Nigeria, related studies emphasize that livelihood outcomes are sensitive to market access, seasonal fluctuations, environmental constraints, and institutional arrangements (Alam & Yousuf, 2024; Bui et al., 2025).

Despite these contributions, most prior studies rely predominantly on descriptive statistics, spatial analysis, surveys, and qualitative assessments to explain market structure and impacts. Few adopt predictive or integrative analytical approaches capable of capturing the complex, non-linear interactions among key market-day indicators such as population density, transportation cost dynamics, environmental conditions, and institutional characteristics. Moreover, the absence of centralized digital platforms for identifying and disseminating market-day information constrains the ability of traders, consumers, transport operators, and policymakers to anticipate conditions and make timely, informed decisions (Adedayo et al., 2023).

Machine learning offers a suitable methodological pathway for addressing these limitations by enabling the modeling of complex relationships inherent in market-day dynamics and providing predictive, interpretable insights for policy and planning (Aguiar-Pérez et al., 2023; Omonayin et al., 2025). Decision-tree-based approaches are particularly relevant due to their transparency and suitability for socioeconomic applications. Within this context, this study integrates two complementary contributions: the development of a machine learning–based framework for modeling the socioeconomic impacts of market-day activities in Kogi State, and the development of a software application for real-time identification of market days across recognized markets in the state.

By unifying real-time market-day tracking with machine learning–driven socioeconomic analysis, this research bridges the gap between analytical insight and practical deployment. The proposed framework extends existing literature on real-time event tracking systems into the domain of traditional market analytics and provides a scalable,

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data-driven foundation for improving market accessibility, economic planning, and governance in emerging economies.

METHODOLOGY

Research Design

This study adopted a hybrid research design that integrates data-driven analytical modeling with software system development. The design combines quantitative analysis using Data analysis and machine learning techniques with an applied system development approach to deliver both theoretical insight and a functional technological artifact. This approach was selected to ensure that the research outcomes not only explain the socioeconomic effects of market-day activities but also provide a deployable software solution for real-time market-day identification in Kogi State.

Study Area

The study was conducted using market data obtained from various Local Government Areas (LGAs) within Kogi State, Nigeria. Kogi State is strategically located in North-Central Nigeria and serves as a commercial link between the northern and southern regions of the country. Traditional market days play a vital role in the state's local economy, influencing trade volume, transportation patterns, pricing of commodities, and social interaction. The diversity of markets across rural and urban LGAs makes the state suitable for studying socioeconomic impacts associated with market-day dynamics.

Data Collection and Description

Collection of this study dataset required the following process:

1. Identification and validation of market-related features focusing of market day identification, economic, social, environmental, and infrastructural dimensions. The validation process were carried out by experts in business and market analysis,
2. Preparation of questionnaire using the market-related features
3. Employment of surveyor for each LGA. Using the prepared questionnaire, the surveyors are responsible for collecting data from all the markets within the LGA.
4. Integration of all data collected in a single repository

The dataset used in this research was obtained from a structured market survey compiled into an Excel file titled *Market Data for Analysis*. The dataset consists of records from 53 markets across Kogi State and includes both economic and infrastructural attributes. Key features in the dataset include Local Government Area, market name, most recent market day, market days intervals, type of market, categories of commodities traded, variation in

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commodity prices on market days, transportation availability, transportation fee hikes, population density, flood conditions, market location, and market establishment ownership.

These variables collectively capture the economic, social, environmental, and infrastructural dimensions required to model the socioeconomic impact of market-day activities. The dataset is largely categorical in nature, making it suitable for classification-based machine learning techniques.

In addition to supporting machine learning analysis, this dataset serves as the foundational data source for the software application, enabling the mapping of market identities to their respective market-day characteristics.

Data Preprocessing and Transformation

Prior to model development, the dataset underwent several preprocessing steps to ensure quality and suitability for machine learning analysis. First, column names were standardized and simplified to enhance readability and ease of implementation. Records with missing values in key target variables, particularly those relating to commodity price behavior were removed to prevent bias and inconsistency in model training.

Since most features were categorical, label encoding was applied (using the python labelEncoder method) to transform textual categories into numerical representations required by machine learning algorithms. This encoding preserved category distinctions while enabling computational processing. The dataset was then partitioned into feature variables (independent variables) and a target variable representing whether commodity prices are lower on market days.

The target variable for the predictive model was defined as commodity price behavior on market days, specifically whether prices are lower on market days compared to other days. This variable serves as a direct indicator of economic impact on consumers and traders.

The independent variables included market type, commodities traded, transportation availability, transportation fee hikes, population density, flood condition, market location, and market establishment type. These features were selected because of their strong relevance to socioeconomic activity, market accessibility, and cost dynamics associated with market days.

Market-Day Identification Modeling

Market-day identification was treated as a core functional requirement of the software system. Each market record was associated with attributes (*Local Government Area, Market name, Most recent market day (Market Current/Past Day), Market Days intervals*)

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that describe its operational characteristics and market-day behavior. These attributes were structured into a lookup and rule-based mapping algorithm (as in figure 1) that enables the system to identify and present the correct market day(s) for each market. This identification mechanism forms the backbone of the software application, allowing users to query markets by name or location and retrieve accurate market-day information in real time.

Input: Market Name, Market Current/Past Day, Market Days Interval (Frequency)
Output: Market Name and Next Market Day
Logic Rule:

1. **Select** *Market Current/Past Day* and *Market Days Interval*
2. **Add** *Market Days Interval* to *Market Current/Past Day*
3. **Check if** *Market Past/Current Day is today* **Or** *after today*:
   If Yes; Next *Market Day* is *today* or *after today*, **If No**;
   Repeat 2.

Figure 1: Algorithm for Market Day Identification

Machine Learning Model Development

Using the sklearn.tree library within python programming platform, a Decision Tree Classifier was employed and implemented as the primary machine learning algorithm for this study. The choice of this algorithm was informed by its simplicity, interpretability, and effectiveness when working with categorical data. Decision trees are particularly suitable for socioeconomic studies because they provide clear insight into how specific features influence outcomes, which is important for policy and planning purposes.

Using the sklearn.model_selection the dataset was split into training and testing subsets using a 70:30 ratio. The training dataset was used to build the predictive model, while the testing dataset was used to evaluate model performance and generalization capability. The model learned decision rules that relate market characteristics to commodity price behavior on market days.

Model Evaluation and Interpretability

To assess the performance of the developed model, standard classification evaluation metrics were employed. These included accuracy, precision, recall, and F1-score, as presented through a classification report. These evaluation measures provide insight into how well the model predicts price reduction outcomes and its reliability in supporting real-

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time market day analytics. Data visualization techniques were applied to enhance interpretability and support analytical insights. Feature importance plots derived from the decision tree model were used to identify the most influential variables affecting commodity price behavior on market days. This helps to highlight key socioeconomic drivers such as transportation cost, population density, and market location.

Software Application Development Methodology

The software application was developed using a modular and incremental development approach, consistent with lightweight agile principles. As described in figure 2, the application architecture consists of three logical layers: data layer, application logic layer, and user interface layer.

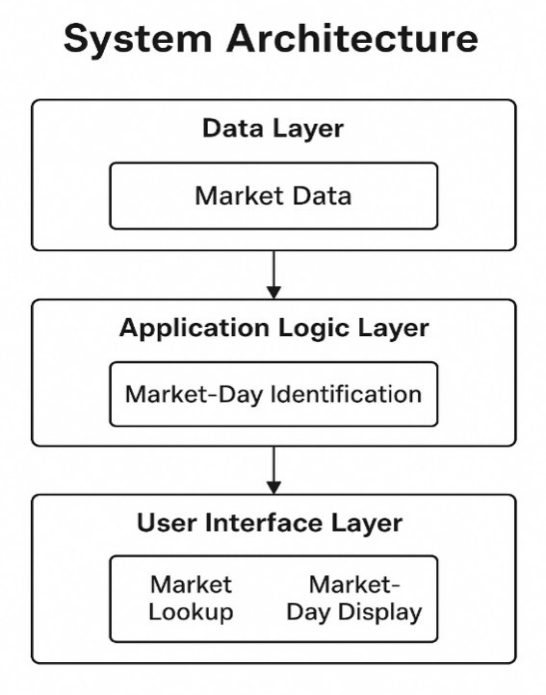


Figure 2: Market Day Identification System Architecture

The data layer manages market records and market-day mappings derived from the preprocessed dataset. The application logic layer implements market-day identification rules and integrates analytical insights derived from the machine learning model. The user interface layer provides an accessible platform through which users can identify market days for specific markets and locations. The design emphasizes simplicity, scalability, and ease of use, ensuring that the application can be extended to incorporate real-time updates, predictive analytics, and notification services in future implementations.

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Ethical Considerations

The dataset used in this study contains no personally identifiable information and focuses solely on market-level characteristics. As such, the research poses minimal ethical risk. All data were used strictly for academic purposes, and interpretations were made objectively to avoid misrepresentation of communities or markets.

RESULTS AND DISCUSSION

Socioeconomic Impact Modelling Results Presentation and Discussion

The socioeconomic impact modelling focused on examining how periodic market dynamics influence commodity pricing, transportation-related features, and environmental constraints within rural market environments.

Commodities Pricing Modelling

For modelling whether commodity prices are lower on market days based on the market-related features dynamics, the decision tree-based model was developed. During the model development, the dependent variable for the predictive analysis was whether commodity prices are lower on market days, while independent variables included the other market-related socioeconomic indicators derived from the survey dataset.

The Decision Tree based model performance is illustrated in figure 3, where 0 indicates No Commodities Price Reduction and 1 indicates Commodities Price Reduction. To understand the Decision Tree based modelled relationships, a feature importance rankings was used. As observed in figure 4 the model outputs revealed clear variations in feature importance, indicating that not all socioeconomic factors contribute equally to price reductions during market days.

```
Classification Report:

              precision    recall  f1-score   support

           0       0.00      0.00      0.00         1
           1       0.92      1.00      0.96        12

    accuracy                           0.92        13
   macro avg       0.46      0.50      0.48        13
weighted avg       0.85      0.92      0.89        13
```

Figure 3: Decision Tree Based Model Performance

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Figure 4: Feature Importance in Market Day Price Reduction

The Decision Tree–based model demonstrated a high overall classification accuracy of 92%, indicating that it was generally effective in predicting whether commodity prices reduce during market days. The strong performance for class 1 (price reduction observed) is evidenced by a precision of 0.92, perfect recall of 1.00, and an F1-score of 0.96. This suggests that the model reliably identifies market-day scenarios associated with reduced commodity prices, which is central to the study's socioeconomic focus. However, the model performed poorly for class 0 (no price reduction), with zero precision and recall. This imbalance is attributable to the very limited number of observations in class 0 (support = 1), which constrained the model's ability to learn meaningful patterns for that class. Consequently, while the overall accuracy is high, the macro-average metrics reveal weaker balanced performance, highlighting the influence of class imbalance in the dataset.

The feature importance ranking derived from the Decision Tree provides valuable insights into the drivers of price reduction during market days. Population density emerged as the most influential factor, underscoring the role of market crowd intensity in promoting competitive pricing through increased buyer–seller interactions and higher transaction volumes. Market location also showed notable importance, reflecting how proximity to highways, towns, or rivers affects accessibility, trader participation, and pricing behavior. Market establishment type is also ranked as an important factor, which suggests that institutional governance and ownership structure significantly influence commodity price behavior during market days. Government-established markets are typically more regulated, with better-organized layouts, standardized levies, and sometimes controlled charges for stalls and access. Such regulation can reduce exploitative pricing and encourage fair competition, thereby increasing the likelihood of price reductions on market days. In contrast, community- or self-established markets may exhibit more

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flexible but less regulated pricing structures, which can either promote competitive pricing through informal bargaining or, in some cases, allow price volatility.

In contrast, factors such as flood conditions, commodity categories, transportation modes, and market type exhibited comparatively lower influence, suggesting that structural and environmental attributes play a secondary role relative to human aggregation and logistics pressures. Overall, the model performance and feature importance results align with the socioeconomic realities of periodic markets. Despite limitations arising from data imbalance, the Decision Tree model provides interpretable and policy-relevant insights, reinforcing the value of machine learning–based approaches for understanding and quantifying the socioeconomic impacts of real-time market day dynamics.

Market Dynamics Influence on Transportation Related Features

For this analysis, the focus was to observe the influence of market population density on transportation hike. Based on the figure 5, the distribution shows that instances where transportation fees increased are overwhelmingly associated with high population density markets. In contrast, cases where no transportation fee hike was reported are largely concentrated within normal and low population density markets. This pattern indicates that crowd intensity is a key driver of transportation cost dynamics in periodic markets.

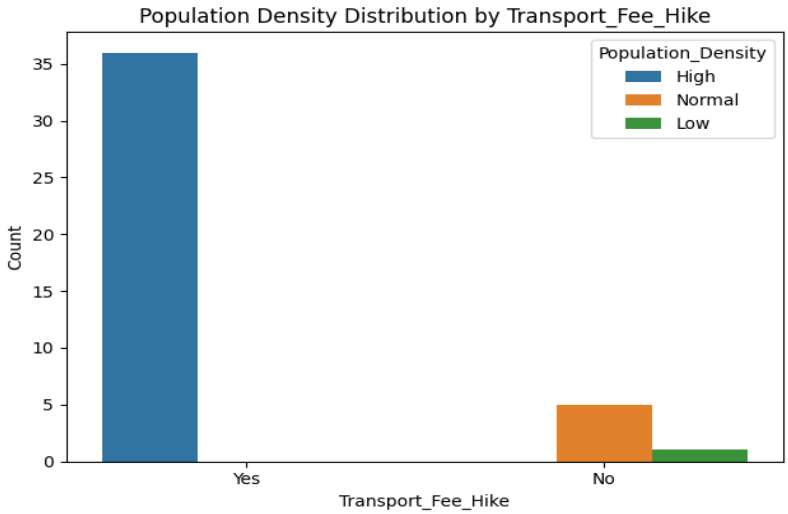


Figure 5: Market population density influence on transportation hike

From an economic perspective, high population density markets attract a larger volume of traders, buyers, and transport operators, leading to increased demand for mobility

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services. Transport providers respond to this surge in demand by raising fares, particularly on market days when congestion, longer waiting times, and higher operational stress are common. The absence or rarity of high-density markets in the "no transport hike" category reinforces the argument that transportation price escalation is demand-induced rather than arbitrary.

In the context of this study, the finding highlights an important interaction effect between population density and transportation costs, which directly influences overall market accessibility and trader behavior. While high-density markets promote competitive pricing and potential commodity price reductions, they simultaneously impose higher transportation costs on participants. This dual effect underscores the importance of real-time market day analytics, as timely information can help traders and consumers plan logistics more efficiently and policymakers design interventions, such as transport regulation or infrastructure improvement to mitigate cost burdens in highly populated markets.

Market Dynamics Influence on Environmental and Constraints

The analysis focus here is to understand how the market environment is affected by its population. In the illustration of figure 6, markets classified as having satisfactory flood conditions are predominantly associated with high population density, with a smaller presence of normal-density markets. This suggests that markets with better drainage and flood management infrastructure are more attractive to traders and buyers, thereby sustaining higher levels of participation even during or after rainfall events. Conversely, markets experiencing unsatisfactory flood conditions show a marked decline in population density, with only a limited number of high-density cases and the presence of low-density markets. This indicates that poor flood conditions discourage attendance.

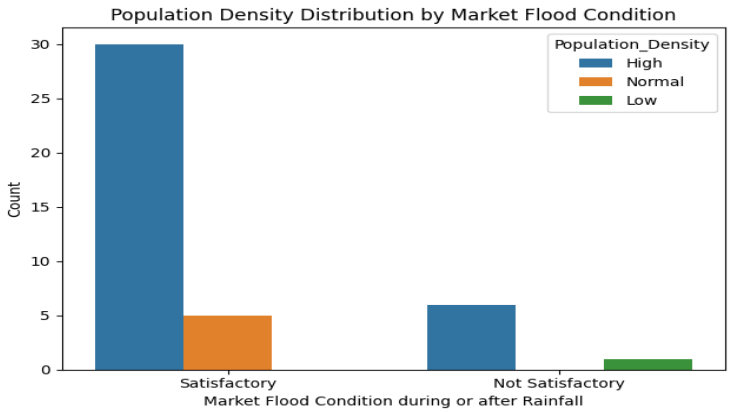


Figure 6: Market population density influence on Market Environment (Flooding Condition)

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In the context of this study, the analysis highlights that environmental resilience—particularly effective flood control—plays a crucial role in sustaining market-day participation. High population density markets tend to coexist with satisfactory flood conditions, reinforcing the need for infrastructural investment in drainage and climate-resilient market design.

Market Day Identification System Development Results

The market day identification system was successfully developed and implemented as a rule-based software application comprising two major modules: the System Administrator (Syst Admin) module and the User module. The system was designed to digitally formalize the traditionally manual process of identifying periodic market days by leveraging stored market attributes and algorithmic date computation.

The User module offers an interactive interface that enables users to determine the next market day by simply entering the name of a selected market. Upon submission, the system applies a rule-based algorithm that utilizes stored market details, specifically the market's current or past market day and the market day interval, to compute and return the next valid market day. Interface screenshots in figure 7 demonstrate that the output is displayed in a clear and timely manner, enabling users to access market-day information without requiring prior knowledge of local market cycles.

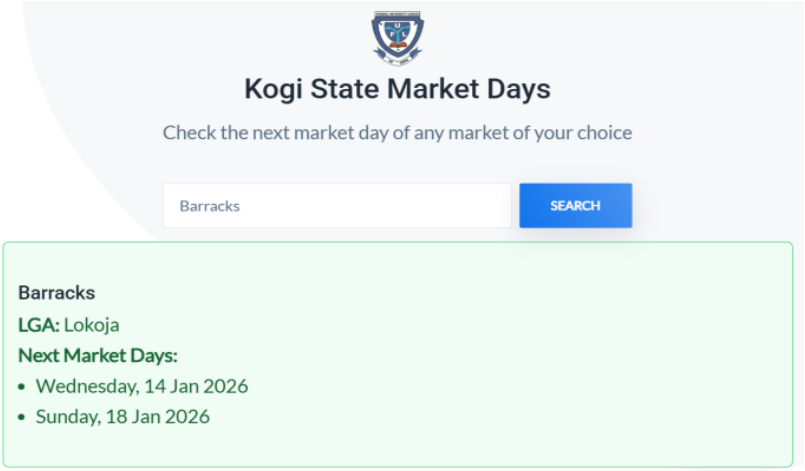


Figure 7: User Interface for Market Day Identification

The System Administrator module consists of two interfaces. The first interface (in figure 8) is a secure login page that authenticates authorized administrators before granting system access. Successful authentication leads to the second administrative interface (depicted in figure 9), where administrators can view, add, update, or delete market

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records. This interface enables the management of essential market parameters, including market name, past or current market day, and market day interval. Screenshots of the administrative interfaces confirm the system's ability to dynamically update the market database, ensuring that market day computations remain accurate and up to date.

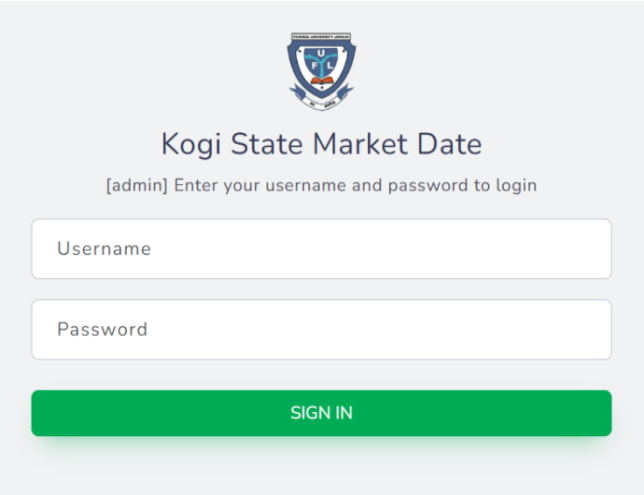


Figure 8: System Admin Authentication Interface

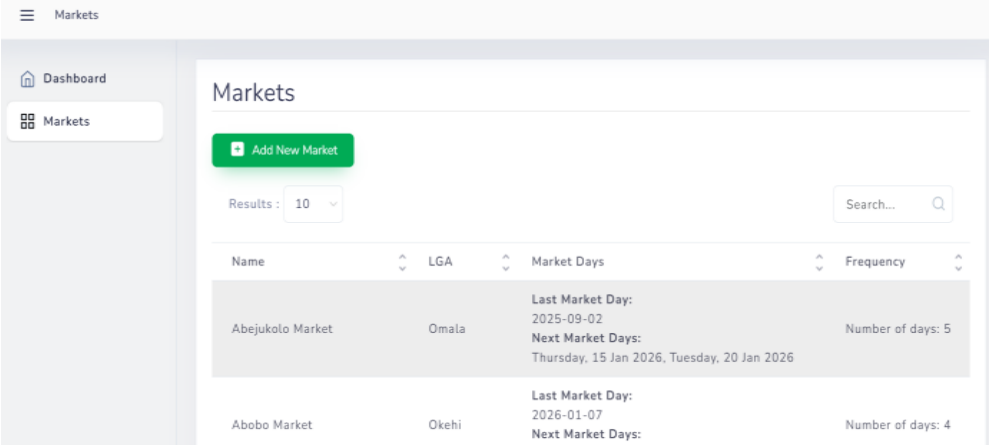


Figure 9: System Admin Market Records Management Interface

Discussion of System Performance and Contribution

The developed system has been deployed and tested in real-time within Federal University Lokoja official web-platform (www.fulokoja.edu.ng). During the real-time testing of the system, several users (students, staffs and Lokoja marketers) randomly selected were made to visit the portal where the system can be used and feedbacks relating to market information accuracy, efficiency, accessibility and consistency were

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collected. The results demonstrate that the developed market day identification system effectively addresses a key gap in traditional market management, where market-day knowledge is often based on informal communication and local memory. By digitizing market attributes and automating date computation, the system improves accuracy, consistency, and accessibility of market-day information. The rule-based approach proved sufficient for capturing the periodic nature of markets, offering a transparent and easily interpretable mechanism for date prediction.

The separation of roles between the User and System Admin modules enhances system usability and integrity. Users benefit from a simplified interface that focuses solely on market-day identification, while administrative functions are restricted to authorized personnel, thereby reducing the risk of data inconsistency. The ability of administrators to update market intervals and dates ensures that the system remains adaptable to changes in market cycles caused by cultural adjustments, environmental disruptions, or policy interventions.

From a research perspective, this system constitutes a practical software contribution that complements the machine learning–based socioeconomic modeling component of the study. While the analytical models explain the impacts of market days, the market day identification system operationalizes these insights by providing a real-time tool that supports informed participation and planning. Collectively, the results confirm that integrating rule-based software systems with data-driven analytics offers a robust framework for improving market transparency, coordination, and socioeconomic outcomes in periodic market environments.

CONCLUSIONS

This study presented a comprehensive approach to understanding and enhancing periodic market systems in Kogi State through the integration of real-time market day identification and machine learning–based socioeconomic impact modeling. By combining a software-driven market day tracking application with data-driven analytical techniques, the research addressed critical gaps in traditional market studies, which have largely relied on static, descriptive, and retrospective analyses. The proposed approach demonstrates that periodic markets are dynamic systems whose socioeconomic outcomes can be better understood and managed through timely data acquisition and intelligent analytics.

The findings reveal that market population density, transportation fee dynamics, market location, and establishment type are key determinants of commodity price behavior during market days. High population density markets were shown to promote competitive pricing and potential price reductions, despite being associated with

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increased transportation costs. Environmental factors, particularly market flood conditions, were also found to significantly influence market participation, underscoring the importance of infrastructural resilience in sustaining market vibrancy. The machine learning models, especially the interpretable Decision Tree–based approach, provided meaningful insights into the relative importance of these factors, validating the suitability of data-driven methods for socioeconomic impact assessment in periodic markets.

Beyond analytical contributions, the development of a market day identification software application represents a practical and scalable solution for improving market accessibility and planning. By enabling accurate, real-time identification of market days across different locations, the system supports better decision-making for traders, consumers, transport operators, and policymakers. When combined with predictive socioeconomic analytics, the platform has the potential to reduce information asymmetry, optimize market participation, and enhance economic efficiency.

In conclusion, this research establishes a novel interdisciplinary framework that bridges software engineering and machine learning with socioeconomic market analysis. The outcomes provide empirical evidence and practical tools for improving the organization, resilience, and economic impact of periodic markets. Future work can build on this foundation by expanding the dataset, addressing class imbalance in modeling, incorporating real-time sensor or mobility data, and extending the system to support predictive market planning and policy evaluation at larger regional and national scales.

Furthermore, based on the findings of this study, Local Government Authorities (LGAs) in Kogi State should institutionalize digital market-day management by deploying the developed market-day web application through LGA secretariats and relevant market administration offices. This would provide traders, consumers, transport operators, and other stakeholders with timely and reliable information on market schedules while reducing dependence on informal knowledge. Given the observed relationship between population density and market flooding, LGAs should prioritize drainage improvement and flood-control infrastructure in high-density markets to sustain accessibility and market participation during adverse weather conditions. Furthermore, the observed association between high market population density and transportation fee increases suggests the need for structured monitoring and regulation of transport fares during peak market days, including collaboration with transport unions to establish reasonable fare limits and prevent excessive charges. Collectively, these interventions would improve market accessibility, reduce avoidable socioeconomic costs, and strengthen data-driven market planning across Kogi State.

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