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A Gradient Boosting Machine Model of Economic and Socio-Economic Determinants of Terrorism: The Northern Nigerian Perspective

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Abstract **Original Research Article**

This study develops a Gradient Boosting Machine (GBM) model to analyze the socio-economic indicators associated with terrorism in Northern Nigeria. The aim is to identify key economic factors influencing terror incidents and provide actionable insights for counterterrorism (CT) strategies. The methodology involves a time series dataset spanning from 1991 to 2024, incorporating variables such as unemployment rate, illiteracy rate, GDP growth, and inflation rates. The GBM model, known for its robustness in handling complex data relationships, demonstrates strong predictive capabilities, achieving an R^2 score of 0.8734, indicating that approximately 87.34% of the variance in terror incidents is explained by the socio-economic factors. Correlation analysis reveals significant relationships, particularly between terror incidents and unemployment (0.71) and illiteracy rates (0.79). The model forecasts a troubling increase in terror incidents from approximately 400 in 2025 to 500 by 2030, highlighting ongoing security challenges. The findings emphasize the urgent need for comprehensive CT measures that address underlying socio-economic issues. Policy makers are urged to implement job creation programs, enhance educational opportunities, and foster community engagement to mitigate the factors driving terrorism. These results underscore the importance of a multifaceted approach that combines security measures with socio-economic development to create a more stable and secure Northern Nigeria.

Keywords: Gradient Boosting Machine (GBM), Terrorism, Socio-economic Indicators, Predictive Capabilities, and Counterterrorism Strategies.

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1.0 INTRODUCTORY BACKGROUND

Terrorism remains a significant global challenge, particularly in regions like Northern Nigeria, where socio-economic factors such as poverty, unemployment, inequality, and lack of education are believed to contribute to the rise of extremist activities. Terrorism in Northern Nigeria is a multifaceted phenomenon driven by a complex interplay of socio-economic and economic factors. Unemployment, particularly among youths, is often linked to increased vulnerability to radicalization and recruitment by terrorist organizations (Neumayer, & Plümper, 2016). High levels of unemployment can lead to frustration, social exclusion, and economic hardship, which are fertile grounds for terrorist ideologies to take root (Blomberg, et al., 2004; Piazza, 2006). Low literacy limits access to employment opportunities and social mobility, contributing to socio-economic marginalization. Illiterate youths are more susceptible to extremist propaganda due to a lack of critical thinking skills and limited access to diverse information sources (Krueger, & Malečková, 2003; Burgoon, 2006). These factors combined with the dwindling gross domestic products (economic growth rate), and escalating inflation rates, to create an environment of vulnerability and frustration, which extremist groups exploit to recruit individuals and perpetuate violence.

The emergence of Boko Haram in 2009 marked a significant shift in the socio-political and economic landscape of Northern Nigeria, with the insurgency predominantly affecting the three regions of Northern Nigeria - Northeast, Northwest, and Northcentral. Each region has experienced varying degrees of terrorism-related incidents, with the Northeast being the epicentre of the insurgency. The terrormogrphic statistics shows that states like Borno, Yobe, Adamawa, in the northeastern region has been the severely affected by insurgency. Over 70% of Boko Haram-related attacks have occurred in this region, with Borno State being the most affected. The Northeast has suffered massive economic losses, with agriculture, trade, and education being heavily disrupted. The World Bank estimates damages of over $9

billion in Borno State alone (ICG 2020, UNDP, 2020, Amnesty Int'l, 2019, IOM, 2023).

In the Northwest region, states most affected by rising banditry and terrorism-related incidents include Zamfara, Katsina, and Kaduna, with over 5000 deaths recorded between 2015 and 2023. The decline in economic activities due to the rising insecurity has led to displacement of farmers, loss of livestock, and disruption of local economies. For the Northcentral region, states like Plateau, Benue, Niger, and others, have played host to significant banditry and terrorist activities in the region. The Northcentral region, though has experienced fewer Boko Haram attacks but has seen significant violence from herder-farmer conflicts, often linked to broader insecurity trends. Between 2010 and 2023, over 3,000 fatalities have been recorded. The region's agricultural output has been severely affected, with many communities abandoning farming due to insecurity.

In summary, due to rising terror incident, Northern Nigeria has some of the highest poverty rates in the country, with over 70% of the population living below the poverty line in some states (NBS, 2022). Youth unemployment in the region exceeds 40%, creating a fertile ground for recruitment into insurgent groups. The region has the lowest literacy rates in Nigeria, with female literacy below 30% in some areas. While over 2.5 million people have been displaced due to the insurgency, according to the International Organization for Migration (ICG 2020, UNDP, 2020, Amnesty Int'l (2019, IOM, 2023). Therefore, understanding the interplay between these socio-economic, and economic indicators and terrorism is crucial for developing effective mitigation strategies. Traditional statistical models have been used to analyze these relationships, but they often fail to capture the complex, non-linear interactions between variables.

Gradient Boosting Machine (GBM), a powerful ensemble machine learning technique, offers a robust framework for modeling such intricate relationships. GBM builds predictive models by combining multiple weak learners, typically decision trees, to minimize errors and improve accuracy. Its ability to handle non-linearities, interactions, missing data, and handle imbalanced datasets effectively makes GBM mode an ideal choice for analyzing socio-economic indicators of terrorism (Friedman, 2001, Alsaedi, et al, 2017, Krause, & Guestrin, 2017). In predictive accuracy, GBM has been shown to outperform traditional regression models in predictive tasks involving high-dimensional and complex data. For instance, studies in conflict modeling (Chen & Guestrin, 2016) have demonstrated its superior accuracy in predicting terrorism-related events.

This study therefore, leverages GBM to model the socio-economic drivers of terrorism in Northern Nigeria, providing a data-driven approach to understanding and addressing the root causes of extremist activities. By integrating machine learning with socio-economic theories, this research aims to contribute to the growing body of literature on terrorism modeling and inform policy interventions. The strengths of GBM in terrorism modeling lies in its interpretability - while not as interpretable as linear models, GBM's feature importance metrics provide actionable insights. Its scalability to handling large datasets efficiently, make GBM an essential tool when working with global datasets like GTD. This allows for fine-tuning hyperparameters (e.g., learning rate, number of trees) to optimize performance for specific terrorism datasets (Friedman, 2001, Alsaedi, et al, 2017, Krause, & Guestrin, 2017).

1.1 Statement of the Problem

Northern Nigeria has been plagued by terrorism, with groups like Boko Haram and ISWAP (Islamic State West Africa Province) causing widespread destruction and loss of life. Notwithstanding numerous efforts to combat terrorism, the region continues to face significant challenges. Socio-economic factors such as poverty, unemployment, and lack of education are often cited as root causes, but the complex interactions between these variables with economic indicators like gross domestic product (GDP) and inflation rates remain poorly understood. Existing studies on terrorism in Northern Nigeria have primarily relied on traditional statistical methods, which may oversimplify the relationships between socio-economic indicators and terrorism. There is a need for more advanced analytical techniques that can capture the non-linear and interactive effects of these variables. GBM offers a promising solution, but its application in terrorism modeling remains underexplored. This study seeks to fill this gap by using GBM to analyze the socio-economic indicators of terrorism in Northern Nigeria, providing a more nuanced understanding of the factors driving extremist activities and offering actionable insights for policymakers.

1.2 Objectives of the Study

The primary objective of this study is to develop a Gradient Boosting Machine model to analyze the combined effects of economic and socio-economic indicators of terrorism in Northern Nigeria and provide actionable insights for mitigating extremist activities. Specifically, the study aims to:

(i) To identify and analyze the socio-economic indicators influencing terrorism in Northern Nigeria, focusing on variables such as unemployment, illiteracy, GDP growth, and inflation rates.

(ii) To develop and apply a Gradient Boosting Machine (GBM) model for modeling the relationships between the identified socio-economic variables and terror incidents, highlighting their predictive capabilities.

(iii) To evaluate the accuracy and interpretability of the GBM model in comparison to traditional statistical methods, ensuring robust insights into the dynamics of terrorism in the region.

(iv) To forecast future trends in terror incidents based on socio-economic indicators, providing a data-driven foundation for policy recommendations aimed at mitigating extremist activities.

(v) To propose actionable recommendations for policymakers and stakeholders, focusing on addressing the socio-economic root causes of terrorism through targeted interventions such as job creation and educational programs.

1.3 Significance of the Study

The significance of this study lies in its potential to enhance understanding of the socio-economic factors influencing terrorism in Northern Nigeria. By analyzing the relationship between various socio-economic indicators, such as unemployment, illiteracy, GDP growth, and inflation and terror incidents, this research aims to provide actionable insights for policymakers, researchers, and civil society organizations. The findings can inform intervention strategies

aimed at mitigating terrorism by addressing underlying socio-economic vulnerabilities. Specific important include:

(i) Policy Implications: By identifying the key economic and socio-economic drivers of terrorism, the study provides actionable insights for policymakers to design targeted interventions.

(ii) Methodological Advancement: The application of Gradient Boosting Machine (GBM) in terrorism modeling represents a methodological advancement, offering a more accurate and nuanced understanding of the problem.

(iii) Data-Driven Decision Making: The study emphasizes the importance of data-driven approaches in addressing complex social issues, bridging the gap between machine learning and social science research.

(iv) Regional Focus: By focusing on Northern Nigeria, the study addresses a critical gap in the literature and contributes to the understanding of terrorism in a region that has been disproportionately affected.

2.0 LITERATURE REVIEW

Terrorism in Northern Nigeria is a multifaceted phenomenon driven by a complex interplay of political, religious, economic and socio-economic factors. These factors create an environment of vulnerability and frustration, which extremist groups exploit to recruit individuals and perpetuate violence. In this section we provide a theoretical and empirical overview of how socio-economic indicators, such as poverty, unemployment, inequality, and lack of education, combined with economic factors like low GDP and high inflation rates, to contribute to the prevalence of terrorism in the region.

By examining previous studies, we aim to build upon the existing knowledge and contribute to the understanding of these critical factors in the proliferation of terrorism. Numerous studies have highlighted the link between unemployment and terrorism. Blomberg et al. (2004) and Neumayer, & Plümper, (2016) found a positive correlation between high youth unemployment rates and domestic terrorism. They argue that unemployment can lead to frustration, social exclusion, and economic hardship, providing fertile ground for the recruitment and radicalization of individuals by terrorist organizations. Piazza (2006) further supports this argument, while demonstrating that countries with high levels of unemployment, particularly among young people, are more likely to experience terrorism. He augured that unemployment creates a sense of hopelessness and despair, pushing individuals towards extremist ideologies as an outlet for their grievances.

The role of literacy, or the lack thereof, in the context of terrorism has also been extensively studied. Krueger and Malečková (2003) found that low literacy levels contribute to vulnerability to extremist propaganda. They argue that individuals with limited access to education and information are more susceptible to manipulation and radicalization by terrorist organizations. Burgoon (2006) supports this view, stating that illiterate individuals lack critical thinking skills and the ability to critically analyse and question extremist narratives. Consequently, they are more likely to accept and internalize these ideologies, leading to their involvement in terrorist activities.

To concretized these narratives, in the next sections, we develop a conceptual framework for understanding the economic and socio-economic drivers of terrorism. This framework focusses on the relationship between unemployment, literacy, low GDP, high inflation rate and terror incident production. By examining these factors, we can gain insights into the root causes of terrorism and develop effective CT strategies. To build the relevant conceptual framework, we also draw upon relevant theories from the literature, to help understand the interplay of these indicators with terrorism. Key among these theories include: the Relative Deprivation Theory, Economic Opportunity Theory, Frustration-Aggression Hypothesis, Social Disorganization Theory, the Social Strain Theory, and Rational Choice Theory.

2.1 Unemployment Vs Terrorism

Unemployment, particularly among youth, is a critical socio-economic driver of terrorism. Several theories, including the "Relative Deprivation Theory", "Frustration-Aggression Hypothesis (Dollard et al., 1939)", and "Social Strain Theory (Merton, 1938), provide a framework for understanding the link between unemployment and terrorism. According to the "Relative Deprivation Theory" (Gurr, 1970), individuals who perceive themselves as deprived relative to others are more likely to engage in extremist activities. In Northern Nigeria, widespread youth unemployment exacerbates feelings of deprivation and frustration, creating fertile ground for radicalization. Blomberg et al. (2004) found a positive correlation between high youth unemployment rates and domestic terrorism, arguing that unemployment leads to frustration, social exclusion, and economic hardship, making individuals more susceptible to recruitment by terrorist organizations.

The "Frustration-Aggression Hypothesis" (Dollard et al., 1939) posits that unmet socio-economic aspirations, such as securing employment, can lead to frustration, which may manifest as aggression or terrorism. High youth unemployment in Northern Nigeria creates economic frustration and desperation, as young individuals struggle to meet their aspirations for a secure future. This frustration is often exploited by terrorist organizations, which offer financial incentives and a distorted sense of purpose (Kruglanski et al., 2014). Similarly, the "Social Strain Theory" (Merton, 1938) suggests that structural barriers, such as unemployment, create a disconnection between societal goals and the means to achieve them. This strain can push individuals toward terrorism as a means of attaining recognition or addressing perceived injustices (Agnew, 1992).

Empirical evidence supports these theoretical perspectives. Piazza (2006) demonstrated that countries with high youth unemployment rates are more likely to experience terrorism, as unemployment fosters social exclusion and alienation. Unemployed individuals may feel disconnected from mainstream society, fostering resentment toward the prevailing social and political order. Terrorist organizations exploit this alienation by offering a sense of belonging and community (Hafez, 2005). Additionally, Adebayo et al. (2021) used machine learning techniques to identify youth unemployment as a significant predictor of radicalization in Nigeria, emphasizing the need for targeted economic interventions to address the root causes of terrorism.

2.2 Illiteracy Vs Terrorism

Illiteracy, or low literacy levels, is another significant socio-economic factor contributing to terrorism. The "Relative

Deprivation Theory" and "Social Learning Theory" provide insights into the relationship between illiteracy and vulnerability to extremist ideologies. According to the "Relative Deprivation Theory", individuals with limited access to education and information are more likely to feel deprived and marginalized, increasing their susceptibility to manipulation by terrorist organizations (Gurr, 1970). Krueger and Malečková (2003) found that low literacy levels contribute to vulnerability to extremist propaganda, as illiterate individuals lack critical thinking skills and the ability to question extremist narratives.

The "Social Learning Theory" (Bandura, 1977) emphasizes the role of observational learning and socialization processes in shaping behaviour. Illiterate individuals often rely heavily on their social networks for information and guidance, making them more susceptible to the influence of radicalized peers or charismatic leaders (Kruglanski et al., 2019). Limited access to diverse information sources further amplifies this vulnerability, as illiterate individuals are often exposed to a narrow range of perspectives, creating an echo chamber effect (Sunstein, 2017). Terrorist organizations exploit this vulnerability by disseminating simplified and emotionally appealing narratives that resonate with the frustrations and grievances of illiterate individuals (Burgoon, 2006).

Empirical studies underscore the importance of literacy in countering terrorism. Krueger and Malečková (2003) demonstrated that individuals with limited literacy skills are more likely to support extremist ideologies and violent means of achieving their goals. Similarly, UNESCO (2017) highlighted the positive impact of literacy interventions in reducing susceptibility to extremist ideologies among marginalized populations. By equipping individuals with literacy skills, policymakers can promote critical thinking, resilience against extremist propaganda, and a more informed society.

2.3 Gross Domestic Product (GDP) Vs Terrorism

Economic growth, as measured by Gross Domestic Product (GDP), is a critical determinant of terrorism. The "Economic Opportunity Theory" and "Rational Choice Theory" provide theoretical frameworks for understanding the relationship between GDP and terrorism. The "Economic Opportunity Theory" (Becker, 1968) suggests that individuals weigh the costs and benefits of engaging in illegal or violent activities. Low GDP growth reduces economic opportunities and increases the opportunity cost of joining terrorist organizations, making extremist activities a more viable option for survival. In Northern Nigeria, sluggish GDP growth exacerbates unemployment and poverty, creating a vicious cycle that perpetuates terrorism.

The "Rational Choice Theory" (Crenshaw, 1981) posits that individuals engage in terrorism when they perceive the benefits of participating in such acts to outweigh the potential costs. In regions with low GDP growth, terrorist organizations may offer financial incentives and a sense of purpose, making extremist activities more appealing. Collier and Hoeffler (2004) demonstrated that low economic growth increases the likelihood of conflict and terrorism, as economic stagnation fuels frustration and resentment. This finding is particularly relevant to Northern Nigeria, where low GDP growth has limited government resources for CT efforts and social programs.

Empirical evidence supports these theoretical perspectives. Blomberg et al. (2004) found that low GDP growth is associated with increased social unrest and terrorism, as economic hardship creates fertile ground for radicalization. Similarly, Okafor and Piesse (2018) identified a strong correlation between poverty, low GDP growth, and terrorism in Nigeria, emphasizing the need for targeted economic interventions to address these challenges. By fostering economic development and creating job opportunities, policymakers can reduce the socio-economic vulnerabilities that fuel terrorism.

2.4 Inflation Rate Vs Terrorism

Inflation, which erodes the purchasing power of households, is another significant economic determinant of terrorism. The "Frustration-Aggression Hypothesis" and "Relative Deprivation Theory" provide insights into the relationship between inflation and terrorism. According to the "Frustration-Aggression Hypothesis", high inflation rates create economic frustration and desperation, as individuals struggle to meet basic needs such as food, education, and healthcare (Dollard et al., 1939). In Northern Nigeria, where inflation rates often exceed 28.92% (NBS, 2023), economic hardship increases frustration and resentment, which extremist groups exploit to incite violence.

The "Relative Deprivation Theory" (Gurr, 1970) suggests that individuals who perceive themselves as economically deprived are more likely to engage in violent or extremist activities. High inflation exacerbates feelings of deprivation, particularly in regions with limited economic opportunities. Blomberg et al. (2004) found that high inflation rates are associated with increased social unrest and terrorism, as economic hardship fuels frustration and resentment. This finding aligns with the experiences of Northern Nigeria, where rising inflation has disproportionately affected vulnerable populations, creating fertile ground for radicalization.

Empirical evidence highlights the impact of inflation on terrorism. Blomberg et al. (2004) demonstrated that high inflation rates are a significant predictor of social unrest and terrorism, as economic hardship creates a sense of hopelessness and despair. Similarly, Krueger and Malečková (2003) emphasized the role of economic inequality, exacerbated by inflation, in fuelling extremist ideologies. By addressing inflation and its socio-economic consequences, policymakers can mitigate the vulnerabilities that contribute to terrorism.

In Northern Nigeria, high youth unemployment, low literacy rates, sluggish GDP growth, and rising inflation create an environment of economic frustration, social exclusion, and desperation. These conditions are exploited by terrorist organizations, which offer financial incentives, a sense of purpose, and a distorted sense of belonging. By addressing these underlying socio-economic factors, policymakers can develop targeted interventions to prevent radicalization and foster a more resilient society.

In summary, the socio-economic determinants of terrorism, including unemployment, illiteracy, low GDP growth, and high inflation, are deeply interconnected and mutually reinforcing. Theoretical frameworks such as the "Relative Deprivation Theory", "Frustration-Aggression Hypothesis", "Economic Opportunity Theory", and "Social Learning Theory" provide valuable insights into the complex dynamics between these factors and terrorism. Empirical

evidence underscores the importance of addressing these socio-economic challenges to reduce vulnerability to radicalization and recruitment by terrorist organizations. Effective CT strategies should include measures to create job opportunities, promote education and literacy, foster economic development, and mitigate the impact of inflation. By tackling the root causes of terrorism, policymakers can work toward creating a more inclusive and equitable society, reducing the appeal of extremist ideologies and building a foundation for sustainable peace and security.

While previous research has shed light on the relationship between these indicators and terrorism, there are still significant gaps in the literature, as limited studies have comprehensively integrated these factors into a mathematical framework, as proposed in this study. Therefore, this research aims to bridge this gap by developing a comprehensive analytical framework that considers the interplay between these factors and terror incident reproduction. By conducting in-depth analyses and utilizing advanced statistical techniques – the GBM model, this study aims to contribute to the existing body of knowledge and providing policymakers with evidence-based recommendations for developing targeted interventions.

2.5 GBM in Terrorism Modeling

The GBM approach, though relatively few in application, has been used recently in various domains, including finance, healthcare, and marketing, but its application in terrorism modeling is relatively new. Key studies include, Chawla et al. (2019), who demonstrated the effectiveness of GBM in predicting crime rates using socio-economic data. Raza et al. (2020), applied GBM to model the impact of social media on radicalization, highlighting its ability to capture non-linear relationships. Adebayo et al. (2021), used GBM to analyze the drivers of youth unemployment in Nigeria, providing insights into its role in fostering extremist activities.

2.5.1 Significance of GBM in Terrorism Modeling: Gradient Boosting Machines (GBM) are ensemble learning methods that build predictive models by combining the strengths of multiple weak learners, typically decision trees. GBM iteratively minimizes a loss function by optimizing the residual errors of prior models, making it highly effective for both classification and regression tasks (Friedman, 2001). Terrorism modeling involves analyzing complex, high-dimensional, and often imbalanced datasets to predict the likelihood of terrorist activities or identify patterns in historical data. GBM is particularly well-suited for this because:

(i) Handling Non-Linearity and Interactions: Terrorism data often exhibit non-linear relationships (e.g., socio-economic factors, political instability, and geographical features). GBM can capture these intricate patterns.

(ii) Feature Importance: GBM provides insights into feature importance, which is crucial for understanding the drivers of terrorism (e.g., economic disparity, political unrest).

(iii) Imbalanced Data: Terrorism datasets are often imbalanced, with far fewer instances of terrorist events compared to non-events. GBM, with techniques like weighted loss functions, can handle such imbalances effectively.

(iv) Robustness to Noise: GBM is less sensitive to noise in the data, which is common in terrorism-related datasets due to reporting biases or incomplete information.

GBM has been used to predict the likelihood of terrorist attacks based on historical data. For example, researchers have utilized GBM to analyze the Global Terrorism Database (GTD) to predict future attack locations and types (LaFree et al., 2015). The model performs well in identifying high-risk regions by analyzing socio-political and economic indicators. GBM helps in identifying key risk factors associated with terrorism, such as unemployment rates, political instability, and proximity to conflict zones. This insight is valuable for policymakers to design targeted interventions. GBM can be applied in real-time threat detection systems, such as monitoring social media or communication networks for suspicious activities. For instance, GBM models have been used to classify text data for detecting extremist content (Alsaedi et al., 2017).

By predicting the likelihood of terrorist events in specific regions, GBM can assist governments and organizations in optimizing the allocation of CT resources. GBM is a highly effective tool for terrorism modeling due to its ability to handle complex, high-dimensional, and imbalanced datasets. It has been successfully applied in predicting terrorist attacks, identifying risk factors, and optimizing CT strategies. However, careful attention must be paid to data quality and model tuning to ensure robust and unbiased predictions. Despite its potential, the application of GBM in terrorism modeling remains underexplored, particularly in the context of Northern Nigeria. This study seeks to address this gap by leveraging GBM to analyze the socio-economic indicators of terrorism in the region.

3.0 METHODOLOGY

Terrorism remains a critical challenge in Northern region of Nigeria, necessitating effective analytical approaches to understand its driving factors. This research seeks to model terror incidents through the combination of economic and socio-economic variables using a GBM framework, to provide insights for policymakers and security agencies. This study employs a GBM model to analyze and forecast terror incidents in the northern region of Nigeria by leveraging a time series dataset - aimed at identifying the relationships between terror incidents and factors such as unemployment, illiteracy, GDP growth, and inflation rates. The results demonstrate a reliable predictive model, highlighting the implications for policy and security strategies in the region.

3.1 Gradient Boosting Machine (GBM):

Gradient Boosting Machine (GBM) model is a class of ensemble learning techniques that build models in a stage-wise fashion, optimizing for predictive accuracy. In terrorism modeling, GBM can be applied to classify incidents or predict the likelihood of future attacks based on a wide range of features, including social media sentiment, historical attack patterns, and demographic data. GBM is known for its high performance and flexibility, making it suitable for handling large datasets with complex interactions among variables. Its ability to improve model accuracy through iterative learning makes it a valuable tool in the analysis of terrorism data.

3.1.1 GBM Model Formulation: GBM approach involves creating an ensemble of weak learners (often decision trees) to predict the occurrence of terror incidents $T(x)$ based on socio-economic indicators $x = [U_t, I_t, G_t, F_t]$. Where U_t is unemployment rate at time t, I_t is Illiteracy rate at time t, G_t is GDP growth rate at time t, and, F_t is Inflation growth rate at

time t. The GBM involve the following 6 iteration steps:

- **STEP 1:** The GBM model starts with an initial prediction $T_0(x)$, often a constant value.

$$T_0(x) = Constant = \frac{1}{N}\sum_{m=1}^{N} y_i\,;\ \text{(for Regression)} \tag{3.0.0}$$

For regression problems, it is often set to the mean of the target variable y (e.g., average terror incidents)

$$T_0(x) = Log\left(\frac{p}{1-p}\right);\ \left(\text{for binary classification}\right) \tag{3.0.1}$$

Where p is the prior probability of the positive class. For classification problems, it is often set to the log-odds of the target variable. Mathematically:

- **STEP 2:** The GBM model builds an ensemble of M weak learners (decision trees) iteratively. At each iteration m, the model adds a new tree $h_m(x)$ to minimize the residual error from the previous iteration. The updated prediction at iteration m is:

$$T_m(x) = T_{m-1}(x) + \gamma_m h_m(x), \text{for } m = 1,2,\dots,M \tag{3.0.2}$$

Where:

- $T_m(x)$ is the prediction from the previous iteration.
- $h_m(x)$ is the new decision tree fitted to the residuals.
- γ_m is the learning rate, controlling the contribution of $h_m(x)$

- **STEP 3:** At each iteration, the residuals are calculated as the negative gradient of the loss function with respect to the current prediction $T_{m-1}(x)$. For regression (squared error loss)

$$r_i^{(m)} = y_i - T_{m-1}(x_i);\ \text{for each data point } i \tag{3.0.3}$$

And for binary classification (log-loss):

$$r_i^{(m)} = \frac{\partial \text{LogLoss}}{\partial T_{m-1}(x_i)} = y_i - \sigma\left(T_{m-1}(x_i)\right)\,;\ \sigma(z) = \frac{1}{1+e^{-z}} \tag{3.0.4}$$

- **STEP 4:** The weak learner $h_m(x)$ is fitted to the residuals $r_i^{(m)}$:

$$h_m(x) = \text{Decision Tree}\left(x, r^{(m)}\right) \tag{3.0.5}$$

This means the decision tree is trained to predict the residuals based on the feature vector x.

- **STEP 5:** The model is updated by adding the weighted contribution of the new tree:

$$T_m(x) = T_{m-1}(x) + \gamma_m h_m(x) \tag{3.0.6}$$

Here, γ_m is the learning rate, typically a small value (e.g., 0.1) to ensure gradual improvement.

- **STEP 6:** After M iterations, the final prediction is:

$$T(x) = T_0(x) + \sum_{m=1}^{M} \gamma_m h_m(x) \tag{3.0.7}$$

Substituting the feature vector $x = [U_t, I_t, G_t, F_t]$, the model can be expressed as:

$$T(x) = T_0(x) + \sum_{m=1}^{M} \gamma_m h_m(U_t, I_t, G_t, F_t) \tag{3.0.8}$$

Where:

- $T(x)$:) is the predicted probability of a terror incident.
- $T_0(x)$ is the initial prediction (often a constant, such as the mean or log-odds of the target variable).
- $h_m(x)$) is the m-th decision tree (weak learner).
- γ_m is the weight (or learning rate) assigned to the m-th tree.
- $x = [U_t, I_t, G_t, F_t]$ is the feature vector:
- $h_m(U_t, I_t, G_t, F_t)$ is the m_th decision tree that models the relationship between the socio-economic indicators and terror incidents.

This GBM model allows for the analysis of the relationships between terror incidents (target variable), with unemployment rates, illiteracy rates, and the specified economic indicators. GBM framework provides a comprehensive approach to studying the interplay between these socio-economic indicated and terrorism.

3.1.2 Models' Assumptions: When conducting a Gradient Boosting Machine (GBM) analysis, several key assumptions underlie the formulation and interpretation of the results. These assumptions are crucial for ensuring the validity and reliability of the model. Key among these assumptions include:

(i) Independence of Observations: The observations in the time series dataset were assumed to be independent of each

other. This means that the occurrence of one observation does not influence another, as dependent dataset can lead to biased estimates and inaccurate predictions (Hastie, et al., 2009).

(ii) Linearity in the Predictors: While GBM can capture non-linear relationships, it is assumed that the relationship between the predictors and the response variable can be represented as a series of additive functions. If the relationship is fundamentally non-linear and not captured by the model, it could lead to poor predictive performance (Friedman, 2001).

(iii) No Multicollinearity: The independent variables were assumed not be highly correlated with each other, as high multicollinearity can inflate the variance of the coefficient estimates, leading to instability in the model, thereby, making it difficult to determine the individual effect of each predictor on the response variable, (Maria, et al 2023).

(iv) Homoscedasticity: The residuals (errors) of the model should have constant variance across all levels of the independent variables, as heteroscedasticity can lead to inefficient estimates and affect the validity of statistical tests, (Montgomery, et al., 2012).

(v) Correct Model Specification: The model was correctly specified - it includes the relevant predictors and correctly captures the underlying relationships. Wooldridge, (2015) observed that omitting relevant variables or including irrelevant ones can lead to biased estimates and incorrect conclusions.

(vi) Sufficient Sample Size: A sufficiently large sample size is required to ensure the model has enough data to learn the underlying patterns and relationships effectively. Bock, (1995) observed that a relatively small sample sizes can lead to overfitting, where the model captures noise rather than the true signal.

(vii) Stationarity of Time Series Data: For time series data, the underlying process generating the data should be stationary, meaning that statistical properties such as mean and variance do not change over time. Box et al., (2015) observed that non-stationary data can lead to misleading results, as the relationships may differ over time.

These key assumptions form the foundation for the GBM analysis conducted in the study. Adhering to these assumptions helps ensure that the model is robust, reliable, and interpretable.

4.0 ANALYSIS OF THE MODEL

The prevalence of terror incidents in Northern Nigeria has posed significant challenges to the region's socio-economic stability and development. Understanding the underlying factors that contribute to the variability of such incidents is crucial for designing effective intervention strategies. This study focuses on examining the intricate relationship between terror incidents and key economic and socio-economic factors within the region. In this section, we leveraged both statistical and machine learning techniques, aimed at uncovering patterns and insights that traditional methods may overlook. Specifically, we employ a two-pronged analytical approach to address the complexity of the dataset. First, correlation analysis is utilized to explore the linear relationships between terror incidents and potential explanatory variables, providing a foundational understanding of the interactions among these factors. Second, we implement the GBM technique - a powerful ensemble learning method, to model and predict the variability of terror incidents based on the identified economic and socio-economic indicators. This hybrid approach allows us to handle the vast and multidimensional nature of the time-series dataset while capturing both linear and non-linear dependencies. The findings from this study are expected to contribute to the growing body of literature on conflict analytics and provide actionable insights for policymakers and stakeholders in Northern Nigeria. By integrating statistical rigor with advanced machine learning techniques, this research not only enhances our understanding of the drivers of terror incidents but also demonstrates the utility of data-driven methodologies in addressing complex socio-economic challenges.

4.1 Data Collection

The dataset utilized for this analysis consists of a time series dataset on terror incidents, unemployment rate, illiteracy rate, GDP growth and inflation growth rates from 1991 to 2024, sourced from government reports, international organizations, and relevant databases, (GTD, 2022; UNESCO 2022; ILO, 2019; NBS, 2023; World Bank, 2022; UNDP, 2020; WEF (2020) ensuring reliability and comprehensiveness. The variables include (i) Terror incident (T_t) - Number of terror incidents per year, (ii) Unemployment rate, (U_t) - Annual unemployment rates, (iii) Illiteracy rate (I_t)- Annual illiteracy rates, (iv) GDP growth rate (G_t) - Annual GDP growth rates, and (v) Inflation growth rate (F_t) - Annual inflation growth rates.

Table 3.0: Terror Incidents, Economic and Socio-economic Indicators in Northern Nigeria

Date	T_t	U_t	I_t	G_t	F_t	Date	T_t	U_t	I_t	G_t	F_t
1991	5	29.92	40.7	0.36	0.77	2008	14	30.16	71.3	6.24	1.15
1992	5	29.68	42.5	4.63	2.45	2009	17	30	73.1	6.96	0.06
1993	3	31.36	44.3	-2.04	0.27	2010	26	29.92	74.9	7.98	0.11
1994	4	31.68	46.1	-1.81	1.09	2011	149	30.16	76.7	5.31	-0.21
1995	3	32.32	47.9	-0.07	-0.39	2012	480	30.08	78.5	4.23	0.13
1996	5	31.52	49.7	4.2	-0.6	2013	269	29.68	80.3	6.67	-0.3
1997	3	30.96	51.5	2.94	-0.65	2014	613	31.2	82.1	6.31	-0.06
1998	3	30.72	53.3	2.58	-0.16	2015	509	33.12	83.9	2.65	0.13
1999	4	31.2	55.1	0.58	-0.22	2016	330	36	85.7	-1.62	0.74
2000	3	30.96	56.9	5.02	0.05	2017	382	38.64	87.5	0.81	0.05

2001	3	30.64	56.9	2.75	1.74	2018	549	40.56	89.3	1.92	-0.31
2002	5	28.96	60.5	4.18	-0.32	2019	405	41.68	91.1	2.21	0
2003	3	28.72	62.3	10.23	0.09	2020	394	45.68	92.9	-1.79	0.25
2004	4	28.48	64.1	6.06	0.11	2021	408	45.12	76.9	3.65	0.18
2005	4	29.52	65.9	6.98	0	2022	433	45.64	77.6	3.25	0.24
2006	3	29.76	67.7	6.44	-0.47	2023	458	45.56	78.4	2.86	0.06
2007	6	30.16	69.5	6.45	-0.34	2024	485	45.6	79.2	3.08	0.58

4.1.1 Data Preprocessing: Prior to analysis, the dataset underwent several preprocessing steps using specialized Python codes, including (i) data cleaning - Missing values were checked and handled appropriately, (ii) date formatting - the Date column was converted to datetime format, and set as the index for time series analysis, and (iii) feature selection - the independent variables were selected based on their relevance to terror incidents, informed by existing literature. Figure 4.0 below give a graphical representation of the dataset in Table 3.0.

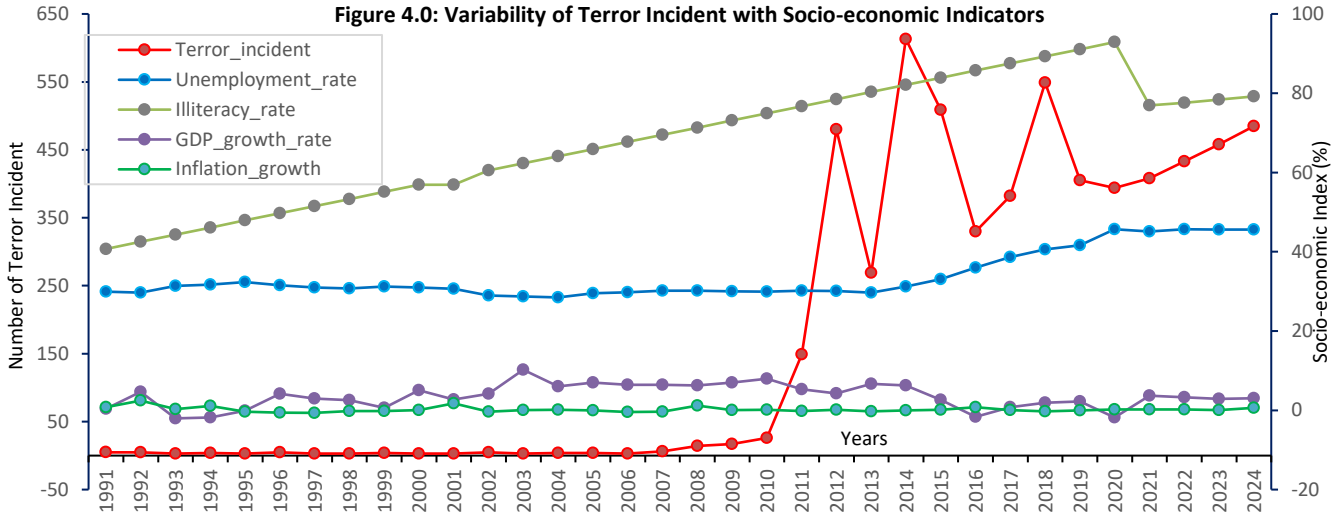


Figure 4.0 Above, illustrates the trends of key socio-economic indicators alongside the number of terror incidents in Northern Nigeria from 1991 to 2024. Below is a detailed interpretation of each element represented in the graph:

(i) Terror Incidents (Red Line) indicate a noticeable increase starting around 2010, with a significant spike around 2014. This period correlates with rising insurgency activities in the region, likely linked to the activities of groups like Boko Haram.

(ii) Unemployment Rate (Blue Line) exhibits a general upward trend, especially from the mid-2000s onward, suggesting growing economic distress. The rising unemployment rate may contribute to socio-economic instability, which can be a breeding ground for terrorism, especially in vulnerable populations.

(iii) Illiteracy Rate (Green Line) shows a gradual increase over the years, indicating persistent educational challenges in the region. Higher illiteracy rates are often associated with decreased economic opportunities and social cohesion, potentially exacerbating the risk of radicalization.

(iv) GDP Growth Rate (Yellow Line) shows fluctuations, with periods of both growth and decline. Notably, after 2014, there appears to be a drop, which could be linked to increased instability and reduced economic activity due to terrorism. Low or negative GDP growth can limit resources available for education, job creation, and social services, contributing further to the cycle of poverty and violence.

(v) Inflation Growth Rate (Black Line) also fluctuates but generally remains low until around 2015, when it begins to rise. Increasing inflation can erode purchasing power, further straining households and potentially leading to increased social unrest and susceptibility to extremist ideologies.

In the overall, the plot suggests a complex interplay between socio-economic indicators and terror incidents. As unemployment and illiteracy rise, and GDP growth stagnates or declines, the region may become more vulnerable to terrorism. The sharp increase in terror incidents around 2014 coincides with rising unemployment and stagnating economic growth, indicating that these socio-economic challenges may have contributed to the escalation in violence. In conclusion, the plot effectively highlights the significance of socio-economic indicators in understanding the dynamics of terrorism, emphasizing the need for integrated policies that address these underlying issues.

4.1.2 Homoscedasticity and Stationarity Test: To ascertain homoscedasticity of the model, the Breusch-Pagan test results yield a p-value of $0.8636 > 0.05$, indicating that the null hypothesis of homoscedasticity cannot be rejected. This suggests that the variance of the residuals is constant across all levels of the independent variable(s), indicating homoscedasticity. While the Augmented Dickey-Fuller (ADF) test results yielded a p-value of $5.6196E-13 < 0.5$, indicate that the null hypothesis of non-stationarity can be rejected.

This suggests that the time series dataset is stationary. In conclusion, based on the available results, the dataset appears to exhibit homoscedasticity and stationarity. However, multicollinearity remains unclear. These findings provide a foundation for further analysis and modeling using the gradient boost machine (GBM) approach to investigate the relationship between terror incidents and socio-economic indicators.

4.1.3 Multicollinearity: To test for multicollinearity of the independent variables, the Variance Inflation Factor (VIF) analysis yield the follows:

(i) Unemployment rate (VIF = 1.2634): The VIF value of 1.26 indicates low multicollinearity, suggesting that the unemployment rate is not highly correlated with the other independent variables in the model, making it a stable predictor.

(ii) Illiteracy rate (VIF = 1.1018): With a VIF of 1.10, this variable also shows low multicollinearity, suggesting that illiteracy rate is unlikely to cause issues related to redundancy or instability in the regression model.

(iii) GDP growth rate (VIF = 1.3677): With a VIF of 1.37, also indicates low multicollinearity, suggesting that GDP growth rate can be considered a reliable predictor without significant correlation with the other predictors.

(iv) Inflation growth rate (VIF = 1.0114): The VIF value of 1.01 suggests very low multicollinearity, indicating that inflation growth rate is not correlated with the other independent variables.

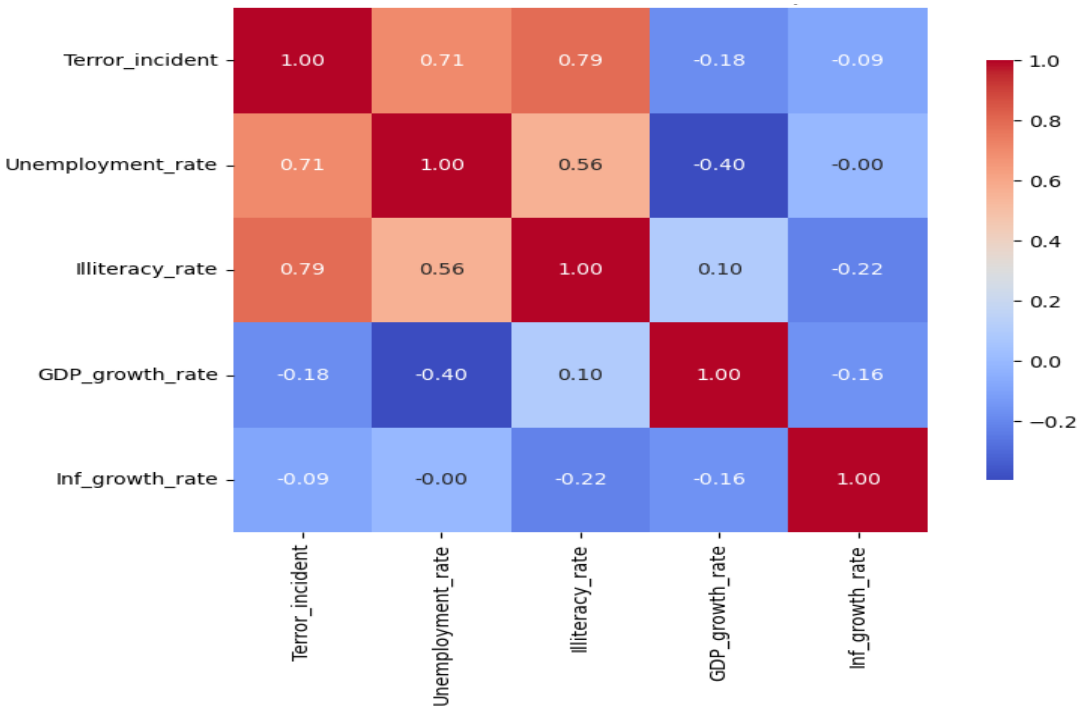
(v) **Intercept (VIF = 1.3874):** The intercept's VIF value of 1.39 is also within an acceptable range, indicating no multicollinearity issues.

In summary, all VIF values are below 5, and most are below 2, indicating that multicollinearity is not a concern in this model. This low level of multicollinearity suggests that each independent variable contributes uniquely to the model without significant redundancy. Therefore, the model's estimates should be stable and interpretable, reinforcing the validity of the GBM analysis.

4.2 Correlation Analysis:

The correlation analysis seeks to establish the relationships between terror incident and the indicators variables. In the context of the GBM analysis, a correlation heatmap in figure 4.1 below, serves as an essential preliminary test for understanding the interplay between the dependent variable (terror incidents) and independent variables (such as unemployment rate, illiteracy rate, GDP growth rate, and inflation growth rate).

Figure 4.1: Correlation Matrix Heatmap



- **Terror incident and Unemployment rate (0.71)**: A correlation coefficient of 0.71, indicate a strong positive correlation between terror incidents and the unemployment rate. This suggests that as unemployment increases, the number of terror incidents tends to increase as well.
- **Terror incident and Illiteracy rate (0.79)**: A correlation coefficient of 0.79 indicate a very strong positive correlation between terror incidents and the illiteracy rate. Higher illiteracy rates are associated with an increase in terror incidents, indicating a potential link between education levels and social unrest.
- **Terror incident and GDP growth rate (-0.18)**: A correlation coefficient of -0.18 indicate a weak negative correlation between Terror incident and GDP growth rate. Though, the correlation is not strong enough to draw definitive conclusions, however, this result suggest that an increasing GDP growth has the potential to decrease terror incidents.
- **Terror incident and Inflation growth rate (-0.09)**: This correlation is negligible, indicating no significant relationship between inflation growth rates and terror incidents.

- **Unemployment rate and Illiteracy rate (0.56)**: A correlation coefficient of 0.56 indicate a moderate positive correlation between unemployment and illiteracy rates, suggesting that higher unemployment may be associated with higher illiteracy rates.
- **Unemployment rate and GDP growth rate (-0.20)**: A correlation coefficient of -0.20 indicate a weak negative correlation, indicating that higher unemployment is associated with lower GDP growth.
- **Unemployment rate and Inflation growth rate (0.22)**: A correlation coefficient of 0.22 indicate s a weak positive correlation, indicating that higher unemployment is associated with high inflation growth rate
- **Illiteracy rate and GDP growth rate (-0.14)**: A weak negative correlation indicates that higher illiteracy rates may be associated with lower GDP growth rate.
- **Illiteracy rate and Inflation growth rate (0.20)**: A correlation coefficient of 0.20 indicates a weak positive correlation, suggesting a potential link between rising inflation and increasing illiteracy rates.

The correlation matrix reveals significant relationships between terror incidents and socio-economic factors, particularly unemployment and illiteracy rates. This suggests that addressing these underlying issues may be important in efforts to reduce terror incidents. The correlations with GDP growth and inflation are weaker, indicating that they may not be as directly influential on the rate of terror incidents in this dataset.

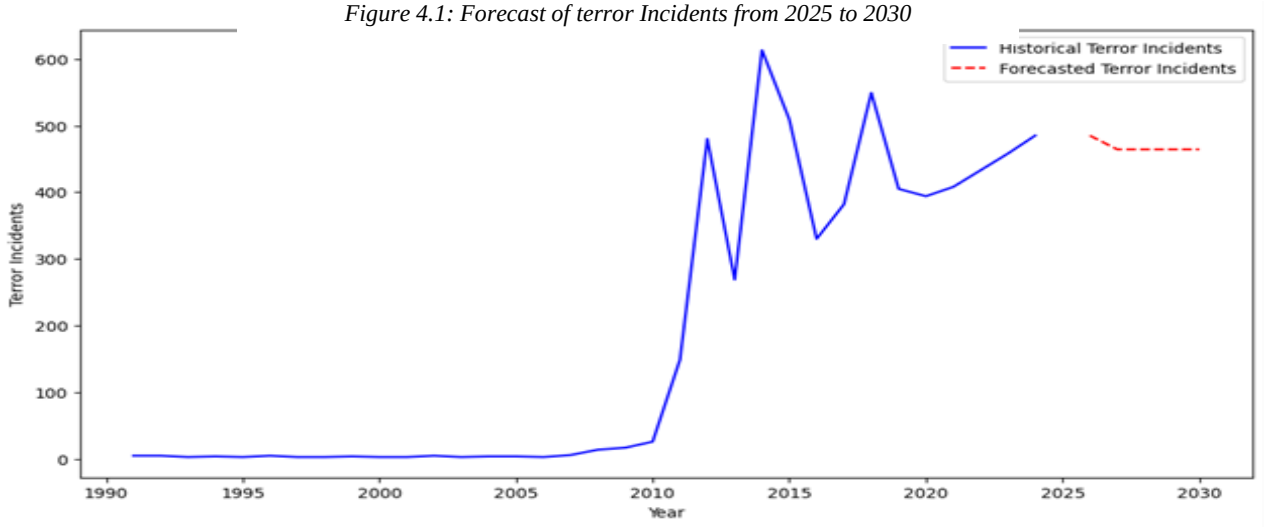
4.3 GBM Model Selection and Analysis

The GBM algorithm was chosen for its robustness in handling non-linear relationships and interactions between variables. This ensemble learning technique builds multiple decision trees and combines their predictions for improved accuracy.

4.3.1 Model Training and Testing: The dataset was split into training (80%) and testing (20%) subsets to evaluate model performance. The GBM model was trained using the independent variables (socio-economic factors) to predict the dependent variable (Terror incident). Key hyperparameters were tuned using cross-validation to optimize model performance.

4.3.2 Model Evaluation and Results: The GBM model performance was evaluated using the mean squared error (MSE) parameter - to assess the average squared errors between predicted and actual values. While the R^2 Score determines the proportion of variance explained by the model. After analysis, the model achieved an MSE of 709.03, indicating the average deviation of predictions from actual incident counts. While the R^2 score was 0.8734, suggesting that approximately 87.34% of the variance in terror incidents was explained by the model, a demonstration of strong predictive capabilities.

Figure 4.1: Forecast of terror Incidents from 2025 to 2030



4.3.3 Model Forecast: Given these results, the trained GBM model, were used to generate forecasts of terror incidents from 2025 to 2030, as show in figure 4.1 below. The forecasts indicated a potential increase in incidents, highlighting ongoing security challenges. The Figure 4.1 above shows the historical and forecasted rates of terror incidents in the Nigerian northern from 1990 to 2030. The blue line represents the historical trends of terror incidents, showing significant fluctuations over the years, with a notable spike occurs around 2011 - where terror incidents reach an unprecedented high, indicating a peak in violence and insecurity during that period. Following this peak, there was a decline but with some fluctuations, indicating ongoing instability and sporadic incidents of terror. The red doted lines represent the forecasted terror incidents from 2025 to 2030, indicates a gradual increase in terror incidents, starting from approximately 400 incidents in 2025 and approaching 500 by 2030. This forecast suggests a stabilization in the number of incidents at a high level, rather than a significant reduction, which is concerning.

4.3.4 Implications of Model forecast: The forecasted increase in terror incidents suggests that the threat of terrorism will remain significant in northern Nigeria, posing challenges for security agencies and policymakers, who may need to allocate resources to combat this persistent threat. The projected increase underscores the urgent need for effective CT measures and socioeconomic interventions. Addressing underlying issues such as unemployment and illiteracy, which may contribute to the rise in terrorism, is crucial. This continued high levels of terror incidents can lead to further destabilization of the region. This can have ripple effects, including increased displacement of populations, disruption of economic activities, and a decline in public safety and trust in government institutions.

Policymakers should prioritize comprehensive

strategies that not only focus on immediate security responses but also on long-term socio-economic development. Investments in education, job creation, and community engagement could help mitigate the factors driving terrorism. Continuous monitoring of the security situation is essential. The predictions should be adapted as new data become available, ensuring that strategies remain relevant and effective in responding to changing dynamics. In summary, the GBM forecast plot indicates a troubling trend of increasing terror incidents, highlighting significant security implications for northern Nigeria. Addressing this challenge will require a multifaceted approach that combines security measures with socio-economic development to create a more stable and secure environment.

5.0 RESULTS OF THE ANALYSIS AND DISCUSSION

Based on the analysis of the GBM model applied to socio-economic indicators of terrorism in Northern Nigeria, we present the following key findings which emerged and their analytical discussion, focusing on the influence of independent variables, implications for CT measures, and policy recommendations.

5.1 Accuracy, Validity, Reliability and Model's Performance

GBM models are renowned for their ability to produce high-quality predictions through an ensemble learning approach. The model work by combining multiple weak learners, typically decision trees, to create a robust predictive model. The accuracy, validity, reliability, and performance of the GBM model is the critical aspects in determining its effectiveness in making predictions. Accuracy refers to how closely the model's predictions match the actual outcomes, while validity ensures that the model accurately represents the underlying relationships in the data. Reliability is concerned with the model's consistency across different datasets and the sampled conditions. In the context of GBM, these attributes can be significantly influenced by properties such as multicollinearity, homoscedasticity, and stationarity. When these properties are satisfied, they enhance the model's performance by ensuring that it can generalize well to new data and produce stable predictions. In summary, recognizing and addressing these parameters is crucial for achieving a GBM model that is not only accurate and valid but also reliable in its performance.

5.1.1 Homoscedasticity and Stationarity: Homoscedasticity and stationarity are vital for the robustness of a GBM model - implies that the variance of model residuals remains constant across different levels of the independent variables, which is essential for the reliability of statistical inferences drawn from the model. Stationarity, particularly in time series data, indicates that the statistical properties of a variable remain constant over time, a requirement for many predictive models to ensure meaningful results. The Breusch-Pagan test confirmed homoscedasticity (p-value $= 0.8636 > 0.05$), indicating that the variance of residuals is constant across all levels of the independent variables. The Augmented Dickey-Fuller (ADF) test confirmed stationarity (p-value $= 5.6196E-13 < 0.05$), suggesting the dataset is appropriate for time-series modeling.

5.1.2 Multicollinearity: Multicollinearity, or the high correlation among independent variables, can distort parameter estimates and inflate standard errors, leading to unreliable conclusions about variable significance. Low multicollinear variables ensures that each predictor contributes uniquely to the model, enhancing its overall performance. The Variance Inflation Factor (VIF) analysis revealed low multicollinearity among the independent variables (all VIF values < 2). This indicates that unemployment rate, illiteracy rate, GDP growth rate, and inflation growth rate contribute uniquely to the model without redundancy.

5.1.3 Model Performance: The validity and performance of a GBM model are assessed through metrics such as Mean Squared Error (MSE) and R^2 score, which evaluate how well the model predicts unseen data. Additionally, the model's ability to generalize to new data is vital for its performance, which can be influenced by the choice of features and the handling of multicollinearity. Overall, the interplay of these parameters and evaluation methods ensures that a GBM model not only achieves high accuracy but also maintains validity and performance across various datasets. The GBM model achieved a Mean Squared Error (MSE) of 709.03, indicating a relatively low average deviation between predicted and actual values. The R^2 score of 0.8734 suggests that approximately 87.34% of the variance in terror incidents is explained by the socio-economic indicators, demonstrating strong predictive capability.

5.1.4 Influence of Independent Variables: The correlation analysis seeks to establish the influence or relationships between dependent and the independent variables. In the context of the GBM analysis, a correlation heatmap in figure 4.1 below, serves as an essential preliminary test for understanding the interplay between the model's variables:

- **Unemployment Rate:** The correlation analysis shows a strong positive correlation (0.71) between terrorist incidents and unemployment - suggesting that higher unemployment may lead to increased instability and discontent, potentially driving individuals toward radicalization. This finding aligned with the "Relative Deprivation Theory", which posit that economic hardship can lead to feelings of disenfranchisement, which may fuel extremist behaviors.
- **Illiteracy Rate:** The illiteracy rate shows an even stronger correlation (0.79) with terror incidents. High illiteracy can limit access to education and economic opportunities, fostering environments where radical ideologies can thrive. This finding aligned with the "Social Learning Theory", indicating that individuals who lack educational opportunities may be more susceptible to extremist propaganda.
- **GDP Growth Rate:** GDP growth shows a weak negative correlation (-0.18) indicates that higher GDP growth may slightly mitigate terror incidents. This suggests that economic growth can contribute to stability, reducing the allure of extremist groups. This finding aligned with the Economic theories, which emphasize that economic development can lead to improved living standards, which may reduce grievances that fuel terrorism.
- **Inflation Growth Rate:** The negligible correlation (-0.09) suggests that inflation may not significantly influence terror incidents directly. However, economic instability can indirectly affect other socio-economic factors.

5.1.5 Forecast of Terror Incidents (2025-2030): The model forecast indicates a gradual increase in terror incidents, rising from approximately 400 incidents in 2025 to 500 incidents by 2030. Historical trends reveal a spike in terror incidents around 2011, followed by a decline with fluctuations, but the forecast suggests a stabilization at high levels of incidents, signalling persistent insecurity. This implies that, given the historical pattern of unemployment rate, illiteracy rate, GDP growth rate and inflation growth rate, terror incidents may increase from approximately 400 incidents in 2025 to 500 incidents by 2030, if urgent proactive CT efforts are not made to address the indicators – unemployment and illiteracy.

5.2 Security Implications

The above findings of the GBM model and forecast have significant security implications for Northern Nigeria. The predicted increase in terror incidents, particularly through 2030, indicates that CT measures must be multifaceted:

- **Persistent Threat of Terrorism**: The projected increase in terror incidents suggests that terrorism will remain a long-term security challenge in Northern Nigeria. This persistent threat could destabilize the region further, undermining efforts to restore peace and stability. Therefore, government may need to allocate more resources to this region, with respect addressing high unemployment and illiteracy rates, as these are significant predictors of terrorism

- **Impact on Governance and Public Trust:** Continued high levels of terror incidents may erode public trust in government institutions and security agencies, especially if the government fails to address the root causes of terrorism effectively. Therefore, emphasis should be placed on preventive measures that address the root causes of terrorism rather than solely reactive security responses.
- **Economic Disruption**: The rise in terror incidents could lead to displacement of populations, disruption of economic activities, and a decline in foreign and domestic investments in the region. This could further exacerbate poverty and unemployment, creating a vicious cycle of insecurity. Therefore, building trust within communities can enhance intelligence-gathering efforts and foster cooperation between citizens and law enforcement, thereby mitigating the impending disruption of economic activities in the region.
- **Humanitarian Crisis**: Increased terror incidents are likely to worsen the humanitarian crisis in the region, with more internally displaced persons (IDPs), loss of lives, and destruction of infrastructure. This could strain government resources and international aid efforts.
- **Regional Instability**: Northern Nigeria's instability could spill over into neighbouring countries, particularly in the Lake Chad Basin region, where groups like Boko Haram and ISWAP operate. This could lead to cross-border terrorism and complicate regional security efforts.

5.3 Sustainable Solutions and Policy Recommendations

Drawing from relevant theories, case studies, and the findings of this research, the following recommendations are proposed to optimize CT efforts in Northern Nigeria:

5.3.1 Addressing Socio-Economic Root Causes: High unemployment rates in Northern Nigeria are a significant driver of terrorism. The government should implement job creation programs, particularly in agriculture, small-scale industries, and entrepreneurship, to provide economic opportunities for the youth. Government should implement aggressive job creation and programs aimed at reducing unemployment through skill development and vocational training, particularly in states most affected by terrorism. Government must support for small businesses, by encouraging entrepreneurship through financial support and access to markets, which can provide alternative livelihoods for at-risk populations. A case study is the Rwanda's post-genocide economic recovery program, that focused on youth employment and vocational training - which helped reduce violence and instability (Ansoms, 2005; Takeuchi, 2019; Kimanuka, 2009)

Illiteracy is another key factor contributing to terrorism. Investments in education infrastructure, particularly in rural areas, are critical. Programs to promote adult literacy and skill acquisition should be prioritized. Government should implement mass literacy programs, and a proactive investment in adult education and literacy initiatives to empower communities, particularly in areas with high illiteracy rates. Engaging schools in promoting critical thinking and civic education would help to counteract extremist ideologies, According to Human Capital Theory, investments in education and skills development lead to economic growth and social stability (Becker, 1964; Schultz, 1961).

5.3.2 Strengthen Security and Counter-Terrorism Measures: Engage local communities in intelligence gathering and community policing to improve the effectiveness of CT operations. A case study is Kenya's community policing initiatives in countering Al-Shabaab, which have shown promise in improving local security. Kenya's community policing initiatives, specifically the Nyumba Kumi (NK) program in countering Al-Shabaab's terrorist activities, highlights the potential in promoting community-led security initiatives. (Omar, 2018; Mwagiru, 2017; Wandera, 2018).

Enhancement of military and law enforcement agencies' capacity through training, modern equipment, and intelligence-sharing mechanisms, is the prerequisite to countering today's geographically more dispersed and tactically adaptable terrorist organization. Becker (1968), applying the Rational Choice Theory to crime and punishment, argued that individuals weigh the potential costs and benefits of engaging in criminal activity, including terrorism. According to Becker, increasing the cost of engaging in terrorism (e.g., through effective law enforcement) can deter individuals from participating in such activities (Becker,1968; Cornish, & Clarke, 1986; Crenshaw, 1981).

5.3.3 Promote Regional Cooperation: Effort to strengthen regional cooperation with neighbouring countries (e.g., Chad, Niger, and Cameroon) to combat cross-border terrorism. This includes joint military operations, intelligence sharing, and border control. A case study of the Multinational Joint Task Force (MNJTF) in the Lake Chad Basin has been effective in coordinating efforts against Boko Haram. The MNJTF has indeed been effective in coordinating efforts against Boko Haram since its reactivation in 2014. The MNJTF has managed to consolidate significant gains, including a decline in the number of terrorist attacks and fatalities in the region, neutralized 22 Boko Haram/ISWAP terrorists, destroyed their infrastructure and equipment, and rehabilitate over 20 towns

and villages in 2021, cleared several Boko Haram/ISWAP strongholds, eliminated top terrorist commanders, and freed over 4,000 civilians in 2022. In aggregate, decrease the number of terrorist attacks and fatalities in the region decreased from 8,119 in 2015 to 1,894 in 2021. (Mariana, 2023).

5.3.4 Enhance Governance and Public Trust: Government should address endemic corruption within government and security agencies to ensure that resources allocated for CT and socio-economic development are used effectively. A case study of Ghana's anti-corruption reforms has improved public trust and governance, contributing to political stability (Rahman, 2018). Inclusive governance should be promoted by ensuring that marginalized communities in Northern Nigeria have a voice in decision-making processes. This can help address grievances that fuel terrorism.

5.3.5 Implement Long-Term Development Strategies: Investment in infrastructure (e.g., roads, electricity, and healthcare) help to improve living conditions and foster economic growth in Northern Nigeria. The Modernization Theory by Lipset, (1959) emphasizes the role of infrastructure and economic development in reducing social unrest and violence. Lipset argues that economic development and modernization are key factors in reducing social unrest and violence, and promoting democracy. He posits that as countries develop economically, they experience increased urbanization, education, and social mobility, which in turn lead to greater political stability and reduced social unrest (Deutsch,1961; Lipset, 1959). Promoting programs that foster social cohesion, interfaith dialogue, and conflict resolution would help to address ethnic and religious tensions that contribute to terrorism.

5.3.6 Continuous Monitoring and Adaptive Strategies: Continuous monitoring and evaluation of socio-economic conditions and their correlation with terrorism is essential. Use of predictive models like the GBM to continuously monitor trends in terror incidents and adapt counter-terrorism strategies accordingly. CT policies should be adaptable based on new data and emerging trends. A case study of the United States used of predictive analytics to anticipate terrorist activities and allocate resources effectively, is a recommendable initiative (Danzon, & Nicholson, 2013). Regularly review and update CT policies to ensure they remain relevant and effective in responding to changing dynamics.

In summary, the GBM model highlights the critical role of socio-economic factors in driving terrorism in Northern Nigeria. The forecasted increase in terror incidents underscores the urgency of implementing a multifaceted approach that combines security measures with socio-economic development. By addressing unemployment, illiteracy, and poverty while strengthening governance and regional cooperation, Northern Nigeria can move toward a more stable and secure future. Policymakers must act decisively to break the cycle of insecurity and create an environment where peace and development can thrive.

CONCLUSION

The findings of this study underscore the critical role of socio-economic indicators in understanding and addressing terrorism in Northern Nigeria. The application of the Gradient Boosting Machine (GBM) model has provided valuable insights into the relationships between terror incidents and key variables such as unemployment and illiteracy rates. With the model achieving a robust R^2 score of 0.8734, it demonstrates a strong predictive capability, indicating that socio-economic factors are significant drivers of terror incidents. The forecasted increase in terror incidents from 2025 to 2030 further emphasizes the urgency for effective counterterrorism strategies.

Addressing the root causes of terrorism is essential for creating a more secure environment. Policymakers must prioritize initiatives that focus on job creation and educational opportunities, particularly in regions most affected by terrorism. Implementing comprehensive socio-economic development programs can alleviate poverty and disenfranchisement, thereby reducing the appeal of extremist ideologies. Additionally, fostering community engagement and trust between citizens and security agencies will enhance the effectiveness of counterterrorism efforts.

Ultimately, the study advocates for a multifaceted approach that integrates security measures with long-term socio-economic development strategies. By tackling the underlying issues of unemployment and illiteracy, Northern Nigeria can move towards a more stable and secure future. Continuous monitoring and adaptive strategies, utilizing predictive models like GBM, will ensure that counterterrorism policies remain relevant and effective in addressing evolving dynamics in the region.

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