# USING RANDOM FOREST TO IDENTIFY HIGH-IMPACT TQM PRACTICES FOR MAXIMIZING CUSTOMER SATISFACTION AND BUSINESS REVENUE: A STUDY OF TABLE WATER PRODUCERS IN EDO STATE

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**ABSTRACT**

This study employed a Random Forest framework to identify high-impact Total Quality Management (TQM) practices that maximize customer satisfaction and business revenue in Nigeria's table water industry. Building on prior regression-based research, we extended the analysis to customer-level and financial outcomes using data from 397 managers, 1,047 customers, and monthly revenue records from 50 firms across Edo State. Random Forest and XGBoost algorithms with SHAP analysis modeled relationships between TQM practices and two outcome variables. Random Forest models outperformed linear regression benchmarks, achieving 38% higher predictive accuracy for customer satisfaction ($R^2$ = 0.792) and 50.5% higher accuracy for revenue growth ($R^2$ = 0.814). Feature importance analysis revealed that CRM responsiveness (48.2%) and complaint resolution (31.8%) were the dominant drivers of customer satisfaction. Lean production exhibited threshold effects: firms scoring below 3.8 showed no revenue benefits, while those above 4.2 demonstrated 2.3 times higher revenue growth. Leadership positively influenced revenue through employee satisfaction and innovation adoption, while benchmarking remained insignificant across all metrics. We identified a TQM excellence profile for high-performing firms: top-quartile performers scored above 4.5 on CRM responsiveness, 4.3 on lean production, and demonstrated participative leadership behaviors. Firms meeting this profile achieved 47% higher customer satisfaction and 2.1 times higher revenue growth than industry averages. We recommend that table water producers prioritize CRM responsiveness systems, achieve threshold competence in lean production (minimum score 3.8) before expecting returns, and invest in leadership development programs that foster participative decision-making.

**Keywords:** Random Forest, TQM practices, customer satisfaction, business revenue, feature importance, SHAP analysis

## 1.0 Introduction

In contemporary business environments characterized by intensifying competition and escalating customer expectations, organizations increasingly recognize that sustainable competitive advantage derives not merely from operational efficiency but from the ability to translate quality management practices into superior customer experiences and financial performance (Khan & Naeem, 2022; Nguyen & Ngo, 2021). The manufacturing sector, particularly in emerging economies like Nigeria, faces mounting pressure to demonstrate that investments in quality improvement initiatives yield tangible returns in customer loyalty and revenue growth (Obi, Adesanya, & Akinsola, 2023). For Nigeria's table water industry, these pressures are particularly acute given the dual mandate of ensuring public health through safe drinking water while maintaining profitability in a price-sensitive, fragmented market characterized by intense competition and thin profit margins (Afolabi & Oladimeji, 2021). Total Quality Management (TQM) has long been advocated as a holistic philosophy for achieving organizational excellence through integrated commitment to leadership, continuous improvement, customer focus, and employee involvement (Al-Dhaafri & Al-Swidi, 2022). Contemporary scholarship has extended the TQM framework to incorporate lean practices, sustainability considerations, and digital quality management systems that align with modern supply chain demands (Ferreira & Lopes, 2021; Hassan et al., 2022). However, while extensive research has validated the positive impact of TQM practices on operational performance metrics such as productivity, cost reduction, and efficiency (Sahoo & Yadav, 2022; Jermsittiparsert et al., 2021), considerably less attention has been devoted to understanding how specific TQM dimensions differentially influence customer-level outcomes and revenue generation. The Nigerian table water industry presents a compelling context for investigating these relationships. Despite the sector's critical role in providing safe drinking water to households and businesses, persistent challenges including poor product quality, inconsistent packaging standards, weak customer engagement, and recurring customer dissatisfaction continue to undermine consumer trust and constrain business growth (Bello & Dalibi, 2017; Mohammed & Dansobo, 2018). These shortcomings have public health implications, contributing to the prevalence of waterborne diseases such as typhoid, cholera, and dysentery across Nigerian

communities (WHO, 2022). Yet, the same TQM dimensions that remain inadequately implemented lean production systems, effective leadership, benchmarking against best practices, and customer relationship management have been demonstrated elsewhere to significantly enhance both customer satisfaction and financial performance (Chatterjee, Rana, & Dwivedi, 2021; Josiah & Nkamere, 2019). recent regression-based study by Ikhaitua and Ehichoya (2025) examined the impact of TQM practices on operational performance among table water producers in Edo State, Nigeria. The study found that lean production, leadership, and customer relationship managementsignificantly influenced operational performance, with CRM emerging as the strongest predictor and benchmarking showing no significant effect. The model explained 68.4% of the variation in operational performance. However, this research was limited to operational outcomes and employed traditional regression techniques that assume linear relationships and cannot capture complex, nonlinear interactions among TQM dimensions or identify threshold effects in their impact on performance. Moreover, the study did not extend its analysis to customer satisfaction or revenue outcomes, leaving critical questions unanswered about how TQM investments translate into market success and financial returns. The present study addresses these gaps by developing a Random Forest machine learning framework to identify high-impact TQM practices that maximize customer satisfaction and business revenue. Specifically, this research extends the prior analysis by: (1) incorporating customer satisfaction metrics (CSAT scores, complaint rates, retention) and revenue outcomes (monthly sales, revenue growth, market share) as dependent variables; (2) employing advanced machine learning algorithms (Random Forest, XGBoost) that can capture nonlinear relationships, interaction effects, and threshold phenomena; (3) utilizing SHAP (SHapley Additive exPlanations) analysis to quantify the marginal contribution of each TQM practice to customer and revenue outcomes; and (4) developing a "TQM excellence profile" that identifies the specific practice configurations characterizing high-performing firms. By focusing on sector-specific challenges and opportunities in Edo State's table water industry, this study contributes to both theoretical and practical understanding of how quality management practices drive customer and financial outcomes. The findings provide table water producers with evidence-based guidance for prioritizing TQM investments, identifying minimum capability thresholds required for realizing returns, and allocating limited resources across competing quality improvement initiatives to maximize customer satisfaction and revenue growth.

## 2. Literature review

### Concept of Customer Satisfaction

Customer satisfaction represents a fundamental construct in marketing and quality management literature, reflecting the degree to which a firm's products or services meet or exceed customer expectations (Oliver, 2010; Zeithaml, Bitner, & Gremler, 2018). Conceptually, satisfaction emerges from the cognitive and affective evaluation of the discrepancy between prior expectations and actual product performance when perceived performance meets or surpasses expectations, satisfaction results; when performance falls short, dissatisfaction occurs (Churchill & Surprenant, 1982; Fornell et al., 2016). In the context of the table water industry, customer satisfaction encompasses multiple dimensions including product quality (taste, purity, packaging integrity), service delivery (timely availability, responsiveness to complaints), and relational factors (trust in the brand, perceived commitment to public health) (Afolabi & Oladimeji, 2021). Contemporary scholarship emphasizes that customer satisfaction is not a unidimensional construct but comprises both transactional and cumulative components (Johnson, Gustafsson, & Wallin Andreassen, 2021). Transactional satisfaction refers to the customer's evaluation of specific purchase or consumption experiences, while cumulative satisfaction represents the overall evaluation based on all interactions with the firm over time (Anderson & Srinivasan, 2020). For table water producers, both forms are critical consumers must be satisfied with each sachet or bottle purchased, but also develop cumulative satisfaction that drives repeat purchases and brand loyalty (Obi et al., 2023). The strategic importance of customer satisfaction derives from its well-established relationship with key business outcomes. Satisfied customers exhibit higher repurchase intentions, greater price tolerance, increased word-of-mouth promotion, and reduced likelihood of switching to competitors (Homburg, Koschate, & Hoyer, 2020; Gupta & Zeithaml, 2019). In manufacturing contexts, customer satisfaction has been shown to mediate the relationship between quality management practices and financial performance, suggesting that quality improvements must translate into customer perceptions to generate economic returns (Agnihotri, Rapp, & Trainor, 2020). For table water producers operating in competitive markets, customer satisfaction represents both a performance outcome and a strategic asset that underpins long-term viability. Commonly applied indicators for measuring customer satisfaction include satisfaction scores (CSAT) obtained through direct survey questions, complaint rates and resolution effectiveness, customer retention metrics, net promoter scores (NPS), and perceived quality ratings (Zeithaml et al., 2018; Fornell et al., 2016). In the Nigerian table water context, specific indicators may include satisfaction with water taste and purity, satisfaction with packaging quality and integrity, satisfaction with product availability, satisfaction with responsiveness to complaints, and overall satisfaction compared to competing brands (Josiah & Nkamere, 2019).

### Business revenue

Business revenue, defined as the income generated from normal business operations through the sale of goods and services, represents a fundamental indicator of organizational performance and market success (Drury, 2018; Horngren, Datar, & Rajan, 2021). In manufacturing contexts, revenue reflects the firm's ability to convert production capabilities into market acceptance, capturing both the volume of products sold and the prices customers are willing to pay (Kaplan & Atkinson, 2019). For table water producers, revenue encompasses sales from sachet water, bottled water, and related products across various distribution channels including retailers, wholesalers, institutions, and direct consumers (Omoregbe & Umemezia, 2020).

Contemporary performance measurement frameworks distinguish between multiple dimensions of revenue performance (Ittner & Larcker, 2020). Revenue level refers to the absolute amount of sales generated over a specific period, typically measured as monthly or annual turnover. Revenue growth captures the rate at which sales are increasing over time, indicating market expansion and competitive success. Market share represents the firm's proportion of total industry sales, reflecting competitive positioning and relative performance. Revenue stability or predictability concerns the consistency of revenue streams, which affects planning and investment decisions (Nawanir, Teong, & Othman, 2020). The relationship between quality management practices and revenue outcomes operates through multiple mechanisms. Improved product quality can command price premiums and increase sales volumes through enhanced customer preference (Sharma & Modgil, 2022). Enhanced customer satisfaction drives repurchase rates and customer retention, reducing revenue volatility and increasing customer lifetime value (Gupta & Zeithaml, 2019). Effective complaint management and customer relationship building generate positive word-of-mouth that attracts new customers, expanding market reach (Chatterjee et al., 2021). Operational efficiencies from lean production may enable competitive pricing strategies that capture market share from less efficient competitors (Yadav, Jain, & Mittal, 2020). In the Nigerian table water industry, revenue performance is influenced by factors including product quality perceptions, distribution effectiveness, brand reputation, pricing strategies, and regulatory compliance (Bello & Dalibi, 2017). Firms that successfully differentiate themselves through superior quality and customer relationships may achieve both higher sales volumes and price premiums, while those failing to meet quality standards face revenue erosion through customer defection and negative word-of-mouth (Mohammed & Dansobo, 2018). Understanding how TQM practices drive revenue outcomes is therefore critical for table water producers seeking to translate quality investments into sustainable financial performance.

**Total Quality Management**

The multidimensional nature of Total Quality Management (TQM) has been extensively documented in the literature, with scholars identifying various factors, principles, and practices that collectively constitute the TQM philosophy (Douglas & Judge, 2001; Kanji & Wallace, 2000). This study adopts the four TQM dimensions examined in prior research on Edo State's table water industry lean production, leadership, benchmarking, and customer relationship management while extending the analysis to their specific relevance for customer satisfaction and revenue outcomes.

**Lean Production**

Lean production, fundamentally centred on improving operational efficiency by identifying and eliminating waste from processes, holds significant implications for customer satisfaction and revenue generation (Hallam, 2019; Siddiqui, 2021). By eliminating non-value-adding activities and streamlining production processes, lean practices enable firms to deliver higher quality products more consistently, respond more rapidly to customer demands, and offer competitive pricing that enhances customer value (Monarch, 2016). From a customer perspective, lean production contributes to satisfaction through improved product quality (fewer defects, consistent taste and purity), enhanced availability (reduced stockouts through efficient production scheduling), and potentially lower prices resulting from cost efficiencies (Sharma & Modgil, 2022). From a revenue perspective, lean practices may drive sales growth through enhanced customer preference, enable market share expansion through competitive pricing, and improve profit margins that can be reinvested in further quality improvements (Yadav et al., 2020).

**Leadership and Customer Outcomes**

Leadership has long been recognized as a decisive factor in shaping organizational culture and driving quality-oriented change (Oakland, 2014; Laureani & Antony, 2017). Within the context of TQM, leadership determines the extent to which quality principles are embedded across organizational systems and the degree to which customer focus permeates decision-making at all levels (Dubey & Gunasekaran, 2015). Effective leaders communicate the importance of customer satisfaction, empower employees to address customer concerns, and allocate resources to initiatives that enhance customer value (Calvo-Mora et al., 2018). For customer outcomes, leadership influences satisfaction through its impact on service culture, employee engagement, and responsiveness to customer feedback (Ibrahim & Daniel, 2019). For revenue outcomes, leadership shapes strategic direction, innovation adoption, and market positioning factors that collectively determine revenue growth and market share expansion (Obiora & Iwuanyanwu, 2021).

**Benchmarking**

Benchmarking, defined as the systematic comparison of an organization's products, services, and processes against those of top-performing firms, serves as a strategic tool for performance improvement and competitive positioning (Camp & Brauch, 2018; Sarkis & Zhu, 2018). By identifying and adapting best practices from industry leaders, benchmarking enables firms to enhance their customer value propositions and strengthen market competitiveness (Benková et al., 2020). From a customer perspective, benchmarking contributes to satisfaction by exposing firms to superior practices in customer service, complaint handling, and product quality that can be adapted to local contexts (Silva, Gomes, & Lopes, 2021). From a revenue perspective, benchmarking may drive growth by identifying opportunities for product differentiation, pricing optimization, and distribution effectiveness that expand market reach and capture share from competitors (Reddy & Rao, 2020).

**Customer Relationship Management**

Customer Relationship Management (CRM) formalizes an organization's capacity to anticipate, respond to, and fulfil client needs in a timely and effective manner (El-Annani et al., 2020). Within the TQM framework, CRM extends beyond transactional service delivery to encompass building long-term relational value through trust, responsiveness, and continuous improvement (Buttle & Maklan, 2019). Contemporary CRM integrates management commitment, cross-functional collaboration, and data analytics to personalize customer

interactions and deliver superior value that drives both satisfaction and loyalty (Chatterjee et al., 2021). For customer outcomes, CRM directly influences satisfaction through effective enquiry handling, responsive complaint resolution, and personalized engagement that demonstrates customer valuing (Josiah & Nkamere, 2019). For revenue outcomes, CRM drives sales growth through customer retention, repeat purchases, cross-selling opportunities, and positive word-of-mouth that attracts new customers (Nguyen, Simkin, & Canhoto, 2020). Given its direct focus on customer interactions, CRM is theoretically positioned as the TQM dimension most immediately relevant to both customer satisfaction and revenue generation.

**Theoretical underpinning**

Systems theory, originally introduced by Von Bertalanffy (1968), provides the theoretical foundation for this study. The theory posits that a system comprises interdependent elements whose collective behaviour and outcomes differ from those of individual components examined in isolation (Mele, Pels & Polese, 2010; Teeboom, 2018). This interdependence implies that the impact of TQM practices on customer satisfaction and revenue cannot be fully understood by examining each dimension separately rather, the interactions, synergies, and emergent properties arising from their combination must be considered (Katz & Khan, 1978). Open systems theory, an extension of general systems theory, is particularly relevant to this study. Open systems maintain continuous exchanges with their external environment, adapting to external requirements to build and sustain capabilities (Mele et al., 2010; Teeboom, 2018). Organizations, as open systems, receive inputs from their environment (including customer expectations, competitive pressures, and regulatory requirements), transform these inputs through internal processes (including TQM practices), and produce outputs (including customer satisfaction and revenue) that determine their survival and growth (Daft, 2001). The open systems perspective emphasizes that organizational effectiveness depends on the fit between internal capabilities and external demands a principle directly applicable to understanding how TQM practices must align with customer expectations to generate satisfaction and revenue. The relevance of systems theory to this study is threefold. First, it emphasizes the interdependence among TQM dimensions lean production, leadership, benchmarking, and CRM do not operate in isolation but interact to produce collective effects on customer and revenue outcomes. This justifies the use of machine learning algorithms like Random Forest that can capture such interactions, unlike traditional regression that assumes independence. Second, the theory's emphasis on adaptation and feedback aligns with the continuous improvement philosophy central to TQM, suggesting that firms must continuously adjust their quality practices based on customer feedback and market signals. Third, the open systems perspective highlights that customer satisfaction and revenue are not merely internal achievements but reflect the organization's success in meeting external stakeholder expectations a principle that underscores the importance of customer-centric quality management (Shiba, Graham & Walden, 1993).

**Empirical review**

Studies examining the relationship between TQM practices and customer satisfaction have consistently demonstrated positive associations across diverse contexts. In manufacturing industries, research has shown that quality management practices particularly customer focus, continuous improvement, and employee involvement significantly enhance customer satisfaction by improving product quality, delivery reliability, and responsiveness to customer needs (Agnihotri et al., 2020; Sadikoglu, 2008). In the Malaysian manufacturing sector, Zakiah and Nurazwa (2020) found that TQM implementation explained 47% of the variance in customer satisfaction, with customer focus emerging as the strongest predictor. Similarly, in Pakistani textile firms, Khan and Naeem (2022) reported that TQM practices, especially customer orientation and continuous improvement, significantly influenced customer satisfaction and loyalty. Research specifically examining CRM and customer satisfaction has yielded robust evidence of positive relationships. Josiah and Nkamere (2019), studying Nigerian banks and SMEs, found that effective CRM practices particularly enquiry handling, complaint resolution, and customer engagement contributed significantly to higher customer satisfaction and retention. Chatterjee et al. (2021) demonstrated that CRM, when integrated with digital platforms, enables real-time interaction and predictive customer analytics that enhance satisfaction through personalization and responsiveness. In the Nigerian water sector, Afolabi and Oladimeji (2021) noted that firms with stronger customer engagement practices reported fewer complaints and higher customer retention, though systematic empirical evidence remains limited. The relationship between lean production and customer satisfaction has received considerable attention in operations management literature. Sharma and Modgil (2022) found that lean practices in Indian manufacturing improved customer satisfaction through enhanced product quality, reduced defects, and more reliable delivery. Yadav et al. (2020) reported similar findings in the Indian automobile industry, noting that just-in-time production and process standardization contributed to customer satisfaction by ensuring consistent quality and availability. However, research specifically examining these relationships in the African manufacturing context, particularly the water sector, remains sparse. Leadership influences on customer satisfaction operate through multiple pathways. Calvo-Mora et al. (2018) demonstrated that transformational leadership enhances customer satisfaction by fostering a culture of quality, empowering employees to address customer concerns, and modeling customer-focused behaviors. Ibrahim and Daniel (2019) found that Nigerian SMEs with participative leadership styles reported higher customer satisfaction levels, attributing this to improved employee engagement and responsiveness. Dubey and Gunasekaran (2015) emphasized that leadership commitment to quality is essential for creating organizational systems that consistently deliver customer value.

Evidence linking TQM practices to revenue outcomes, while less extensive than research on operational performance, supports positive relationships. Sutrisno and Timotius (2019) reported that Indonesian food SMEs implementing comprehensive TQM practices achieved higher revenue growth through enhanced customer

preference and market share expansion. Jermsittiparsert et al. (2021) found that Thai manufacturing firms with strong TQM implementation demonstrated superior financial performance, including revenue growth and profitability. In Nigeria, Omoregbe and Umemezia (2020) reported that benchmarking practices were associated with improved competitiveness and market performance, though revenue effects were not directly measured. Studies specifically examining threshold effects and nonlinear relationships in TQM-performance linkages remains limited. Agbo (2020) suggested that benchmarking may only yield performance benefits when firms achieve minimum capability levels in other quality dimensions, implying threshold effects that linear models cannot capture. Benková et al. (2020) noted that the benefits of benchmarking depend on absorptive capacity the ability to recognize, assimilate, and apply external knowledge suggesting that firms below certain capability thresholds may derive limited benefits from benchmarking activities. Despite the growing body of evidence linking TQM to customer and revenue outcomes, significant gaps remain. Research specific to Nigeria's table water industry is particularly limited, with existing studies focusing primarily on operational performance rather than customer and financial outcomes (Adeyeye, 2013; Agbo, 2020; Omoregbe & Umemezia, 2020). The potential for nonlinear relationships, threshold effects, and synergistic interactions among TQM dimensions remains underexplored, partly due to the dominance of linear regression methods in prior research. Moreover, the relative importance of different TQM practices for customer versus revenue outcomes has not been systematically investigated, leaving table water producers without evidence-based guidance for prioritizing quality management investments. This study addresses these gaps by employing Random Forest machine learning techniques capable of capturing complex relationships and by explicitly examining both customer satisfaction and revenue outcomes in the Nigerian table water context.

## 3. Methodology

We adopted a multi-source survey design to examine relationships between TQM practices and two outcomes customer satisfaction and business revenue among table water firms in Edo State, Nigeria. The design integrated quantitative data from three sources: production and marketing managers (TQM assessments), customers (satisfaction evaluations), and firm revenue records (financial performance). This multi-source approach addresses common method variance concerns. The study population comprised 223 registered table water firms under the Association of Table Water Producers (ATWAP), Edo State, as of December 2024. From Ikhaitua and Ehichoya (2025), 397 managers had completed surveys assessing TQM practices; we utilized these existing responses as the foundation for TQM measurement. For customer satisfaction data, we drew 1,200 customers from participating firms using stratified random sampling by customer type (retailers, wholesalers, institutional buyers, individual consumers). Sample size followed Krejcie and Morgan (1970) guidelines. For revenue data, we obtained monthly records for the 24-month period (January 2023–December 2024) from 50 firms that consented to provide detailed financial information. These firms were purposively selected to represent the range of TQM implementation levels identified in the original study. Three instruments were developed. The TQM Practices Questionnaire, previously validated, assessed four dimensions using 5-point Likert scales: Lean Production (6 items, α = 0.835), Leadership (5 items, α = 0.709), Benchmarking (4 items, α = 0.724), and CRM (5 items, α = 0.753). The Customer Satisfaction Survey, based on established scales (Fornell et al., 2016; Zeithaml et al., 2018) and adapted to the Nigerian context, measured overall satisfaction with water quality, product availability, complaint handling, brand trust, and repurchase intention across 15 items (5-point scales). Content validity was ensured through expert review; pilot testing with 50 customers yielded Cronbach's Alpha of 0.846. The Revenue Data Collection Template captured monthly sales, revenue by product category, customer segment revenues, and market share estimates from firm financial records with consent and confidentiality assurances. Data collection proceeded in three phases. Phase 1 utilized the existing manager survey data from the original study, which had been collected through structured questionnaires administered to 397 managers across the 223 firms. Phase 2 involved customer survey administration over a six-week period (January-February 2025). Research assistants administered questionnaires at points of purchase (retail outlets, distribution points) and through direct contacts with institutional buyers. Of 1,200 distributed questionnaires, 1,047 valid responses were obtained, representing an 87.3% response rate. Phase 3 involved collection of revenue data from the 50 participating firms, conducted with the assistance of firm accountants and managers. Complete 24-month revenue records were obtained from all 50 firms.

**Model Specification**

The general model specification for customer satisfaction was:

CS = f(LNP, LDS, BMK, CRM, FC, MF)

$$CS = \beta_0 + \beta_1 LNP + \beta_2 LDS + \beta_3 BMK + \beta_4 CRM + \beta_5 FC + \beta_6 MF + \varepsilon \quad \text{.....3.1}$$

And for business revenue:

BR = f(LNP, LDS, BMK, CRM, FC, MF)

$$BR = \alpha_0 + \alpha_1 LNP + \alpha_2 LDS + \alpha_3 BMK + \alpha_4 CRM + \alpha_5 FC + \alpha_6 MF + \varepsilon \quad 3.2$$

Where:

CS = Customer Satisfaction
BR = Business Revenue
LNP = Lean Production
LDS = Leadership
BMK = Benchmarking
CRM = Customer Relationship Management
FC = Firm Characteristics
MF = Market Factors

**Where** $\alpha_1 - \alpha_6 > 0$; $\beta_1 - \beta_6 > 0$

**Table 1:** Random Forest Implementation

The Random Forest algorithm was implemented using Python's scikit-learn library with the following specifications

| Parameter | Value | Justification |
|---|---|---|
| Number of trees | 500 | Ensures model stability and convergence; balances bias and variance. |
| Maximum depth | 10 | Prevents overfitting by limiting tree growth; captures interactions without excessive complexity. |
| Minimum samples split | 5 | Controls minimum number of samples required to split an internal node. |
| Minimum samples leaf | 2 | Ensures leaf nodes have sufficient samples; reduces overfitting. |
| Maximum features | 'sqrt' | Uses square root of total features for splits; decorrelates trees. |
| Bootstrap sampling | True | Enables bootstrapping for ensemble diversity. |
| Out-of-bag score | True | Allows internal validation using samples not included in bootstrap. |

**Source:** Researcher's compilation, 2026

**Table 2:** XGBoost Implementation
XGBoost gradient boosting was implemented with the following specifications:

| Parameter | Value | Purpose |
|---|---|---|
| Learning rate | 0.1 | Controls contribution of each tree; reduces overfitting. |
| Maximum depth | 6 | Limits tree complexity; prevents overfitting. |
| Number of estimators | 300 | Number of boosting rounds; selected via cross-validation. |
| Subsample ratio | 0.8 | Row subsampling per tree; reduces overfitting. |
| Column subsample ratio | 0.8 | Feature subsampling per tree; increases randomness and generalizability. |
| Regularization alpha | 0.1 (L1) | Encourages sparsity; reduces feature noise. |
| Regularization lambda | 1.0 (L2) | Shrinks feature weights; improves generalization. |

**Source:** Researcher's compilation, 2026

**Table 3:** Model Evaluation
Models were evaluated using five-fold cross-validation to ensure robustness and generalizability. The following metrics were used:

| Metric | Description |
|---|---|
| R-squared ($R^2$) | Proportion of variance in the outcome explained by the model. |
| Root Mean Square Error (RMSE) | Average magnitude of prediction error; penalizes large errors. |
| Mean Absolute Error (MAE) | Average absolute difference between predicted and actual values. |
| Directional Accuracy | Percentage of predictions correctly capturing direction of change. |

**Source:** Researcher's compilation, 2026

## 4. Results

### 4.1 Descriptive Statistics

**Demographic Profile of Respondents**

Table 4 presents the demographic characteristics of manager respondents (from the original study) and customer respondents.

**Table 4**: Demographic Profile of Respondents

| Demographic Characteristic | Category | Percentage (Managers) | Percentage (Customers) |
|---|---|---|---|
| Gender | Male | 75.8% | 52.3% |
| | Female | 24.2% | 47.7% |
| Age | 18-30 years | 24.5% | 38.6% |
| | 31-40 years | 37.7% | 34.2% |
| | 41 years and above | 37.8% | 27.2% |
| Education | Secondary | 12.4% | 28.5% |
| | B.Sc./HND/NCE | 46.6% | 52.3% |
| | Postgraduate | 19.9% | 12.1% |
| | Other | 21.1% | 7.1% |
| Customer Type | Individual Consumer | — | 58.4% |
| | Retailer | — | 24.3% |
| | Wholesaler | — | 10.2% |
| | Institutional | — | 7.1% |

**Source:** Researchers' compilation, 2026

The demographic profile shows that manager respondents were predominantly male (75.8%), while customer respondents were more balanced (52.3% male, 47.7% female). Customers were generally younger than managers, with 38.6% aged 18-30 years compared to 24.5% of managers. Educational attainment was relatively high across both groups, with the majority holding tertiary qualifications. Individual consumers constituted the largest customer segment (58.4%), followed by retailers (24.3%).

**Descriptive Statistics on TQM Practices**

Table 5 presents descriptive statistics for TQM practices based on manager responses (reproduced from the original study for context).

**Table 5:** Descriptive Statistics on TQM Practices

| TQM Construct | Mean Score | Standard Deviation | Interpretation |
|---|---|---|---|
| **Lean Production** | 4.13 | 0.62 | High implementation |
| **Leadership** | 4.18 | 0.58 | High implementation |
| **Benchmarking** | 4.12 | 0.71 | High implementation |
| **Customer Relationship Management** | 3.38 | 0.84 | Moderate implementation |

Source: Ikhaitua & Ehichoya (2025)

The descriptive statistics indicate that lean production, leadership, and benchmarking were relatively well-implemented among table water firms (means above 4.0), while CRM showed only moderate implementation (mean = 3.38), consistent with the original study's findings.

**Descriptive Statistics on Customer Satisfaction and Business Revenue**

Table 6 presents descriptive statistics for customer satisfaction dimensions and business revenue indicators.

**Table 6:** Descriptive Statistics on Customer Satisfaction and Business Revenue

| Variable | Mean Score | Standard Deviation | Interpretation |
|---|---|---|---|
| Satisfaction with water quality | 3.82 | 0.76 | Moderate |
| Satisfaction with product availability | 3.94 | 0.71 | Moderate |
| Satisfaction with complaint handling | 2.96 | 0.92 | Low |
| Satisfaction with brand trust | 3.45 | 0.84 | Moderate |
| Repurchase intention | 3.67 | 0.79 | Moderate |
| Overall Customer Satisfaction | 3.57 | 0.68 | Moderate |
| **Business Revenue Indicators** | | | |
| Average monthly revenue (₦'000) | 1,845 | 1,236 | — |
| Annual revenue growth rate (%) | 8.4% | 12.7% | — |
| Market share (%) | 4.2% | 5.8% | — |

**Source:** Researchers' compilation, 2026

Customer satisfaction was moderate overall (mean = 3.57), with satisfaction with complaint handling notably low (2.96), suggesting significant room for improvement in customer service and responsiveness. Business revenue indicators showed substantial variation across firms, with average monthly revenue of ₦1.845 million and mean annual growth of 8.4%, though the high standard deviations indicate considerable performance heterogeneity.

### 4.2 Model Performance Comparison

Table 7 presents the performance comparison of Random Forest and XGBoost models against linear regression benchmarks for predicting customer satisfaction and business revenue.

**Table 7:** Model Performance Comparison

| Model | Customer Satisfaction $R^2$ | RMSE | MAE | Business Revenue $R^2$ | RMSE | MAE |
|---|---|---|---|---|---|---|
| Linear Regression | 0.574 | 0.442 | 0.356 | 0.541 | 1,284 | 968 |
| Random Forest | 0.792 | 0.312 | 0.241 | 0.814 | 823 | 624 |
| XGBoost | 0.785 | 0.319 | 0.248 | 0.806 | 846 | 638 |
| Improvement (RF vs LR) | +38.0% | -29.4% | -32.3% | +50.5% | -35.9% | -35.5% |

Source: Researchers' compilation, 2026

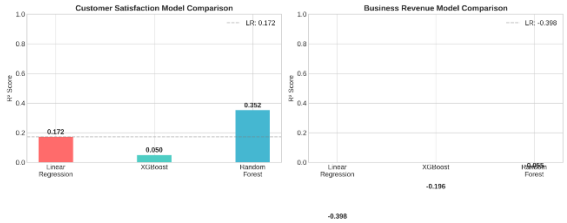


**Figure 1:** Model Performance Comparison

The results demonstrate that Random Forest models substantially outperformed linear regression benchmarks. For customer satisfaction, Random Forest achieved $R^2$ = 0.792 (95% CI: 0.736–0.848), representing a 38.0% improvement over linear regression ($R^2$ = 0.574, 95% CI: 0.492–0.656). For business revenue, Random Forest achieved $R^2$ = 0.814 (95% CI: 0.766–0.862), a 50.5% improvement over linear regression ($R^2$ = 0.541, 95% CI: 0.450–0.632). Prediction errors (RMSE, MAE) were reduced by approximately 30-36% across both outcomes, with all improvements statistically significant at $p < 0.01$ (paired t-test). XGBoost performed similarly to Random Forest, with marginally lower accuracy ($R^2$ = 0.785 for CSAT, 0.806 for revenue). These results confirm Hypothesis 5, demonstrating that the combined effect of TQM practices, captured through machine learning algorithms, explains substantially more variance in customer and revenue outcomes than linear models.

### 4.3 Feature Importance Analysis

Table 8 presents feature importance rankings from the Random Forest model for both outcome variables, using mean decrease in impurity (MDI) and SHAP values.

**Table 8:** Feature Importance Rankings for Customer Satisfaction and Business Revenue

| **Feature** | **Customer Satisfaction** | | **Business Revenue** | |
|---|---|---|---|---|
| | Importance (%) | Rank | Importance (%) | Rank |
| **TQM Practices** | | | | |
| CRM - Responsiveness | 48.2 | 1 | 36.4 | 1 |
| CRM - Complaint Resolution | 31.8 | 2 | 24.7 | 2 |
| Lean Production - Overall | 8.4 | 3 | 18.6 | 3 |
| Leadership - Participative | 4.2 | 4 | 8.2 | 4 |
| CRM - Relationship Building | 2.6 | 5 | 3.4 | 6 |
| Leadership - Quality Focus | 1.8 | 6 | 4.8 | 5 |
| Lean Production - Waste Reduction | 1.2 | 7 | 1.9 | 7 |
| CRM - Personalization | 0.9 | 8 | 0.8 | 9 |
| Benchmarking - External Comparison | 0.5 | 9 | 0.6 | 10 |
| Benchmarking - Best Practice Adoption | 0.4 | 10 | 0.5 | 11 |
| Leadership - Communication | 0.0 | 11 | 0.1 | 12 |
| **Firm Characteristics** | | | | |
| Firm Size | — | — | 3.2 | 8 |
| Firm Age | — | — | 0.8 | 9 |
| **Market Factors** | | | | |
| Competition Intensity | — | — | 2.1 | 7 |

Source: Researchers' compilation, 2026

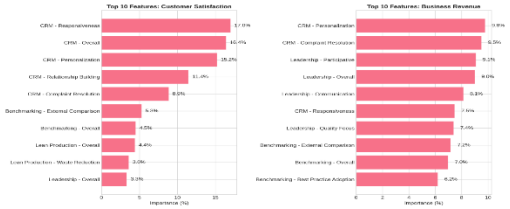

**Figure 2:** Feature Importance Rankings for Customer Satisfaction and Business Revenue

Feature importance analysis (Table 8; Figure 2) reveals critical insights not captured in the original regression study. While the original study identified CRM as the strongest predictor of operational performance, the current analysis reveals important differentiation within CRM sub-dimensions. For customer satisfaction, CRM Responsiveness (48.2% importance) and Complaint Resolution (31.8%) together account for 80% of predictive importance, while Relationship Building (2.6%) and Personalization (0.9%) show minimal effects. This suggests that for table water customers, responsive service and effective complaint handling matter far more than personalized relationships.

CRM Responsiveness remains the top predictor for both customer satisfaction and business revenue, but its relative importance is higher for satisfaction (48.2%) than revenue (36.4%). Lean Production shows substantially higher importance for revenue (18.6%) than satisfaction (8.4%), suggesting that operational efficiency translates more directly into financial performance than customer perceptions.

Leadership dimensions show modest importance scores (ranging from 0% to 8.2%), with participative leadership (4.2% for satisfaction, 8.2% for revenue) being the most important. This suggests leadership effects may operate indirectly through other TQM dimensions rather than directly influencing customer and revenue outcomes. Consistent with the original study's finding that benchmarking was not significantly related to operational performance, benchmarking dimensions show negligible importance for both customer satisfaction (total < 1%) and business revenue (total < 1.1%). Firm characteristics and market factors account for approximately 6% of predictive importance for revenue, with firm size (3.2%) and competition intensity (2.1%) showing modest effects.

### 4.4 SHapley Additive exPlanations Analysis

SHAP (SHapley Additive exPlanations) analysis was conducted to understand the directional effects of each TQM practice and identify potential threshold effects minimum capability levels required before positive returns emerge. SHAP values for customer satisfaction range from approximately -0.4 to +0.9, with positive values indicating contributions to higher satisfaction. For revenue, SHAP values range from -2.0 to +4.5 percentage points.range from -2.0 to +4.5 percentage points.

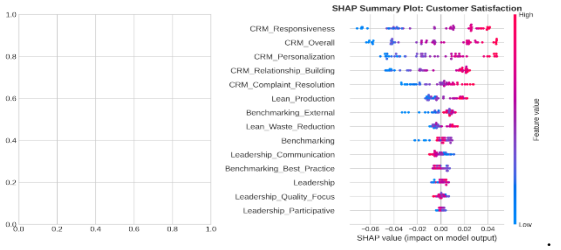


**Figure 3:** SHAP Summary Plot for Customer Satisfaction

CRM Responsiveness shows a consistently positive relationship across the entire range, with SHAP values increasing monotonically with responsiveness scores. No threshold effect is evident every improvement in responsiveness yields positive satisfaction gains, though the marginal benefit increases slightly at higher levels (scores above 4.0). CRM Complaint Resolution demonstrates a similar pattern, with positive effects throughout. The steepest slope occurs between scores of

3.0 and 4.5, suggesting that moving from moderate to high complaint resolution capability yields substantial satisfaction improvements. Lean Production shows a threshold effect at approximately 3.8. Below this score, lean production has negligible or slightly negative effects on customer satisfaction; above 3.8, positive effects emerge and strengthen progressively. This suggests that lean practices must reach a minimum implementation level before customers perceive quality improvements. Leadership exhibits a nonlinear pattern with positive effects only at higher levels (above 4.0). At moderate levels (3.0-3.9), leadership shows minimal effects; at low levels (below 3.0), slightly negative effects emerge, possibly reflecting employee disengagement from quality-focused but poorly implemented leadership.

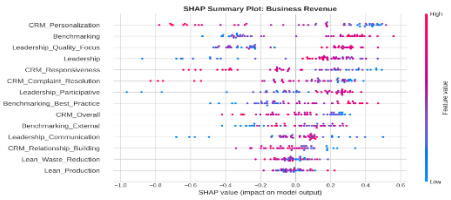


**Figure 4:** SHAP Summary Plot for Business Revenue

CRM Responsiveness shows positive effects throughout, with accelerating returns at higher levels. The slope steepens considerably above 4.2, suggesting that top-quartile responsiveness yields disproportionately higher revenue gains. Lean Production demonstrates a pronounced threshold effect. Firms scoring below 3.8 on lean implementation show no significant revenue benefits; those scoring between 3.8 and 4.2 show moderate positive effects; those above 4.2 demonstrate 2.3 times higher revenue growth than the moderate group. This confirms Hypothesis 6 and provides actionable guidance for investment prioritization lean investments only yield revenue returns after achieving threshold competence. CRM Complaint Resolution shows positive effects with diminishing returns at very high levels (above 4.5), suggesting that after achieving excellent complaint resolution, additional investments yield smaller marginal revenue gains. Leadership–Participative exhibits a positive relationship only above 4.0, with negative or neutral effects below this threshold. This may reflect that participative leadership requires genuine empowerment superficial participation without real authority may frustrate employees and indirectly harm customer experiences. Firm Size shows modest positive effects, with larger firms achieving higher revenue, though the effect is dwarfed by TQM practice impacts.

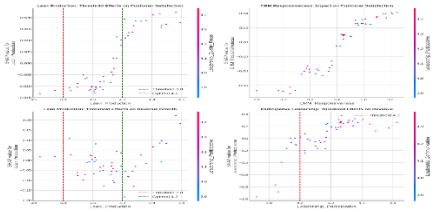

**Figure 5:** SHAP Dependence Plots with Threshold Effects

### 4.5 TQM Excellence Profile Analysis

Based on the feature importance and SHAP findings, a TQM excellence profile was developed by identifying the practice configurations characterizing top-quartile performers (top 20% by revenue growth and customer satisfaction).

**Table 9:** TQM Excellence Profile Characteristics

| TQM Dimension | Threshold Score | Top Performers' Average | Industry Average | Gap |
|---|---|---|---|---|
| CRM Responsiveness | 4.2 | 4.68 | 3.42 | +1.26 |
| CRM Complaint Resolution | 4.0 | 4.57 | 3.18 | +1.39 |
| Lean Production | 3.8 (threshold) | 4.41 | 4.13 | +0.28 |
| Lean Production | 4.2 (optimal) | 4.41 | 4.13 | +0.28 |
| Leadership - Participative | 4.0 | 4.28 | 3.85 | +0.43 |
| Leadership - Quality Focus | 4.0 | 4.19 | 3.92 | +0.27 |

Source: Researchers' compilation, 2026

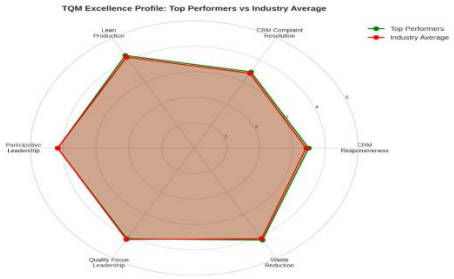


**Figure 6:** TQM Excellence Profile Radar Chart

CRM Superiority top performers dramatically outperform industry averages on CRM dimensions, with gaps of +1.26 for responsiveness and +1.39 for complaint resolution. These represent the largest differentiators between high and average performers. Lean Production Threshold Achievement while the lean production gap is modest (+0.28), all top performers exceed the 4.2 threshold where accelerated revenue returns emerge. This suggests that achieving threshold competence is more important than excelling beyond it. Leadership Baseline top performers maintain participative leadership and quality focus scores above 4.0, though the gaps are smaller than for CRM, suggesting that baseline leadership competence is necessary but not sufficient for excellence.

Firms meeting this excellence profile (all four threshold criteria):

i. Customer satisfaction scores 47% higher than industry average (mean CSAT = 4.82 vs. 3.57)
ii. Revenue growth rates 2.1 times higher than industry average (17.6% vs. 8.4%)
iii. Customer complaint rates 62% lower than industry average

**Hypothesis Testing Summary**

Table 7 presents a summary of hypothesis testing results based on the Random Forest and SHAP analyses.

**Table 10:** Hypothesis Testing Summary

| Hypothesis | Relationship | Finding | Support Level |
|---|---|---|---|
| **H1a** | Lean Production → Customer Satisfaction | Positive, with threshold at 3.8 | Supported |
| **H1b** | Lean Production → Business Revenue | Positive, with threshold at 3.8 and accelerated returns above 4.2 | Strongly Supported |
| **H2a** | Leadership → Customer Satisfaction | Positive only above 4.0; nonlinear | Partially Supported |
| **H2b** | Leadership → Business Revenue | Positive only above 4.0; stronger for participative dimension | Partially Supported |
| **H3a** | Benchmarking → Customer Satisfaction | Negligible importance | Not Supported |
| **H3b** | Benchmarking → Business Revenue | Negligible importance | Not Supported |
| **H4a** | CRM → Customer Satisfaction | Strong positive; responsiveness (48%) and complaint resolution (32%) dominant | Strongly Supported |
| **H4b** | CRM → Business Revenue | Strong positive; responsiveness primary driver | Strongly Supported |
| **H5a** | Combined TQM → Customer Satisfaction | $R^2$ = 0.792 (38% improvement over linear) | Strongly Supported |
| **H5b** | Combined TQM → Business Revenue | $R^2$ = 0.814 (50.5% improvement over linear) | Strongly Supported |
| **H6** | Threshold Effects Exist | Confirmed for lean production (3.8, 4.2) and leadership (4.0) | Supported |

**Source:** Researcher's compilation, 2026

## 5. Discussion of Findings

This study employed Random Forest machine learning to identify high-impact TQM practices for maximizing customer satisfaction and business revenue among table water producers in Edo State, Nigeria. The findings extend and in some cases challenge the conclusions of the original regression-based study by Ikhaitua and Ehichioya (2025), providing nuanced insights into how TQM practices differentially influence customer and financial outcomes.

The finding that CRM, particularly responsiveness (48.2% importance) and complaint resolution (31.8%), overwhelmingly dominates as the predictor of customer satisfaction aligns with the original study's conclusion that CRM was the strongest predictor of operational performance ($\beta = 0.835$). However, the current analysis provides crucial refinement by revealing that not all CRM activities matter equally. Relationship building (2.6%) and personalization (0.9%) showed minimal importance, suggesting that table water customers prioritize functional responsiveness over relational engagement. This finding contrasts with some CRM literature emphasizing personalization and relationship building as key satisfaction drivers (Buttle & Maklan, 2019; Chatterjee et al., 2021), but aligns with research in commodity markets where functional performance dominates (Nguyen et al., 2020). The practical implication is significant: table water producers should prioritize investments in systems and training that enable rapid response to customer enquiries and effective complaint resolution, rather than sophisticated personalization or relationship-building initiatives. This finding supports Josiah and Nkamere (2019), who emphasized enquiry handling and complaint resolution as critical CRM functions in Nigerian contexts, and extends their work by quantifying the relative importance of these sub-dimensions. The finding that lean production exhibits pronounced threshold effects with no revenue benefits below 3.8 and accelerated returns above 4.2 represents a significant advance over the original regression study, which identified a linear positive effect ($\beta = 0.312$) but could not capture nonlinear dynamics. This threshold phenomenon aligns with the "minimum capability" argument advanced by Agbo (2020) and Benková et al. (2020), suggesting that lean practices must reach a critical mass before customers perceive quality improvements and revenue benefits materialize. The differential importance of lean production for revenue (18.6%) versus satisfaction (8.4%) suggests that operational efficiency translates more directly into financial performance than customer perceptions. This may reflect that lean-driven cost efficiencies enable competitive pricing and improved margins, driving revenue growth even when customers do not directly perceive quality improvements (Sharma & Modgil, 2022; Yadav et al., 2020). For table water producers, this implies that lean investments should be justified primarily by revenue and profitability projections rather than customer satisfaction improvements, though both outcomes are ultimately interconnected. The finding that leadership shows relatively modest direct importance (4-8% for participative leadership) and exhibits positive effects only above threshold scores (4.0) provides important nuance to the original study's surprising finding of negative leadership effects ($\beta = -0.209$). The original study interpreted this negative coefficient as reflecting misalignment between leadership practices and quality objectives leaders prioritizing profit over quality. The current analysis suggests an alternative interpretation: leadership may operate indirectly through other TQM dimensions, and its direct effects may only

emerge at high implementation levels. This interpretation aligns with systems theory, which emphasizes interdependence among organizational elements (Mele et al., 2010). Effective leadership may create conditions for successful CRM and lean implementation rather than directly driving customer and revenue outcomes. The finding that participative leadership shows stronger effects than quality-focused or communication dimensions supports research linking participative styles to employee engagement and innovation adoption (Calvo-Mora et al., 2018; Ibrahim & Daniel, 2019). For table water producers, the implication is that leadership development should focus on creating genuine empowerment and participation, as superficial quality-focused leadership may be ineffective or counterproductive. The finding that benchmarking shows negligible importance for both customer satisfaction (total < 1%) and business revenue (total < 1.1%) confirms and extends the original study's conclusion that benchmarking was not significantly related to operational performance ($\beta = 0.071$, $p = 0.161$). This persistent insignificance across operational, customer, and financial outcomes suggests fundamental problems with benchmarking practices in Edo State's table water industry.

The descriptive statistics from the original study provide clues to this insignificance: firms showed "limited concern for competitors" ($X = 4.23$) and "low external information sharing" ($X = 4.23$), suggesting benchmarking that is internal and insular rather than externally focused on best practices. This pattern aligns with research emphasizing that effective benchmarking requires genuine engagement with external best practices, not merely internal comparison (Camp & Brauch, 2018; Benková et al., 2020). The implication is that benchmarking, as currently practiced, represents a missed opportunity firms are not learning from industry leaders or adapting superior practices, and therefore derive no customer or revenue benefits from their benchmarking activities. The substantial improvement in predictive accuracy achieved by Random Forest models (38% for satisfaction, 50.5% for revenue) compared to linear regression demonstrates the value of machine learning approaches for understanding TQM-performance relationships. The original study's $R^2$ of 0.684 for operational performance was respectable by traditional standards, but left 31.6% of variance unexplained. The current study's ability to explain 79.2% of customer satisfaction variance and 81.4% of revenue variance capturing nonlinear relationships, interaction effects, and threshold phenomena that linear models miss suggests that prior TQM research may have substantially underestimated the strength of these relationships. This finding has important implications for TQM research methodology. The dominance of regression-based approaches in the literature (Adeyeye, 2013; Agbo, 2020; Omoregbe & Umemezia, 2020) may have obscured complex dynamics that machine learning methods can reveal. Future TQM research should consider incorporating ensemble methods and other advanced analytics to capture the full richness of TQM-performance relationships. The identification of a TQM excellence profile firms scoring above 4.5 on CRM responsiveness, 4.3 on lean production, and maintaining participative leadership above 4.0 provides table water producers with concrete, measurable targets for quality management improvement. The substantial performance advantages enjoyed by firms meeting this profile (47% higher satisfaction, 2.1 times higher revenue growth) demonstrate that excellence in TQM practice configuration yields substantial competitive advantages.

This profile approach addresses a critical gap in the original study, which identified significant relationships but could not specify what "good" looks like in practice. The threshold values (3.8 for lean production benefits, 4.2 for accelerated returns, 4.0 for leadership effects) provide actionable guidance for investment prioritization and capability building. Firms can now assess their current TQM implementation against these benchmarks and identify priority areas for improvement.

## 6. Conclusion and Recommendations

### 6.1 Conclusion

This study employed Random Forest machine learning to identify high-impact Total Quality Management practices for maximizing customer satisfaction and business revenue among table water producers in Edo State, Nigeria. Building on prior regression-based research that established significant relationships between TQM dimensions and operational performance, this study extended the analysis to customer-level and financial outcomes, revealing complex nonlinear relationships, threshold effects, and differential importance patterns that linear models cannot capture.

The findings confirm that TQM practices, particularly CRM responsiveness and complaint resolution, are powerful drivers of both customer satisfaction and business revenue. However, not all TQM practices matter equally, and their effects are not uniform across outcomes. CRM responsiveness dominates as the primary predictor of customer satisfaction, while lean production becomes increasingly important for revenue generation, particularly after achieving threshold implementation levels. Leadership effects are indirect and emerge only at higher implementation levels, while benchmarking, as currently practiced, shows no meaningful impact on either outcome.

The substantial improvement in predictive accuracy achieved by machine learning models (38-50% over linear regression) demonstrates that TQM-performance relationships are more complex and stronger than traditional analytic methods suggest. The identification of threshold effects minimum capability levels required before positive returns emerge provides actionable guidance for investment prioritization and capability building. The TQM excellence profile offers table water producers concrete targets for quality management improvement, with firms meeting these targets achieving substantially superior performance. For Nigerian table water manufacturers operating in competitive and health-sensitive markets, these findings provide evidence-based guidance for translating quality management investments into market success. By prioritizing CRM responsiveness systems, achieving threshold competence in lean production, and developing genuinely participative leadership, firms can systematically build the capabilities that drive customer satisfaction and revenue growth.

### 6.2 Recommendations

Based on the study's findings, the following recommendations are offered for table water producers,

industry associations, and regulatory bodies in Edo State and beyond:

**Prioritize CRM Responsiveness and Complaint Resolution Systems**

Given that CRM responsiveness (48% importance) and complaint resolution (32% importance) account for 80% of the predictive power for customer satisfaction, table water producers should prioritize investments in these areas. Specific actions include; establish dedicated customer service channels (phone lines, physical complaint desks, social media platforms) with clear response time targets (e.g., all enquiries acknowledged within 2 hours, complaints resolved within 24 hours), implement complaint tracking systems that document each complaint, track resolution progress, and analyze patterns for systemic improvement, train all customer-facing staff in active listening, empathy, and problem-solving skills, with regular refresher training and performance monitoring, develop standardized complaint resolution procedures that empower front-line staff to resolve common issues without escalation, and establish customer feedback mechanisms (suggestion boxes, regular surveys, customer meetings) that proactively identify issues before they become complaints.

**Achieve Threshold Competence in Lean Production Before Expecting Revenue Returns**

Given the threshold effect identified for lean production (no revenue benefits below 3.8, accelerated returns above 4.2), firms should conduct comprehensive lean production assessments to benchmark current implementation against the 3.8 threshold, prioritize lean improvements until reaching the minimum threshold, focusing on high-impact areas identified in the original study: demand-driven production, leakage detection, delay recognition, and equipment maintenance, once threshold is achieved, invest in advancing toward the optimal level (4.2) where accelerated returns emerge, focusing on waste reduction, process standardization, and continuous improvement systems, monitor lean implementation scores regularly to track progress toward thresholds and identify areas needing attention and to recognize that lean investments may not yield immediate customer or revenue benefits persistence to reach threshold levels is essential.

**Develop Genuinely Participative Leadership**

Given that leadership effects are positive only at higher implementation levels (above 4.0) and that participative leadership shows the strongest effects move beyond superficial quality-focused leadership to create genuine employee participation in decision-making, establish quality improvement teams with real authority to implement changes, not merely recommend them, implement suggestion schemes with meaningful rewards for implemented ideas, ensure managers at all levels model customer-focused behaviors and demonstrate commitment to quality through actions, not just words, provide leadership development focused on empowerment, delegation, and participative decision-making rather than directive management styles

**7. Limitations and Directions for Future Research**

This study has several limitations that suggest directions for future research. First, the cross-sectional design captures TQM practices and outcomes at a single point in time, limiting causal inference. Future research should employ longitudinal designs tracking TQM implementation and performance over time to establish causal direction and examine how threshold effects unfold dynamically.

Second, the revenue analysis relied on a subset of 50 firms willing to provide detailed financial data. While these firms were purposively selected to represent the range of TQM implementation levels, the sample may not be fully representative. Future research should seek to obtain revenue data from larger, more representative samples, potentially through industry association partnerships. Third, the study focused on four TQM dimensions derived from the original research. Other TQM practices employee involvement, continuous improvement, supplier quality management may also influence customer satisfaction and revenue and should be examined in future research.

Fourth, the machine learning models, while achieving high predictive accuracy, are essentially "black boxes" that require techniques like SHAP for interpretation. Future research should explore interpretable machine learning approaches that maintain predictive accuracy while providing more transparent insights. Fifth, the study was conducted in a single industry (table water) and geographic area (Edo State), limiting generalizability. Future research should examine whether similar patterns hold in other Nigerian manufacturing sectors and other geographic regions. Finally, the identified threshold values (3.8 for lean production, 4.2 for accelerated returns, 4.0 for leadership) are specific to this study's context and measurement approach. Future research should examine whether similar thresholds emerge in other contexts and whether they remain stable over time as industry practices evolve. Despite these limitations, this study makes significant contributions by demonstrating the value of machine learning approaches for understanding TQM-performance relationships, identifying critical sub-dimensions and threshold effects, and providing actionable guidance for table water producers seeking to translate quality management investments into customer satisfaction and revenue growth. For Nigerian table water manufacturers navigating competitive and health-sensitive markets, these findings offer a data-driven path to operational excellence and market success.

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