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IoT-Powered Customer Engagement for Marketing Optimization in Tanzania SMEs

Khalifa Mkali[1], Ramadhani Sinde[2], Geoffrey Karokola[3]

[1, 2]Nelson Mandela African Institution of Science and Technology, Tanzania
[3]The University of Dar es Salaam Computing Centre (UDSM-UCC), Tanzania
Email: [1]mkalik@nma-ist.ac.tz, [2]ramadhani.sinde@nm-aist.ac.tz, [3]karokola@udsm.ac.tz,

Abstract

Embracing Internet of Things (IoT) technologies presents significant opportunities for enhancing customer engagement. However, Tanzanian Small and Medium Enterprises (SMEs) are confronted with persistent challenges, including limited infrastructure, financial barriers, and low digital literacy. This study proposes an IoT-powered customer engagement platform built using Python-Django specifically tailored for Tanzanian SMEs to generate actionable customer insights and strengthen engagement strategies. A mixed-methods approach, combining surveys, observations, and interviews with SME owners and customers in Dar es Salaam and Arusha, revealed operational inefficiencies and gaps in customer interaction. Based on these insights, a scalable and cost-effective IoT solution was designed to automate feedback collection, monitor customer behavior in real-time, and deliver personalized services. The platform was evaluated through simulated testing, expert reviews, and performance analysis. Results showed a 15 - 20% improvement in customer retention, a 30% reduction in inquiry response time, 99.50% system uptime, and an 80% user-friendliness score. These findings demonstrate the novelty and effectiveness of integrating IoT, real-time monitoring, and marketing optimization in the Tanzania SME context. Overall, the research highlights the transformative potential of IoT in enabling data-driven decision-making, enhancing customer relationships, and promoting sustainable growth in underserved business environments.

Keywords: IoT, Customer Engagement, Marketing Optimization, SMEs, IoT-powered Platform.

1 INTRODUCTION

Small and Medium Enterprises (SMEs) are pivotal in driving economic growth, fostering innovation, and creating employment, especially in developing countries. According to the World Bank, the global workforce will require an estimated 600 million new jobs by 2030, a target that heavily relies on the growth and development of SMEs [1]. These businesses play an essential role in promoting entrepreneurship, technological innovation, and inclusive growth. However, despite their significant socio-economic impact, SMEs frequently encounter systemic challenges related to data utilization, digital adoption, and sustainable

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growth [2]. In Sub-Saharan Africa, for instance, there are approximately 44 million formal SMEs, with over 51% of them reporting limited access to finance as a major growth barrier [3]. As a result, promoting entrepreneurship and encouraging digital transformation have become crucial strategies for boosting competitiveness in the increasingly globalized economy [4].

Tanzania's SME Development Policy, updated in 2023, classifies enterprises based on employee numbers and capital. Micro-enterprises have up to 4 employees and capital below TZS 5 million, small enterprises employ 5–49 people and possess capital ranging from TZS 5–200 million, while medium enterprises employ 50–99 people or have capital between TZS 200–800 million [5]. SMEs in Tanzania are vital contributors to the nation's economy, yet they face significant challenges, including limited access to credit, technical knowledge, market information, and digital technologies [6]. One of the primary obstacles is their inability to maintain customer relationships effectively, collect actionable data, and respond to changing consumer demands. This issue is compounded by their limited adoption of emerging technologies, such as the Internet of Things (IoT), and the inherent risks that come with these technologies [7].

IoT is a transformative technology that connects physical objects to networks, enabling them to share information about their status and surroundings [8]. IoT has revolutionized business-customer interactions by allowing for real-time data collection, monitoring, and analysis. When combined with artificial intelligence (AI) and big data, IoT offers opportunities for personalized customer interactions, optimized marketing strategies, and improved operational efficiency [9]. For Tanzanian SMEs, leveraging IoT technologies could be a solution to many of the challenges they face, particularly in customer engagement, insight collection, and service delivery.

Despite their critical role in Tanzania's economy, SMEs continue to face barriers to growth and competitiveness, particularly in areas such as marketing and customer engagement. Larger businesses typically have access to advanced data tools and IT infrastructure, while SMEs struggle with technological limitations, inadequate infrastructure, low brand visibility, weak digital presence, and fragmented customer relationship management [10], [11]. In today's data-driven economy, understanding and engaging with customers is essential for maintaining competitiveness. Unfortunately, many Tanzanian SMEs lack IoT-based systems that enable real-time tracking of customer behavior, automated feedback, and personalized communication. While previous studies have explored IT adoption among SMEs, few have investigated the integration of IoT for customer engagement, particularly within the Tanzanian context. Existing solutions tend to be expensive, technologically complex, and insufficiently localized, leaving SMEs without the tools needed to collect actionable customer data or adapt services to

individual preferences. This gap represents a significant challenge for SME growth, employment creation, and the country's ability to compete globally.
The aim of this study is to design and evaluate an IoT-powered customer engagement platform specifically tailored for Tanzanian SMEs. The research seeks to:

1) Identify marketing challenges related to customer engagement and market reach.
2) Develop a web-based IoT solution that aligns with SME needs and resource limitations.
3) Assess the platform's effectiveness in improving customer engagement and marketing outcomes.

The study is guided by three key research questions:

1) What are the primary marketing challenges faced by SMEs in Tanzania?
2) How can an IoT-powered platform be developed to address these challenges within SME constraints?
3) What is the impact of the IoT-powered platform compared to traditional customer engagement approaches?

This research focuses on customer-facing SMEs in Dar es Salaam and Arusha, representing both urban and semi-urban settings. The study specifically targets SMEs engaged in direct customer interactions, excluding large enterprises and SMEs operating outside these regions. While the research emphasizes the practical application of IoT for customer engagement, it does not delve deeply into the technical aspects of IoT hardware and software.

The study's contribution lies in proposing a cost-effective and scalable IoT-powered customer engagement platform, designed to meet the marketing challenges of Tanzanian SMEs. By integrating affordable IoT components, sensors, and microcontrollers into a web-based system, the platform enables real-time monitoring of customer activity and environmental conditions. Through features like real-time data visualization, automated feedback, and personalized services, the platform enhances decision-making processes and advances research on IoT adoption in developing economies. Furthermore, the study supports the United Nations Sustainable Development Goals (SDGs) by empowering SMEs through IoT-driven engagement, contributing to SDG 8 (economic growth), SDG 9 (innovation), and SDGs 10 and 17 (reducing digital gaps and fostering digital collaboration) [12], [13], [14].

2. RELATED WORKS

This study builds upon existing research by integrating the Technology Acceptance Model (TAM) and the Diffusion of Innovation (DOI) theory with the Internet of Things (IoT) to optimize marketing strategies for Small and Medium Enterprises

(SMEs). TAM emphasizes the importance of perceived usefulness and ease of use in technology adoption, while DOI highlights constructs such as relative advantage and compatibility [15], [16]. By combining these models with IoT, this study provides a novel perspective that links the adoption of technology to real-time customer insights and engagement. This enables SMEs to harness IoT data to enhance marketing effectiveness and improve competitiveness, particularly in resource-constrained environments such as Tanzania [15], [16].

In Tanzania, SMEs represent over 95% of formally registered businesses, contribute about 35% to the Gross Domestic Product (GDP), and provide 40–50% of employment opportunities [10]. Despite their significant role in the economy, these businesses face several challenges in adopting new technologies like IoT. These challenges include perceived complexity, low digital literacy, limited infrastructure, and high implementation costs [10]. To increase adoption rates, localized and mobile-based IoT solutions that align with the principles of TAM and DOI can be developed to cater to the specific needs of Tanzanian SMEs, enhancing their usability and accessibility [17], [6].

The adoption of IoT in developing economies is on the rise, though it remains limited due to infrastructural deficits, high costs, and skill shortages [18]. For SMEs in these regions, IoT presents clear advantages, such as real-time inventory tracking and gaining insights into customer behavior. These benefits align well with the DOI constructs of relative advantage and observability, which suggest that the adoption of innovative technologies can significantly improve business operations by providing a competitive edge [19]. However, the broader adoption of IoT in SMEs is still hindered by these challenges, particularly in low-resource settings.

IoT has the potential to revolutionize marketing strategies by enabling real-time tracking, personalized customer interactions, and predictive analytics. By utilizing Location-Based Services (LBS) and sensor data, SMEs can deliver targeted promotions and enhance customer experiences [14], [22]. This transformation is particularly crucial for SMEs in competitive markets where understanding customer preferences and behaviors is essential. The integration of IoT into marketing can offer SMEs valuable opportunities for engaging their customers more effectively, improving service delivery, and making data-driven decisions that can optimize their marketing outcomes [20], [21].

In terms of marketing and analytics, IoT offers SMEs powerful tools for real-time, data-driven decision-making, reinforcing the perceived usefulness aspect of TAM [20], [23]. However, despite the potential, adoption remains relatively low among SMEs, and cybersecurity concerns pose significant barriers to effective implementation [9], [19]. Addressing these concerns and overcoming the limitations associated with IoT adoption are crucial for SMEs to fully realize the

technology's potential in enhancing their marketing efforts and maintaining competitiveness in the marketplace.

Despite growing interest in IoT's potential, research focused specifically on its application for Tanzanian SMEs remains scarce. Many existing solutions are either expensive, not sufficiently localized, or fail to address critical barriers such as inadequate infrastructure and low digital literacy [2], [6]. These gaps highlight the need for a tailored IoT engagement model that is designed specifically for the unique challenges faced by Tanzanian SMEs. The following table provides a summary of key findings and limitations in prior studies related to IoT adoption and its applications in SMEs:

Table 1. Summary of Previous Studies, Contexts, and Limitations

Study	Context	Key Findings	Limitations
Gabriel Kumar (2024)[19]	IoT-integrated inventory systems for SMEs	IoT automation improves real-time stock control, efficiency, and decision-making	Focused mainly on inventory management; lacks marketing integration perspective
J. Thomas & M. Gabriel (2024) [7]	IoT, predictive analytics, and cybersecurity in SMEs	Demonstrated that IoT and analytics enhance SME growth and strategic decisions	Conceptual approach; limited empirical data from developing economies
Magaletti et al. (2025) [24]	IoT and AI integration in SME manufacturing (Italy)	Found that IoT–AI systems improve production efficiency, predictive maintenance, and innovation	Developed-country case; limited applicability to developing SME contexts
Preethi Rajan (2024) [25]	IoT analytics in marketing decision-making	Showed that IoT data analytics enhance marketing accuracy, performance, and customer insights	Focused on analytics; limited consideration of adoption barriers and infrastructure issues
Ezekwueme et al. (2024) [26]	IoT adoption and supply chain optimization (Nigeria)	Provided evidence that IoT adoption improves SME efficiency, coordination, and transparency	Concentrates on supply chain; minimal marketing-related insights

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The current body of research underscores the need for region-specific IoT models that prioritize user-friendly design and lightweight deployment, which can better suit the operational realities of SMEs in developing countries [17], [13]. Consequently, this study aims to address these gaps by developing a tailored IoT-powered customer engagement model specifically designed for Tanzanian SMEs. This model will consider the unique challenges faced by SMEs in Tanzania and offer a practical, scalable solution that enhances their marketing capabilities and overall competitiveness.

3. METHODOLOGY

3.1. Study Area and Selection Criteria

The research was carried out in Arusha and Dar es Salaam, two urban regions in Tanzania selected for their vibrant SME ecosystems, higher technology adoption rates, and accessibility for research activities, as observed in The United Republic of Tanzania (URT) 2022 Population and Housing Census [27], [28]. Urban SMEs were selected intentionally to ensure the feasibility of IoT deployment, given that rural SMEs face much greater infrastructural limitations, significantly lower internet penetration, and substantial logistical challenges that could hinder both data collection and technology integration [10].

The researcher applied clear inclusion and exclusion criteria to ensure relevant and reliable findings. Included SMEs were registered, urban-based, customer-facing businesses, and were willing to adopt digital tools, while rural SMEs, large enterprises, and those without direct customer engagement or unwilling to participate were excluded. Customers selected were individuals who had engaged with these SMEs within the past six months and consented to participate, ensuring data reflected the dynamics of urban SME customer engagement practices. Participant recruitment was conducted through local SME associations, social media groups, and direct invitations to ensure balanced representation across business types.

3.2. Sampling Design and Justification

A stratified random sampling method was applied for customers to ensure proportional representation across different demographic groups and SME sectors. This method enhances precision in capturing varied perspectives across age groups, gender, education levels, and income brackets, thereby improving generalizability within the urban SME context. A total of 340 customers were sampled. This sample size, determined using Yamane's (1967) formula (Equation 1), was informed by prior studies on IoT adoption in developing economies, resource limitations, and the statistical power required for Chi-square and

independent samples t-tests. A confidence level of 95% and an acceptable margin of error of 5% were applied to ensure statistical reliability and representativeness of the study population.

$$n = N / [1 + N(e)^2] \quad (1)$$

where N is the estimated customer population and e = 0.05, ensuring statistical reliability.

For SMEs, 50 owners/managers were purposively selected based on their involvement in customer engagement and willingness to adopt IoT tools. Purposive sampling allowed targeted exploration of practical adoption challenges and readiness for IoT deployment.

3.3. Research Hypotheses and Analytical Methods

Three hypotheses were formulated based on the study objectives and literature review:

1) H1: There is a significant association between location (urban vs. semi-urban) and familiarity with IoT technology.
2) H2: Age groups significantly influence IoT feature preferences.
3) H3: Education levels are positively associated with IoT familiarity and feature preferences.

To test these hypotheses:

1) The Chi-Square test was employed to examine relationships between categorical variables such as age, location, and IoT familiarity.
2) The Independent Samples t-test was applied to compare IoT familiarity across urban and semi-urban respondents.

These tests were selected for their appropriateness in analyzing relationships and differences in categorical and continuous data. Before analysis, assumptions for these tests (e.g., independence of observations, expected frequency counts for Chi-Square, and normality for t-tests) were verified to ensure statistical validity.

3.4. System Development Approach

The IoT-powered customer engagement platform was developed using an Agile Scrum framework to enable iterative design, testing, and stakeholder feedback integration [29]. This approach followed four main stages:

1) Requirements Analysis – Captured SME and customer needs through surveys, interviews, and observations.

2) System Design – Adopted a modular architecture integrating cost-effective IoT components to ensure adaptability, scalability, and sustainability.
3) Testing and Quality Assurance – Performed functional, integration, and unit testing validated by domain experts to ensure robustness.
4) Deployment and Maintenance – Deployed to the cloud via https://www.topgenuine.com for scalable, secure remote access.

3.5. Technical Architecture and IoT Integration

The platform adopts a four-layer IoT architecture—perception, network, application, and presentation (Figure 1). Hardware components include the HC-SR501 PIR sensor for motion detection, DHT22 for temperature and humidity sensing, Arduino Uno for signal processing, and ESP32 for wireless communication. These devices were selected for their affordability, durability, low power use, and suitability for resource-limited SMEs [30]. The DHT22 provides ±2% humidity accuracy and fast response, while the HC-SR501 ensures reliable motion detection at minimal cost—making both ideal for cost-effective IoT deployment in Tanzanian SMEs.

Table 2. Platform Application Architecture

Layer	Functionality
Perception Layer	Data collection via IoT devices (HC-SR501 PIR, DHT22, Arduino Uno, ESP32)
Network Layer	Secure, real-time data transmission using REST APIs and WebSockets over HTTPS with token-based authentication. Data formatted in JSON for interoperability.
Application Layer	Backend developed with Python 3.10.5**,** Django 5.1.5**,** and Django REST Framework for API support. Frontend uses HTML5, CSS3, and JavaScript for responsive design. SQLite was used for development; PostgreSQL was planned for production deployment to enhance scalability and reliability.

3.6. Design and Hardware Integration

Sensors are interfaced with the Arduino Uno via General-Purpose Input/Output (GPIO) pins, powered by a regulated Direct Current (DC) source to ensure stable operation. Data is collected through Universal Asynchronous Receiver/Transmitter (UART) and analog/digital pins, processed locally by the Arduino Uno, and transmitted to the ESP32 microcontroller via a wired UART connection [30]. The ESP32 functions as the Connectivity Layer, bridging the local sensor network to the cloud via Wi-Fi to enable secure, high-speed, and reliable data transmission. This design supports modular scalability and ensures

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performance efficiency across varied SME environments. Integration testing confirmed stable transmission, with an average latency of 1.2 seconds and 98% message delivery reliability under Wi-Fi conditions.

3.7. Development and Deployment

The backend, developed in Python–Django, is structured to handle real-time data aggregation, analytics, and visualization [31]. WebSocket APIs receive sensor data from the ESP32, storing it in an SQLite database. Processing scripts analyze incoming data streams, producing actionable insights displayed via a responsive web dashboard. For deployment, the Django application is hosted on a cloud server for SME, customer, and visitor access. The ESP32 employs the Message Queuing Telemetry Transport (MQTT) protocol to publish sensor data securely to the cloud [31]. This layered architecture ensures continuous connectivity and enables SMEs to monitor environmental conditions and customer interaction patterns in real time, thereby optimizing operations and customer engagement.

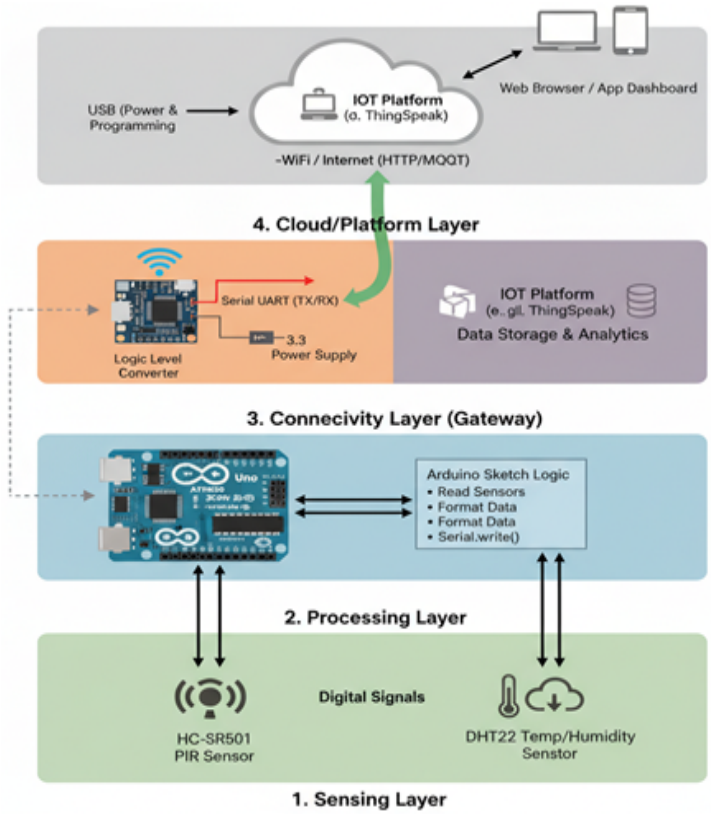

Figure 1. Platform Application Architecture

The architecture supports efficient data handling and SME engagement. Data flows from the Perception Layer (sensors), through the Processing Layer (Arduino Uno), Connectivity Layer (ESP32), to the Cloud/Platform Layer for storage, analysis, and visualization. The Presentation Layer delivers real-time insights through dashboards, enabling configuration, monitoring, and informed decision-making.

3.8. Data Collection Instruments and Validation

All instruments were pilot tested with 10 SME representatives and 30 customers for clarity, relevance, and consistency. Based on feedback, items were refined. Reliability was assessed using Cronbach's alpha**,** with all scales exceeding 0.75, confirming acceptable internal consistency.

1) Surveys: Structured questionnaires to collect demographics, IoT awareness, and engagement behaviors.
2) Interviews: Semi-structured interviews with SME owners/managers to explore perceptions and adoption challenges.
3) Observations: Customer engagement patterns recorded using predefined checklists.

3.9. Ethical Considerations

The study adhered to strict ethical standards by obtaining informed consent, ensuring anonymity, and offering opt-in mechanisms for IoT data collection. It complied with the General Data Protection Regulation (GDPR), the Tanzania Personal Data Protection Act (2023), and Tanzania Communications Regulatory Authority (TCRA) guidelines. The system was designed with energy-efficient, low-power components to promote environmental sustainability, accompanied by transparent communication on data use and platform capabilities. Beyond compliance, the platform enhanced security through encrypted data storage, secure authentication, robust access controls, and comprehensive user consent management. IoT data collected during simulations was anonymized, stored securely for 30 days, and deleted automatically after analysis to uphold ethical standards.

4. RESULTS AND DISCUSSION

4.1. Quantitative Results

Surveys were used to collect quantitative data from 340 SME customers, ensuring representation across different business types and demographic groups, aimed to capture customer engagement preferences, feedback on current engagement practices, and their expectations from an IoT-based engagement platform.

4.1.1. Demographic Profile of Respondents

Survey data were analyzed by location (urban and semi-urban), age group (children, youth, adults, elderly), and gender to identify key trends in customer behavior. Appendix A, Table 4 presents the age and gender distribution, while Tables 5 – 7 provide respondents with detailed breakdowns by location, age, and gender. As shown in Figure 2, these demographic patterns indicate factors influencing IoT adoption and customer engagement among SMEs, providing insights into technology readiness across different demographic groups.

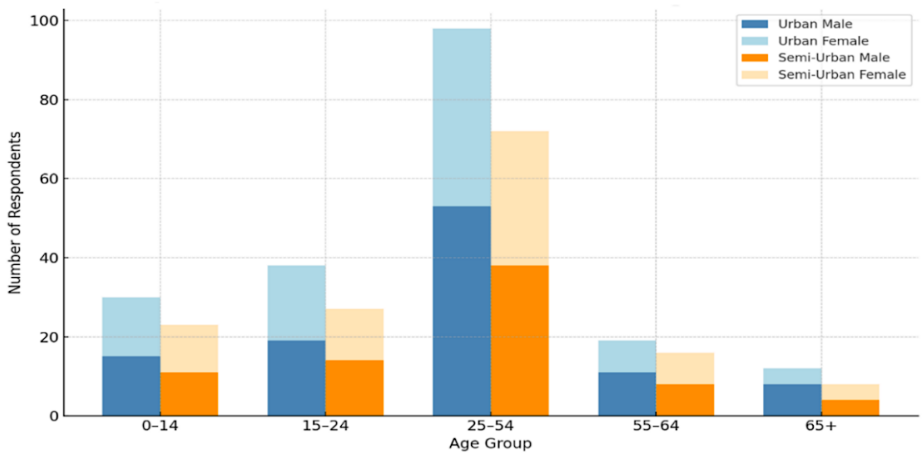

Figure 2. Demographic distribution by location, age, and gender

Adults aged 25–54 (50%) and youth aged 15–24 (19.12%) are the largest respondent groups, suggesting they are the primary potential adopters of IoT in SMEs. Urban respondents (57.65%) outnumber semi-urban (42.35%), indicating higher adoption potential in urban areas. Gender distribution is balanced (males 53.24%, females 46.76%), highlighting the need for inclusive strategies. Smaller proportions of younger and elderly groups suggest lower direct IoT engagement, offering key insights for targeted customer engagement approaches.

4.1.2. Survey Insights on Customer Behaviors and Preferences

The researcher asked SME customers questions to understand respondents' awareness, preferences, and behaviors regarding SMEs in Tanzania, focusing on awareness channels, purchase influencers, satisfaction with SME services, perceived SME challenges, preferred communication channels, and desired engagement features. Survey results revealed notable differences between urban and semi-urban SME customers, as shown in Table 3.

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Table 3: Comparative Overview of Customer Preferences by Location

Question	Urban SMEs	Semi-Urban SMEs
Awareness Channels - (See Figure 3 and Appendix B Figure 12)	Social media (Facebook, Instagram, TikTok) is dominant.	Mix of traditional advertising and social media
Purchase Influencers (Appendix B Figure 13)	Product quality, reliability, brand trust	Price sensitivity and accessibility
Satisfaction with SME Services (Appendix B Figure 14)	High (particularly ages 25–54)	Neutral or dissatisfied, especially among older respondents
SME Challenges (Appendix B Figure 15)	Digital marketing skills gaps, limited budgets	Budget constraints, poor infrastructure
Preferred Communication Channels (Figure 3 below and Appendix Figure 12)	Social media, in-app messaging	Phone calls, face-to-face interactions, email
Desired Engagement Features (Appendix B figure 16)	Real-time notifications, loyalty incentives	Basic alerts, and ease-of-use features

Figure 3 illustrate that SME location, resources, and customer profiles significantly influence customer engagement and IoT adoption. Table 3 and Figure 3 show that urban customers primarily use social media, value product quality and trust, and report higher satisfaction. In contrast, semi-urban customers use both traditional and digital channels, are more price-sensitive, and prefer simpler communication methods. These differences highlight the need for targeted customer engagement strategies and capacity-building initiatives to support IoT adoption.

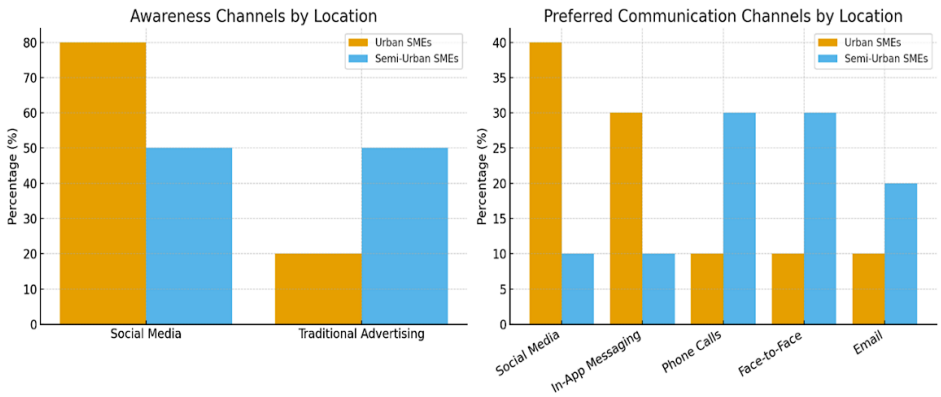

Figure 3. Comparative overview of awareness and communication channels by location

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4.1.3. Inferential Statistics

Inferential statistical analyses examined relationships between demographic factors and their influence on IoT familiarity, communication, and feature preferences. All three hypotheses (H1–H3) were supported. Figure 4 and Appendix A, Table 8, present the results, highlighting significant associations between demographic variables, IoT familiarity, and feature preferences.

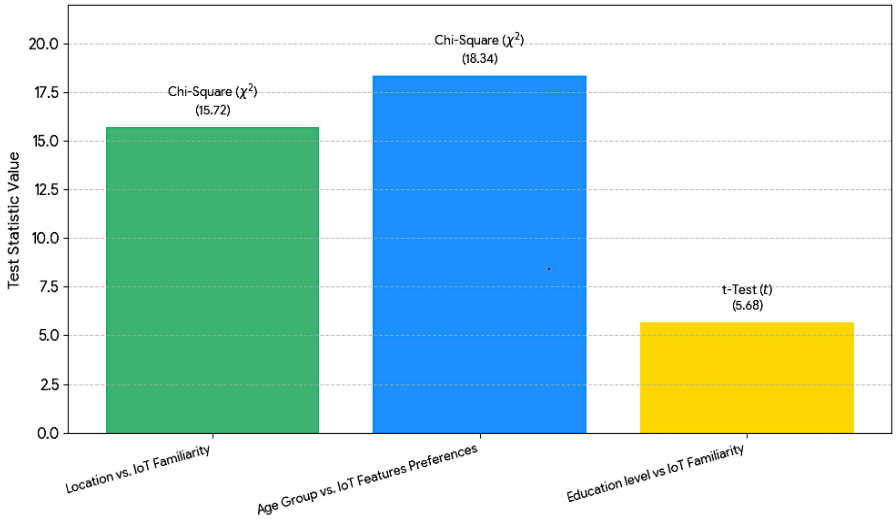

Figure 4. Inferential statistical analysis results

Summary of tested hypotheses:

1) H1: Urban SMEs exhibited significantly higher IoT familiarity.
2) H2: Younger respondents (15 – 34 years) expressed stronger preferences for interactive features such as real-time notifications and personalization.
3) H3: Educated participants demonstrate a positive familiarity with IoT technologies.

4.2. Qualitative Results

Qualitative data were collected through semi-structured interviews with 50 SME owners and managers, supplemented by field observations. The study explored challenges SMEs face in implementing effective customer engagement strategies, their adoption of technology, and perceptions of IoT integration's potential benefits. This approach allowed for deeper insights into unique operational contexts.

4.2.1. SME Challenges

Analysis of interview data revealed six key themes related to challenges and opportunities for SMEs. A significant majority (85%) of SME owners reported difficulties in effectively engaging customers, citing limited marketing resources and challenges in tracking customer behavior. Additionally, 70% stressed the need for real-time communication tools to meet customer expectations, while 50% expressed dissatisfaction with traditional engagement methods such as social media, phone calls, and physical visits, describing them as inefficient and difficult to scale. A strong perception emerged that IoT could address these challenges. Eighty percent of respondents viewed IoT as a means to streamline operations, improve customer targeting, and deliver personalized experiences, with 60% emphasizing its potential for personalization and interaction tracking. Furthermore, 40% believed IoT could reduce operational costs by automating tasks such as customer follow-ups and feedback collection. These insights highlight SMEs' interest in adopting IoT as a strategic tool to enhance engagement and operational efficiency.

4.2.2. Perceived Benefits

Interview and observation findings revealed that IT integration in SME's operations improved customer engagement and business performance among SMEs already adopting such tools. Specifically:

1) Approximately 80% reported increased customer satisfaction, including better feedback and more repeat visits.
2) A 30% reduction in time spent on manual engagement tasks was observed.
3) SMEs using IT solutions recorded an average revenue growth of about 15% within six months.

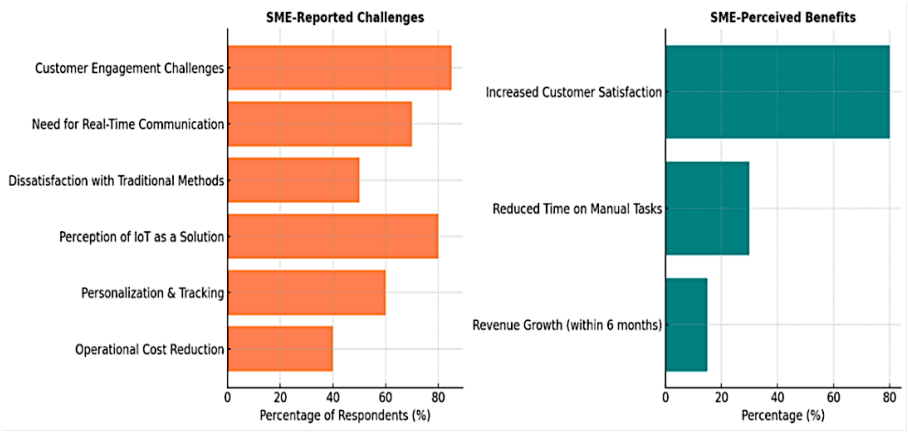

Figure 5. SME-reported challenges and IoT Perceived Benefits

Statements from participants noted: "*We now respond faster to customer issues. It makes a big difference."* — SME Manager, Arusha; *and "With business system automation, we no longer forget follow-ups. That's helping our reputation."* — Retail Owner, Dar es Salaam. The figure below shows SME-reported challenges and IoT perceived benefits described above.

4.3. Secondary Data Integration and Operational Implications

Secondary data and primary findings confirm strong SME demand for advanced technologies like IoT to improve efficiency and competitiveness [7], [24]. For long-term success, SME managers should adopt cost-effective, scalable, and energy-efficient IoT solutions that support advanced analytics, predictive marketing, and sustainable growth while enhancing competitiveness and customer satisfaction.

4.4. Functional and Non-Functional Requirements

The findings indicate that SMEs require IoT-powered engagement platforms with specific functional capabilities, including real-time notifications, personalized offers, customer interaction tracking, multi-channel communication, and automated feedback collection. These functionalities should address challenges such as limited marketing resources, difficulty in tracking customer behaviors, and delays in communication. Non-functional requirements include scalability to accommodate growth, cost-effectiveness for SMEs with budget constraints, reliability to ensure consistent engagement, ease of use for both customers and SMEs, and energy efficiency to support sustainable operations. Together, these requirements aim to enhance customer engagement, operational efficiency, and business performance for SMEs.

4.5. System Implementations and Evaluations

This section presents a summary of the developed IoT-powered customer engagement platform and its key interfaces.

4.5.1. System Overview

The IoT-powered customer engagement platform facilitates real-time interaction between SMEs and customers, as well as integrating environmental monitoring and customer detection through connected IoT devices, as illustrated in the block diagram, as shown Figure 6. The diagram presents a high-level view of the IoT-powered customer engagement platform, where sensors and microcontrollers collect and transmit data to a centralized web dashboard, providing SMEs with real-time insights to enhance customer experience, decision-making, and marketing strategies. For example, temperature and humidity sensors (DHT22)

monitor environmental conditions in a store, helping SMEs adjust air conditioning or product placement for customer comfort. Motion sensors (HC-SR501) detect customer presence or movement, triggering personalized notifications or promotional displays. This real-time data, visualized on the dashboard, enables SMEs to understand customer behavior patterns, optimize service delivery, and make data-driven marketing decisions. Furthermore, IoT enhances SME marketing by transforming customer and environmental data into actionable insights. Real-time analytics guide personalized promotions, strategic product placement, and timely offers based on customer behavior. This data-driven precision enables SMEs to attract, engage, and retain customers more effectively, maximizing marketing impact with minimal resources.

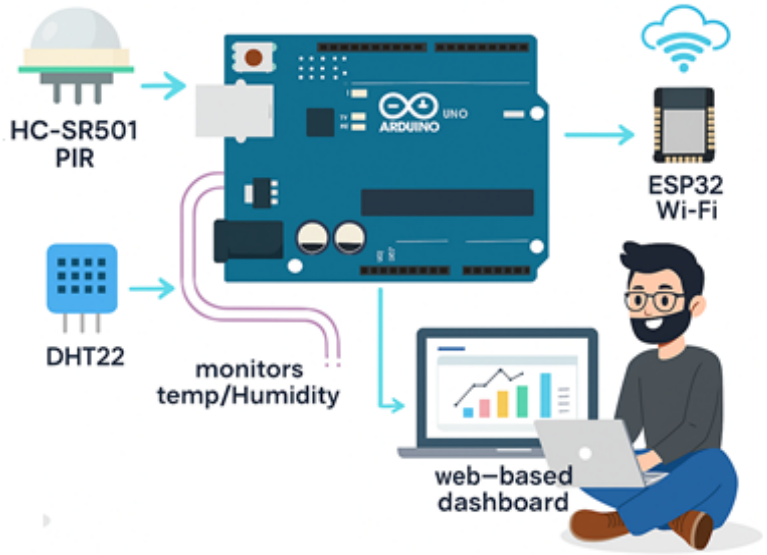

Figure 6. The platform context diagram

4.5.2. Key Platform Interfaces

The platform is designed with several key interfaces that ensure a seamless experience for SMEs and their customers, enhancing functionality and ease of use. The Home Page, as shown in Figure 7, serves as the central hub for users, offering an intuitive navigation menu that directs them to various sections such as products, services, feedback, login, and other important platform links. It is equipped with search and filtering tools to help users quickly find the items they are looking for. Additionally, the home page highlights promotions, product listings, device management options, reporting features, and access to terms and conditions. This user-friendly layout is designed to enhance both customer engagement and ease of navigation, ensuring that SMEs can efficiently showcase their products and services while maintaining a simple, clear structure for visitors.

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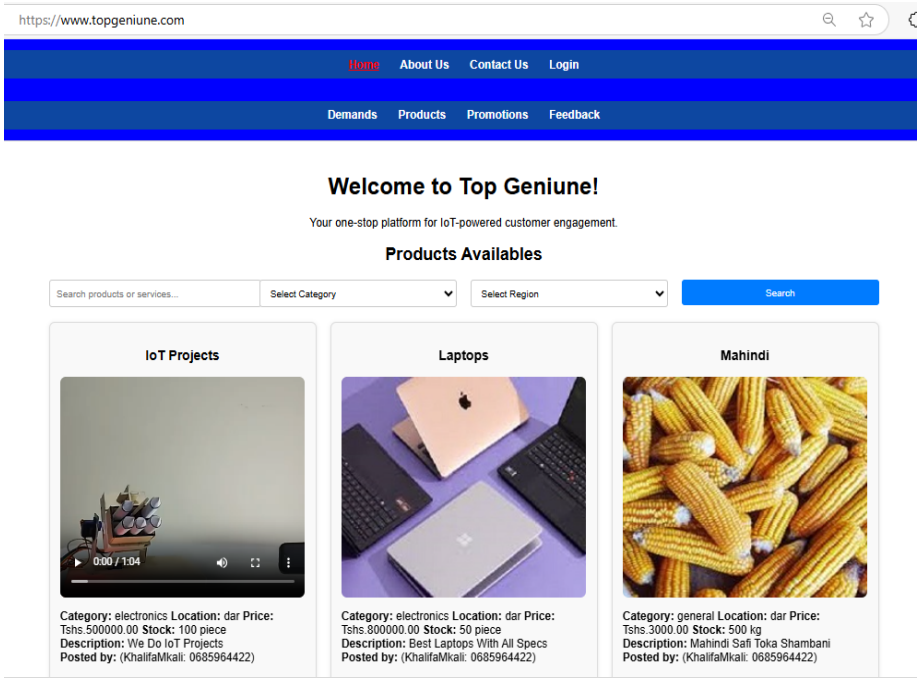

Figure 7. The home page of the platform

In terms of User Access and Management, the platform includes a secure User Authentication system that ensures safe access for SMEs, customers, and visitors alike. This system supports key features such as account sign-up, login, and password recovery, with added layers of security, including hashing and lockout mechanisms. The Admin Interface provides centralized control over user management, content moderation, and IoT integrations, allowing administrators to monitor real-time analytics and receive alerts about user interactions. Meanwhile, the User Dashboard is personalized for each individual, displaying relevant information such as product listings, promotions, recommendations, and a history of past interactions to foster deeper engagement and improve customer satisfaction.

The Device Management interface, as shown in Figure 8, plays a crucial role in integrating IoT sensors with the platform, enabling administrators to connect, configure, and monitor various IoT devices. This interface offers real-time data on customer presence and environmental conditions, empowering SMEs to make informed decisions based on current data. The module also supports remote device management, firmware updates, and the adjustment of security settings, ensuring that all devices remain up-to-date and secure. This feature is critical in maintaining seamless functionality and security across the platform, allowing SMEs to efficiently manage their IoT infrastructure.

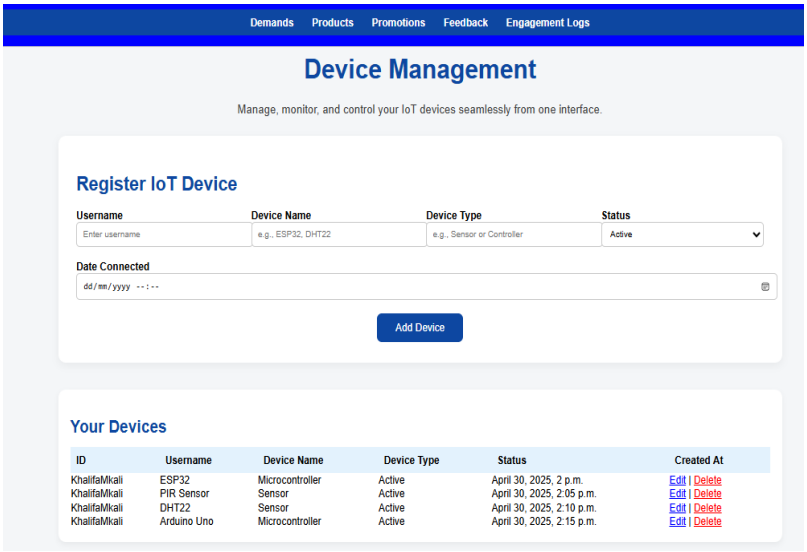

Figure 8: Device Management interface

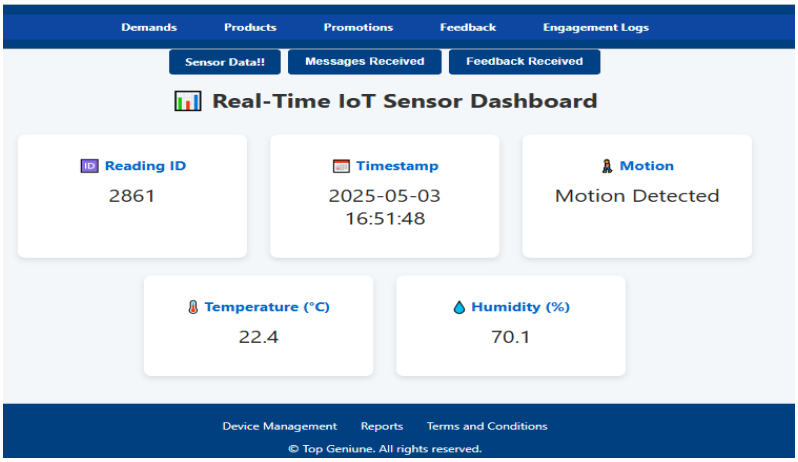

Figure 9: The platform Engagement logs interface

The Engagement Logs module, shown in Figure 9, facilitates dynamic interactions between IoT devices, customers, and SMEs. This system integrates sensor alerts, in-app messaging, and feedback mechanisms. IoT sensors transmit data through microcontrollers to notify users about changes in the environment or customer activity, enabling SMEs to respond in real time. Customers, in turn, can provide immediate feedback, and SMEs can engage with their customers directly through the messaging feature. This interface is designed to foster ongoing communication, ensuring that SMEs stay connected with their customers and are alerted to

important events or behaviors that could influence their marketing and customer service strategies.

Finally, the Reports and Analytics module, as shown in Figure 10, provides powerful data-driven insights, offering SMEs and administrators the ability to generate customizable reports on user activity, engagement trends, and IoT device usage. The module supports visual tools such as charts, graphs, and heatmaps, making it easier for users to analyze and interpret data. These reports are invaluable for tracking performance, understanding customer behavior, and making informed decisions that can optimize marketing efforts and enhance business outcomes. This functionality empowers SMEs to leverage data in meaningful ways, improving both operational efficiency and customer engagement. Together, these interfaces combine to create a comprehensive, user-friendly platform that not only enhances customer engagement but also provides SMEs with the tools they need to manage, analyze, and optimize their marketing strategies.

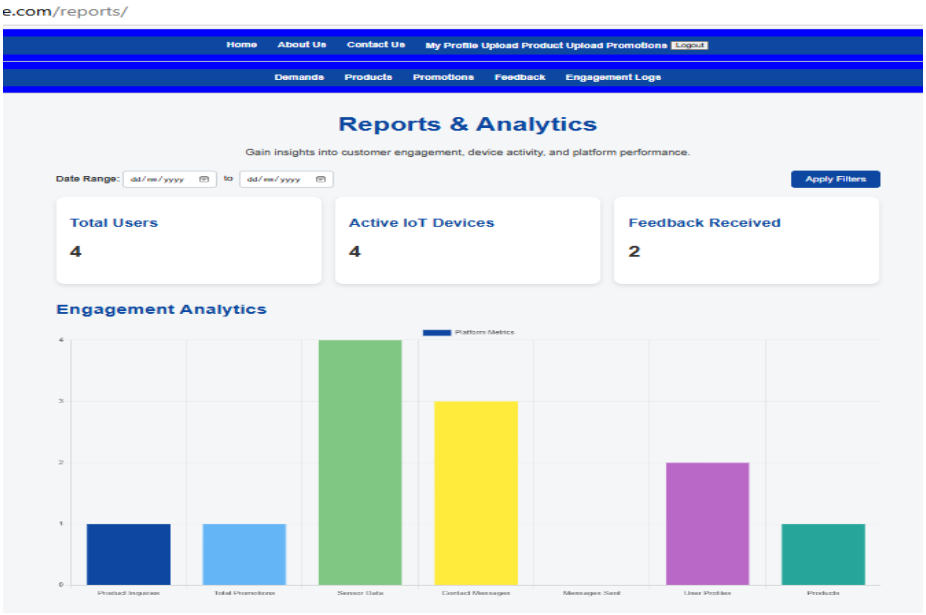

Figure 10: The platform report and analysis interface

4.6. Platform Effectiveness and Evaluation

This section evaluates the effectiveness of the developed platform in meeting its functional, technical, and business requirements, employing a multi-dimensional approach. The evaluation process includes simulated user engagement testing, expert usability reviews, technical performance analysis, and a theoretical assessment of the platform's business impact. Each of these methods contributes

to providing a comprehensive understanding of the platform's ability to support SMEs in optimizing customer engagement through IoT technologies. Simulated engagement testing was conducted to replicate typical SME scenarios and assess both the usability and the adoption potential of the platform. Key functionalities, including real-time notifications, customer feedback collection, and IoT device management, were thoroughly evaluated. System logs confirmed that the platform performed reliably even under load conditions, ensuring that it could handle the demands of SME environments. A detailed summary of the outcomes of this testing is provided in Appendix C, Table 9.

To assess the platform's usability, a structured review was conducted by five industry professionals who evaluated the interface design, navigation, and overall accessibility of the platform's features. The results from this usability testing indicated that the platform is highly intuitive, with users finding it easy to navigate and interact with its core features. This finding is further confirmed by the results shown in Appendix C, Table 10, where the platform received high marks for user-friendliness. In terms of technical performance, the platform underwent stress and performance testing to measure its stability, scalability, and responsiveness. These tests confirmed that the platform maintained consistent reliability even under peak load conditions. Performance metrics showed that the platform could handle significant usage without compromising its stability, which is crucial for ensuring that SMEs can rely on it for day-to-day operations. These findings, including details on the platform's scalability and response times, are summarized in Appendix C, Table 11.

A business impact analysis was also conducted to estimate the benefits that SMEs could gain from adopting the platform. The theoretical analysis projected significant improvements in key business areas such as customer retention, operational efficiency, and overall engagement effectiveness. The results suggested that the platform could lead to better customer loyalty, streamlined operations, and more effective interactions, as detailed in Appendix C, Table 12. The platform's cost-benefit analysis further supports its viability by estimating a favorable return on investment (ROI) and operational savings. Preliminary assessments indicated that the platform has the potential to improve SME productivity and profitability, confirming its value as a cost-effective solution for small businesses. A summary of the cost-benefit findings is provided in Appendix C, Table 13.

The evaluation results, as summarized in Figure 11, demonstrate strong technical performance and high projected user acceptance. The platform achieved an impressive 99.50% uptime rate and an 85.00% user-friendliness rating. Additionally, it is projected that user retention rates will reach 75.00%. Simulations also indicated improvements in key operational metrics, including a 30.00% reduction in inquiry response times, a 12.50% decrease in operational costs, and a

17.5% increase in customer retention. The platform showed low-latency performance, with an average response time of just 300 milliseconds and a tested capacity of 500 concurrent users. Furthermore, users spent an average of 12 minutes per session, indicating sustained engagement. These findings confirm the platform's stability, responsiveness, and suitability for SMEs, highlighting its potential for scalable IoT-driven customer engagement optimizations.

Based on the evaluation, this study makes several recommendations for future IoT platform development for SMEs. It is suggested that platforms integrate predictive analytics, customizable alerts, advanced dashboards, and mobile payment systems to further enhance transactions, decision-making, and operational efficiency. The development of such platforms should focus on a user-centered design that ensures ease of use, while also incorporating modular scalability, robust cybersecurity, and performance optimization to guarantee reliability. Collaboration between policymakers, developers, and SME stakeholders is essential to create enabling environments that support these innovations, thus driving broader adoption and advancing scalable IoT-driven marketing solutions for SMEs.

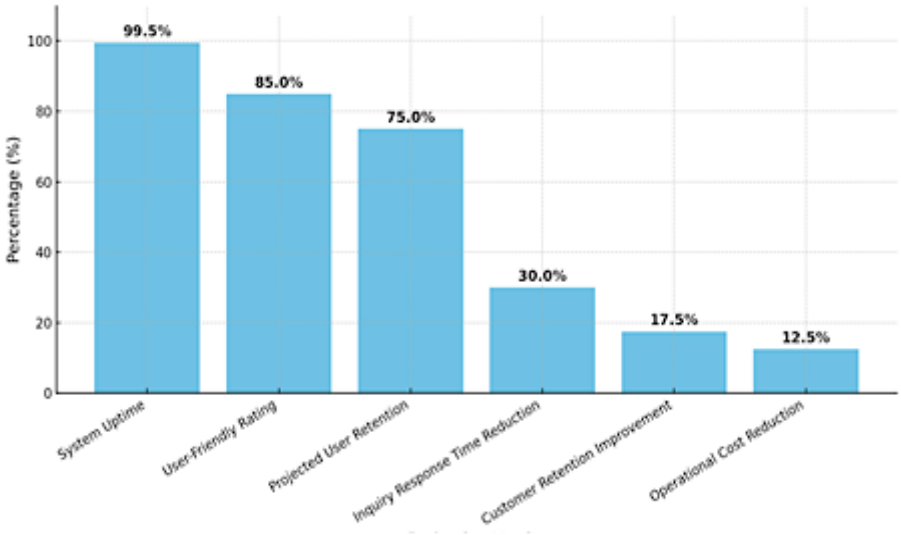

Figure 11. Key Performance and Impact Metrics

4.7. Discussion

The findings from this study demonstrate that IoT-powered platforms can significantly improve customer engagement for Tanzanian SMEs by addressing key challenges related to marketing, customer interaction, and operational efficiency. Despite their critical role in the economy, SMEs in Tanzania face numerous obstacles, including limited access to digital tools, inadequate

infrastructure, and low adoption of emerging technologies such as IoT. The development and evaluation of an IoT-powered customer engagement platform aimed at overcoming these barriers proved to be effective in enhancing both business performance and customer satisfaction.

The evaluation results confirm the platform's ability to meet the functional, technical, and business needs of SMEs. The simulated user engagement testing, which replicated typical SME scenarios, highlighted the platform's capacity to handle real-time notifications, customer feedback collection, and IoT device management. Importantly, system logs showed that the platform maintained reliable performance even under load conditions, reinforcing its suitability for high-demand SME environments. Additionally, usability testing, conducted by five industry professionals, demonstrated that the platform is intuitive and easy to navigate, receiving high ratings for user-friendliness. These findings suggest that SMEs will likely find the platform accessible, which is crucial for encouraging adoption among businesses with varying levels of technical expertise.

Technical performance was another critical area of evaluation. Stress and performance testing revealed that the platform remains stable and responsive even under peak usage, which is essential for ensuring consistent service delivery. The platform's ability to support up to 500 concurrent users and maintain low-latency performance (with an average response time of 300 milliseconds) is a strong indication of its scalability and reliability. These results suggest that the platform can support a large number of users without compromising the quality of service, making it a viable option for SMEs in both urban and semi-urban settings.

From a business perspective, the theoretical analysis indicated that the platform could drive significant improvements in key areas such as customer retention, operational efficiency, and overall engagement effectiveness. By providing SMEs with tools for real-time data collection, personalized engagement, and data-driven decision-making, the platform has the potential to enhance customer loyalty and streamline business operations. The cost-benefit analysis further supported this conclusion, showing a favorable return on investment (ROI) and operational savings, which are critical for SMEs with limited budgets. These findings reinforce the idea that IoT-driven customer engagement can help SMEs achieve long-term sustainability and growth.

The study's evaluation also uncovered several areas for future development. One notable recommendation is the integration of predictive analytics and customizable alerts, which could further optimize decision-making and customer engagement strategies. The addition of advanced dashboards and mobile payment systems would also improve the platform's functionality, enabling SMEs to manage transactions and track customer behavior more effectively. Moreover, the

platform's development should prioritize a user-centered design, modular scalability, robust cybersecurity, and performance optimization to ensure reliability and ease of use. This is particularly important for SMEs in resource-constrained environments like Tanzania, where technological solutions must be both affordable and practical for widespread adoption.

Finally, the IoT-powered customer engagement platform developed in this study demonstrates considerable potential in addressing the unique challenges faced by Tanzanian SMEs. By offering a cost-effective, scalable solution that integrates real-time customer insights and enhances operational efficiency, the platform holds promise for improving SMEs' competitiveness and supporting their digital transformation. The study also underscores the importance of continued collaboration between policymakers, developers, and SMEs to create an enabling environment that fosters the adoption of innovative technologies and drives sustainable economic growth.

5. CONCLUSION

Tanzanian SMEs face significant marketing challenges, including limited customer insights, low personalization capacity, and inefficiencies in engagement strategies, driven by resource constraints, inadequate infrastructure, and low technology adoption. This study addressed these challenges by developing an IoT-powered customer engagement platform integrating affordable sensors and microcontrollers, enabling real-time data collection, analytics, and personalized interactions tailored to SME limitations. The platform demonstrated clear advantages over traditional approaches, enhancing operational efficiency, decision-making, customer engagement, and return on investment. These findings confirm that IoT can transform SME marketing, but successful adoption requires institutional and policy support, including enabling regulations, financial incentives, investment in digital infrastructure, and national awareness campaigns. To maximize impact, SMEs should adopt scalable IoT systems and invest in digital literacy and training programs to improve adoption and utilization. Furthermore, future research should explore cross-industry applications, AI and machine learning integration for predictive analytics and personalization, and longitudinal studies to assess the platform's sustainability and scalability across sectors and developing economies, thereby providing a strategic roadmap for scaling IoT-enabled marketing in resource-limited contexts.

LIST OF ABBREVIATIONS

AI	Artificial Intelligence
API	Application Programming Interface
CEM	Customer Engagement Management

CSS3	Cascading Style Sheets (Version 3)
CRM	Customer Relationship Management
DHT22	Digital Humidity and Temperature Sensor 22
DOI	Diffusion of Innovation
ESP32	Espressif Systems Microcontroller (ESP32)
GDP	Gross Domestic Product
GDPR	General Data Protection Regulation
HC-SR501 PIR	Passive Infrared Sensor (HC-SR501)
HTML5	HyperText Markup Language (Version 5)
HTTPS	Hyper-Text Transfer Protocol Secure
IoT	Internet of Things
JSON	JavaScript Object Notation
LBS	Location-Based-Services
REST APIs	Representational State Transfer Application Programming Interfaces
ROT	Return on Investment
SDGs	Sustainable Development Goals
SME	Small and Medium Enterprises
SPSS	Smart Product Service Systems
SQLite	Structured Query Language – Lite
SSL/TLS	Secure Sockets Layer/Transport Layer Security
TAM	Technology Acceptance Model
TCRA	Tanzania Communications Regulatory Authority
UI	User Interface
URT	United Republic of Tanzania

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APPENDICES

Appendix A: Supplementary Tables and Figures (Referenced in Section 4.1)

Table 4. Distribution of Respondents by Age Group and Gender

Location	Age Group	Male Respondents	Female Respondents	Total	Percentage (%)
Urban	0–14	15	15	30	8.82
	15–24	19	19	38	11.18
	25–54	53	45	98	28.82
	55–64	11	8	19	5.59
	65+	8	4	11	3.24
Semi-Urban	0–14	11	12	23	6.76
	15–24	14	13	27	7.94
	25–54	38	34	72	21.18
	55–64	8	8	15	4.41
	65+	4	4	8	2.35
Total		**181**	**159**	**340**	**100.00**

Table 5. Respondents by Location

Location	Total Respondents	Average per Age Group	Percentage (%)
Urban	196	39.2	57.65

Semi-Urban	144	28.8	42.35

Table 6. Respondents by Age Group

Age Group	Total Respondents	Average per Location	Percentage (%)
0–14	53	26.50	15.59
15–24	65	32.50	19.12
25–54	170	85.00	50.00
55–64	34	17.00	10.00
65+	19	9.50	5.59

Table 7. Respondents by Gender

Gender	Total Respondents	Average per Age Group	Percentage (%)
Male	181	36.20	53.24
Female	159	31.80	46.76

Table 8. Inferential Statistical Analysis Results

Analysis	Variables	Test Statistic	p-value	Findings
Chi-Square Test	Location vs. IoT Familiarity	$\chi^2 = 15.72$	$p < 0.05$	Statistically significant; urban respondents demonstrated higher IoT familiarity.
Chi-Square Test	Age Group vs. IoT Features Preferences	$\chi^2 = 18.34$	$p < 0.05$	Statistically significant differences: younger users favored interactive features.
Independent t-Test	Education level vs IoT Familiarity	$t(198) = 5.68$	$t(198) = 5.68$	Educated participants are familiar with IoT technologies.

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Appendix B: Figures 12–16. Survey Response Visualizations (Referenced in Sections 4.1)

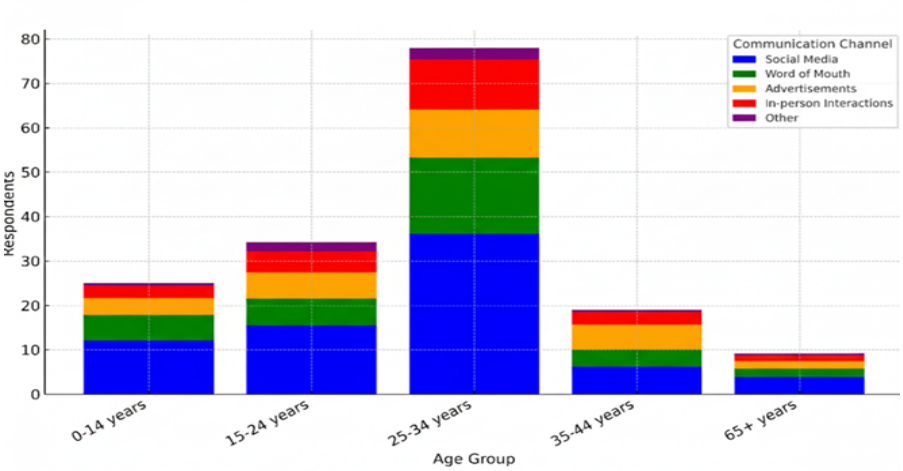

Figure 12. Channels through Which Customers Learn about New Products or Services

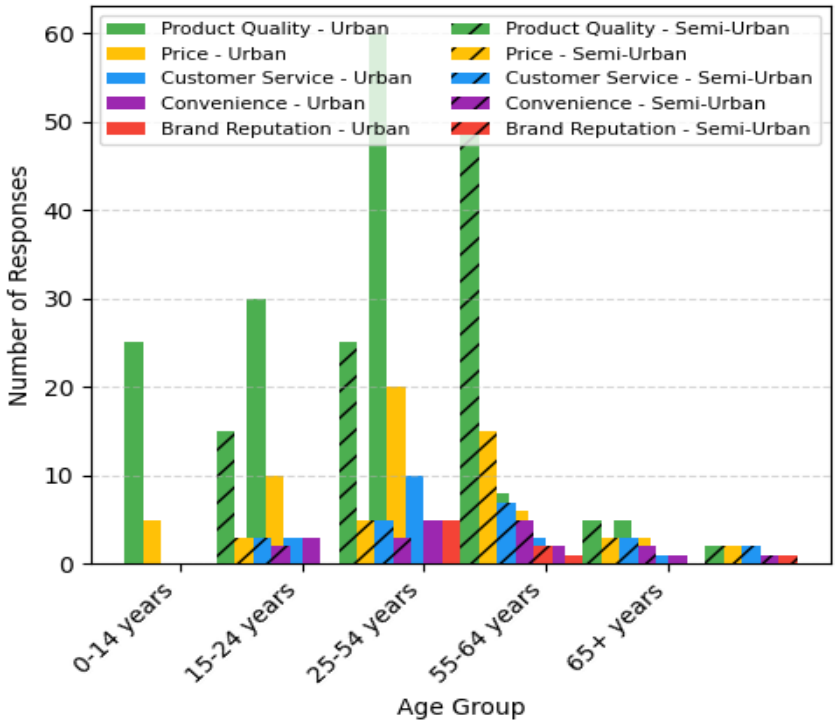

Figure 13. Factors Influencing Customer Engagement

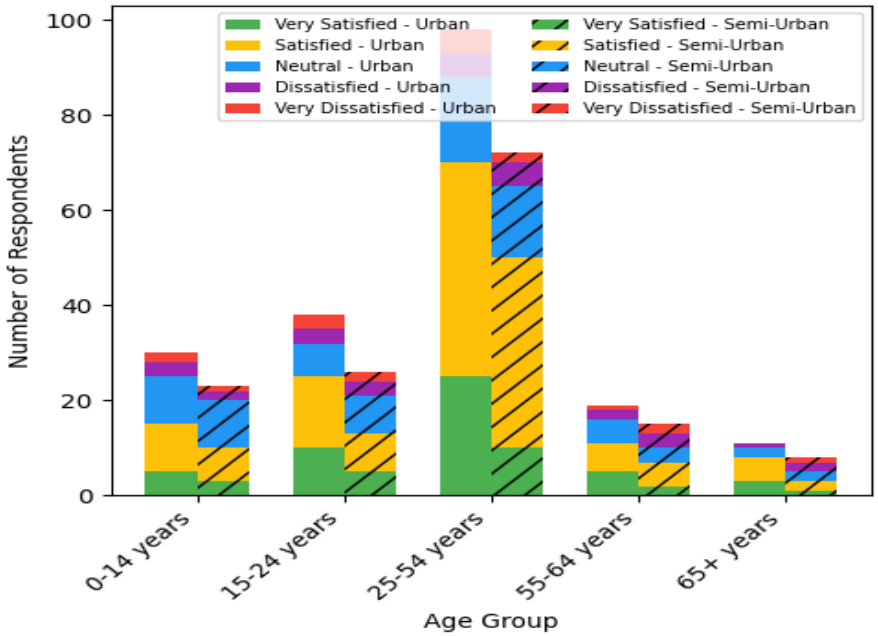

Figure 14. Customer Satisfaction Levels

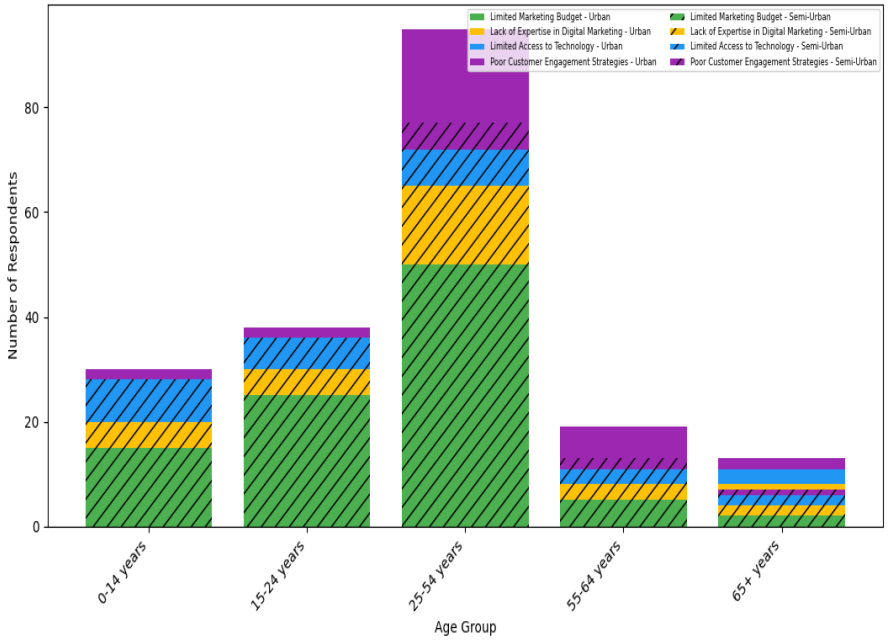

Figure 15. Key Barriers Faced by SMEs

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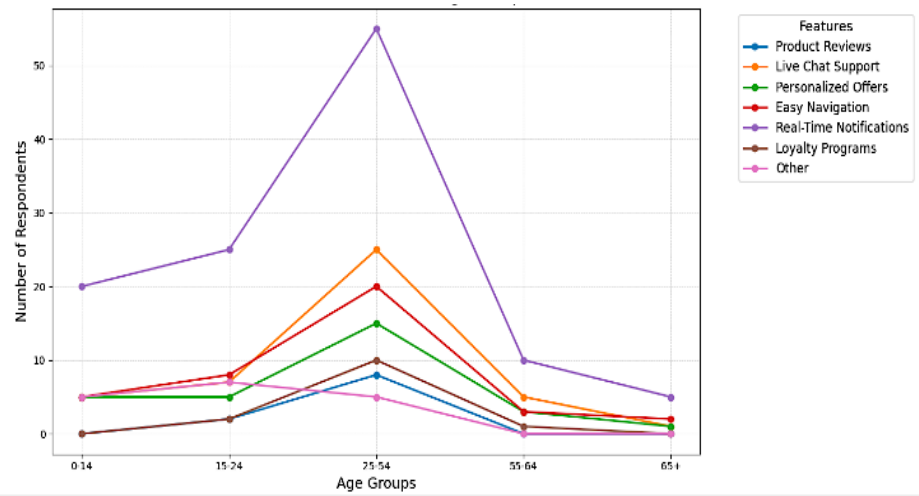

Figure 16: Desired IoT-Based Engagement Features

Appendix C: Platform Performance and Evaluation (Referenced in Section 4.5)

Table 9. Simulated User Engagement Metrics

Metric	Simulated Value
Average Session Duration	12 minutes
Most Engaged Feature	Real-Time Notifications
Projected User Retention	75%

Table 10. Usability Review Summary

Usability Indicator	Expert Review Results
User-Friendly Rating	85%
Ease of Navigation	High
Feature Accessibility	Good

Table 11. System Performance Metrics

Performance Indicator	Test Result
System Uptime	99.50%
Average Response Time	300 milliseconds
Simulated Max Concurrent Users	500 users

Table 12. Projected Business Impact

Business Metric	Expected Outcome
Customer Retention Improvement	15–20%
Inquiry Response Time Reduction	30%
Revenue Growth Potential	Moderate to High

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Table 13. Projected Cost-Benefit Outcomes

Cost-Benefit Factor	**Projected Impact**
Reduction in Inquiry Response Time	30%
Revenue Growth	Potential
Operational Cost Reduction	10–15%
Overall Efficiency Gains	High
SME Adoption Feasibility	Medium to High