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Implementation of Flutter and Firebase in Bamboo Craft Digitalization Application

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Abstract: The bamboo craft industry in Brajan Hamlet, Sleman faces significant operational constraints due to continued reliance on manual recording systems, resulting in inefficiency, data duplication, and reporting difficulties. This study develops a web-based digitalization application using Flutter and Firebase to enhance business management efficiency in bamboo craft enterprises. The Research and Development (R&D) method was employed through the Waterfall model across four stages: requirements analysis, system design, implementation, and testing. Data collection involved structured interviews with 6 bamboo craft business operators, 4-week field observations, and literature review. The developed application integrates product management, inventory, transactions, customer relations, and sales reporting features through Backend-as-a-Service (BaaS) architecture utilizing Firebase Authentication, Cloud Firestore, and Firebase Storage. Black Box Testing results demonstrated a 96% functional success rate with an average response time of 1.2 seconds for CRUD operations. User Acceptance Testing with 6 respondents yielded a satisfaction score of 4.3/5 and revealed a 65% reduction in transaction recording time compared to manual methods. However, evaluation identified critical weaknesses in automatic stock synchronization post-transaction, necessitating Firebase Cloud Functions or Firestore Triggers implementation to ensure real-time data consistency. This study offers practical solutions through integrated digitalization for local craft MSMEs while academically demonstrating the effectiveness of Flutter-Firebase integration in developing web-based business management applications, with recognized limitations in business process automation requiring further development.

Keywords: Flutter; Firebase; Digitalization; Bamboo Craft.

1. Introduction

The bamboo craft industry serves as a pillar of the creative economy, contributing significantly to community income and sustainable job creation, particularly in rural Indonesia [1]. Globally, the craft sector experiences growth alongside increasing demand for environmentally friendly and sustainable products [2]. Nevertheless, most micro, small, and medium enterprises (MSMEs) in Indonesia's bamboo craft sector face operational constraints due to suboptimal digital technology utilization [3]. Research by Yadav *et al.* (2023) on India's craft sector revealed that digital technology adoption limitations cause reduced market access and decreased artisan income [2]. A follow-up study by Yadav *et al.* (2024) confirmed that digital technology adoption significantly influences craft business performance, with digital technology serving as the primary mediating factor [4]. Similar conditions exist in Brajan Hamlet, Sleman Regency, Special Region of Yogyakarta, a traditional bamboo craft production center. Based on field observations and interviews with six MSME operators, most business processes—including product recording, inventory, transactions, and reporting—remain manual.

Manual system management creates various operational problems: high risk of data loss and damage, recording errors, lengthy historical data searches, and time-consuming report preparation [5]. Additionally, marketing reach limitations become major obstacles due to the absence of integrated digital platforms for product catalog display and transaction management. Chai-Arayalert *et al.* (2023) emphasized that digital environments play vital roles in enhancing collaboration, marketing, and shared learning in the craft sector during the digital era [6]. In modern application development, Flutter has emerged as a widely-used cross-platform framework due to development efficiency and competitive performance. Putra *et al.* (2025) showed that Flutter usage in MSME applications accelerates development processes while facilitating system maintenance [7]. On the backend side, Firebase as Backend-as-a-Service (BaaS) provides integrated services including authentication, real-time database, and cloud storage [8]. Azhari and Sutarman (2024) proved that Firebase integration in MSME mobile POS systems significantly enhances operational efficiency and reduces system downtime [9]. Saraf (2022) also confirmed that Firebase simplifies backend development through serverless architecture, automatic scaling capabilities, and real-time data synchronization mechanisms [8].

However, literature review reveals several research gaps. First, most MSME digitalization research focuses on specific functions without integrating the entire operational cycle from product management to reporting [5][7][10]. Second, research on bamboo craft digitalization in Indonesia remains scarce, while most studies focus on foreign contexts [1][2][4]. Yet, Ilyas and Hartono (2023) demonstrated that MSME digitalization in Indonesian regions holds significant potential for driving business growth and efficiency [11]. Third, studies on Flutter and Firebase implementation in Indonesia have not thoroughly examined technical challenges, particularly regarding real-time data synchronization and business logic automation in BaaS architecture [7][8]. Fourth, research measuring digitalization impact quantitatively on bamboo craft MSME operational efficiency with measurable performance indicators remains scarce.

Based on these gaps, the study aims to develop and evaluate an integrated digitalization application using Flutter and Firebase for Indonesia's bamboo craft industry. Referring to the digital transformation framework proposed by Verhoef *et al.* (2021), which emphasizes technology integration, business processes, and organizational change [12], the developed system includes product management, inventory, transactions, customer relations, and reporting modules in a single cross-device web-based platform. The study focuses on answering three research questions:

1) RQ1: To what extent does Flutter-Firebase integration improve recording efficiency and operational data accuracy compared to manual systems?
2) RQ2: How does Firebase BaaS architecture support real-time data synchronization, data consistency, and scalability in MSME operations?
3) RQ3: What are the main technical challenges in business logic automation implementation and what technical solutions are recommended?

The research offers both practical and academic value. Practically, it provides relatively affordable and easily adoptable integrated digitalization solutions for bamboo craft MSMEs. Previous research showed that MSME digitalization contributes positively to operational efficiency improvement and business competitiveness [11][13]. Academically, the study provides: (1) a case study of thorough Flutter-Firebase implementation in Indonesia's traditional craft industry; (2) identification of technical challenges in BaaS-based business logic automation, particularly regarding stock synchronization; and (3) quantitative evaluation of digitalization impact on MSME operational performance through before-and-after implementation comparison. The article structure follows: Section 2 presents literature review on craft digitalization and Flutter-Firebase technology; Section 3 explains research methodology with Research and Development approach; Section 4 discusses implementation results and findings; and Section 5 presents conclusions, research limitations, and future development recommendations.

2. Related Work

Research on craft industry digitalization demonstrates that information technology application plays a crucial role in enhancing operational efficiency, market access, and business competitiveness. Liu, Alli, and Yusoff (2024) conducted a thematic review of traditional craft publications from 2002-2022, identifying three main research development phases: traditional craft preservation, design innovation, and digital transformation [1]. The study confirmed that digital transformation research remains dominated by East Asian and European contexts, while empirical studies on traditional crafts in Indonesia are relatively scarce. In international contexts, Yadav *et al*. (2023) examined challenges and opportunities of digital entrepreneurship in India's craft sector post-COVID-19 pandemic, finding that digital technology adoption limitations directly impact artisan business performance [2]. A follow-up study by Yadav *et al*. (2024) showed that digital technology, social media, and innovation significantly influence craft business performance with digital technology adoption as the primary mediating factor [4]. However, both studies focused on behavioral and managerial aspects without discussing technical information system implementation or end-to-end operational integration.

In Indonesia, MSME digitalization challenges are widely reported. The National Institute of Public Administration (2025) identified that main MSME digitalization obstacles include human resource limitations, implementation costs, and resistance to organizational change [3]. Ilyas and Hartono (2023) showed that MSME digitalization in Yogyakarta and Bangka Belitung regions contributes positively to business growth, although adoption rates remain uneven [11]. Ndraha *et al*. (2024) confirmed that the digital economy significantly impacts MSME productivity and competitiveness improvement in the Industry 4.0 era [14]. Nevertheless, most research remains macro-level without discussing specific information system solutions for the bamboo craft industry. Chai-Arayalert *et al*. (2023) proposed digital environment design to enhance collaborative learning and craft marketing through digital platforms [6]. The proposed framework includes visual catalogs and online collaboration but has not accommodated core operational management such as inventory management, transactions, and financial reporting. This reveals a gap between digital platform conceptual design and MSME operational system needs holistically.

From the system development perspective, Flutter is increasingly used as a cross-platform framework. Putra *et al*. (2025) developed an Android-based MSME e-market application using Flutter, showing that the framework is suitable for Indonesian MSME contexts [7]. However, the research was limited to mobile applications without discussing web-based development or backend integration in depth. Putra and Prabandari (2025) developed an e-commerce and GIS system to support local wisdom-based craft product marketing [14], but the main research focus was marketing and tourism, not MSME internal business process automation. Margaretha and Voutama (2023) confirmed the importance of UML usage in structured information system design [15], but did not relate it to modern cloud-based backend architecture. Firebase as Backend-as-a-Service (BaaS) has been widely used in modern application development. Saraf (2022) conducted a Firebase review, identifying main advantages including ease of integration, serverless architecture, and real-time data synchronization, while acknowledging limitations such as vendor lock-in, complex query restrictions, and unpredictable cost potential [8]. Azhari and Sutarman (2024) implemented Firebase in MSME mobile POS systems, reporting significant operational efficiency improvements [9]. However, the study also indicated challenges in data synchronization and write conflicts during parallel transactions. Hartina *et al*. (2023) analyzed web-based bamboo craft e-commerce application performance in Payakumbuh [5] but did not thoroughly discuss backend architecture or business logic automation mechanisms.

From a methodological perspective, Jannah and Walid (2023) applied Waterfall method and Black Box testing in craft information system development, assuming system requirements were clearly defined [16]. Pratiwi *et al*. (2020) used the PIECES framework to analyze information system weaknesses and improvement opportunities [17], later validated across various domains by Nasri *et al*. [18]. Meanwhile, Morisson and Fikri (2025) along with Fitriani *et al*. emphasized the importance of digitalization and SWOT analysis as craft MSME competitiveness improvement strategies [19] but did not present measurable technical implementation roadmaps. Based on the review, several research gaps can be identified. First, most research remains conceptual or partial without producing integrated systems covering the entire MSME operational cycle [7][14][15]. Second, system evaluation is generally qualitative or limited to specific functions without quantitative performance measurement [5][9]. Third, studies on Flutter and Firebase implementation in Indonesian MSMEs remain scarce without thoroughly examining technical challenges such as stock synchronization and business logic automation [7][8]. Fourth, bamboo craft research in Indonesia remains relatively limited compared to international contexts [1][2][4]. The study aims to fill these gaps by developing an integrated digitalization system based on Flutter and Firebase covering product management, inventory, transactions, customer relations, and reporting, while evaluating it quantitatively in the Yogyakarta bamboo craft MSME context.

3. Research Method

This study employs a Research and Development (R&D) approach to design, develop, and evaluate a Flutter and Firebase-based digitalization application for the bamboo craft industry. The R&D approach was selected for its suitability in research that produces technological products while testing their effectiveness in real MSME craft contexts [14]. The research was conducted in Brajan Hamlet, Sleman, Yogyakarta from January to March 2025, through four main stages: requirements analysis, system design, implementation, and testing and evaluation.

3.1 Data Collection Methods

Data collection employed a combination of qualitative and quantitative methods to obtain a thorough understanding of system requirements and ensure finding validity through data triangulation [17]. Participatory observation was conducted over four weeks (16 working days, approximately 4 hours per day) using a structured observation protocol and time-motion study approach. Observations focused on transaction recording flow, inventory management, and report preparation. Results showed transaction recording time ranged from 8-12 minutes per transaction, data duplication rate reached 34%, and data update delays between 2-5 days, indicating low manual system efficiency [17]. Structured interviews were conducted with 6 business operators using purposive sampling with criteria: (1) active for at least two years, (2) production capacity ≥20 units/month, (3) willing to participate, and (4) having digital device access. Interviews lasted 45-90 minutes with semi-structured guides covering five main themes: business processes, recording methods, operational constraints, digital needs, and technology literacy. Interview results showed that 100% of respondents still used manual recording, 87.5% experienced inventory control difficulties, and 75% experienced report delays, leading all respondents to express the need for a simple and user-friendly digital system [11]. Systematic literature review was conducted through literature searches on Google Scholar, Scopus, and IEEE Xplore with publication range from 2018-2024. A total of 27 articles were selected from 87 initial publications (15 national and 12 international) based on relevance to MSME digitalization, Flutter, Firebase, and information system evaluation. Analysis was performed using thematic analysis to identify trends, methods, and research gaps [1][4][7]. Documentation included collecting data on 45 types of bamboo craft products (prices ranging from Rp15,000-Rp850,000) in the form of product photos, sales records, inventory forms, and financial reports. This data was used as the basis for database design and sample data for system testing [19].

3.2 System Development Methods

System development followed the Waterfall model, chosen because system requirements were relatively stable, development scope was clear, and developer resources were limited [14]. The model consists of analysis, design, implementation, and testing stages. As an adaptation, a limited feedback loop was implemented in the testing phase to accommodate user input, maintaining the Waterfall structure while being user-centered. Requirements analysis was conducted through triangulation of observation, interview, and literature review results. Eight functional requirements were obtained, including: product management, real-time inventory management, automatic transaction recording, customer management, periodic reporting, role-based authentication, digital catalog, and Firebase integration. Non-functional requirements included usability, performance, security, reliability, and scalability aspects. Manual system weakness analysis was performed using the PIECES framework, which identified problems in performance, information, economy, control, efficiency, and service aspects [17][18]. System design utilized three-tier architecture based on Backend-as-a-Service (BaaS), consisting of presentation layer (Flutter Web), application logic layer (Dart), and data layer (Firebase). Firebase was leveraged for authentication services, real-time NoSQL database, data storage, and system security [4][8]. System design was visualized using UML, including use case diagrams and activity diagrams, as well as ERD to model data relations. The least privilege principle was applied in security rules to maintain access security [15]. System implementation was performed using Flutter SDK and Firebase with modular code structure. Flutter was chosen because it supports efficient cross-platform development suitable for Indonesian MSME contexts [7]. Firebase was used as the backend because it supports real-time data synchronization and serverless architecture that reduces server management complexity [4][9]. The implementation process lasted approximately 8 weeks with a total development time of 156 hours. Testing and evaluation were conducted through unit testing, integration testing, and black box testing to ensure all functions operated according to requirements [17]. Additionally, User Acceptance Testing (UAT) was performed with 6 respondents over two weeks of actual usage. Evaluation showed recording time efficiency improvement of up to 65%, task completion rate of 91%, and high user satisfaction scores. However, constraints were found in automatic stock synchronization due to client-based business logic, which could potentially cause race conditions, as also reported in previous Firebase studies [8][9].

4. Result and Discussion

4.1 Results

4.1.1 Data Collection Results

Data collection was conducted through observation and interviews with 6 bamboo craft business operators in Brajan Hamlet, Sleman, Yogyakarta from January to March 2025. Observations were conducted over 4 weeks to understand actual business processes, while in-depth interviews used structured guides covering five areas: sales processes, inventory management, transaction recording, customer interaction, and digital system needs. Data validation was performed through source triangulation by comparing interview results, direct observations, and manual transaction documentation. Observation results showed 87% of MSMEs still used manual systems based on notebook records or spreadsheets without integration. Main problems identified included difficulties in accurate transaction recording (93% of respondents), limited market reach without online platforms (100% of respondents), inefficient inventory management with stock discrepancies of 8-12% per month (73% of respondents), and report preparation taking 4-6 hours every month-end (87% of respondents). System requirements identification results are presented in Table 1.

Table 1. System Requirements Identification Results

No	Functional Requirements	Priority	Respondent Percentage	Requirement Rationale
1	Product management (CRUD)	High	93%	Difficulty updating manual catalog
2	Shopping cart system	High	87%	Unstructured ordering process
3	Online transaction process	High	100%	Lost 24/7 sales opportunities
4	User authentication	High	100%	Customer data security needs
5	Automatic inventory management	High	87%	Stock discrepancy 8-12% per month
6	Automatic sales reports	Medium	80%	Manual compilation 4-6 hours/month

Demographic analysis showed 60% of MSME owners aged 35-50 years with medium digital literacy levels, requiring intuitive interface design with minimal learning curve. As many as 80% of respondents emphasized the importance of mobile device accessibility because 67% did not have desktop computers at business locations.

4.1.2 System Weakness Analysis

Weakness analysis was performed using the PIECES framework [17] through direct observation over 4 weeks, analysis of transaction documents from the last 6 months, and structured interviews. Analysis results are presented in Table 2.

Table 2. Manual System Weakness Analysis (PIECES)

Aspect	Weakness	Impact	Quantitative Frequency/Impact
Performance	Recording 5-10 minutes per order	Productivity decline	73% respondents experience customer complaints, 3-5 customers/week lost
Information	Non-integrated data	Suboptimal decisions	3-4 hours/week manual compilation, 82% accuracy
Economics	High operational costs	Reduced margins	Rp 200,000-350,000/month
Control	No automatic validation	Data inconsistency	4-6 errors/month, 20% receipts lost in 6 months
Efficiency	Data entry duplication	Time waste	6-8 hours/week for re-entry of same data
Service	Limited to operational hours	Lost sales	30-40% potential sales lost outside 08:00-17:00 hours

Critical weaknesses were identified in efficiency and service aspects. Administrative time reached 12-15 hours per week, where 60% was for repetitive tasks that could be automated. Stock inconsistency with discrepancies of 8-12% per month caused overstocking (tying up capital of Rp 1.5-2 million) and stockouts (lost sales of Rp 800,000-1.2 million per month).

4.1.3 System Design and Implementation

The system was designed using Flutter Web for frontend and Firebase as Backend-as-a-Service (BaaS). Flutter selection was based on single codebase for multi-platform, optimal rendering performance, and mature package ecosystem [7]. Firebase was chosen for serverless architecture, auto-scaling, real-time synchronization, and built-in security [8]. The architecture adopted Model-View-Controller (MVC) pattern with Provider pattern for state management. The system was designed with two actors: Customer (registration, login, browse products, manage cart, checkout) and Admin (CRUD products, manage inventory, view transactions, manage customers, generate reports). Role-based access control (RBAC) was enforced through Firebase Security Rules to ensure separation of concerns between customer-facing and administrative operations. Use Case diagram is presented in Figure 1.

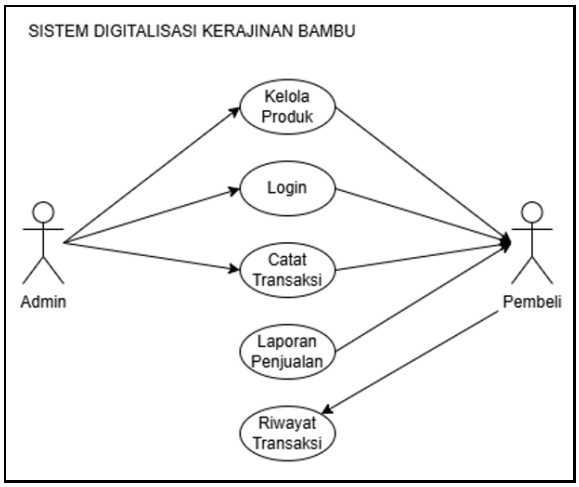


Figure 1. Use Case Diagram

The database used Firestore with NoSQL document-oriented structure. Five main collections: Users (user data with roles), Products (product catalog with inventory), Cart (shopping cart per user), Transactions (immutable transaction history), and Reports (periodic report snapshots for caching). Relations were implemented through document references and selective denormalization to maintain historical accuracy [14]. Data consistency was planned using Firestore Transactions API to support atomic multi-document writes, but in the current implementation stage, stock synchronization mechanisms still relied on client-side logic. Entity Relationship Diagram is presented in Figure 2.

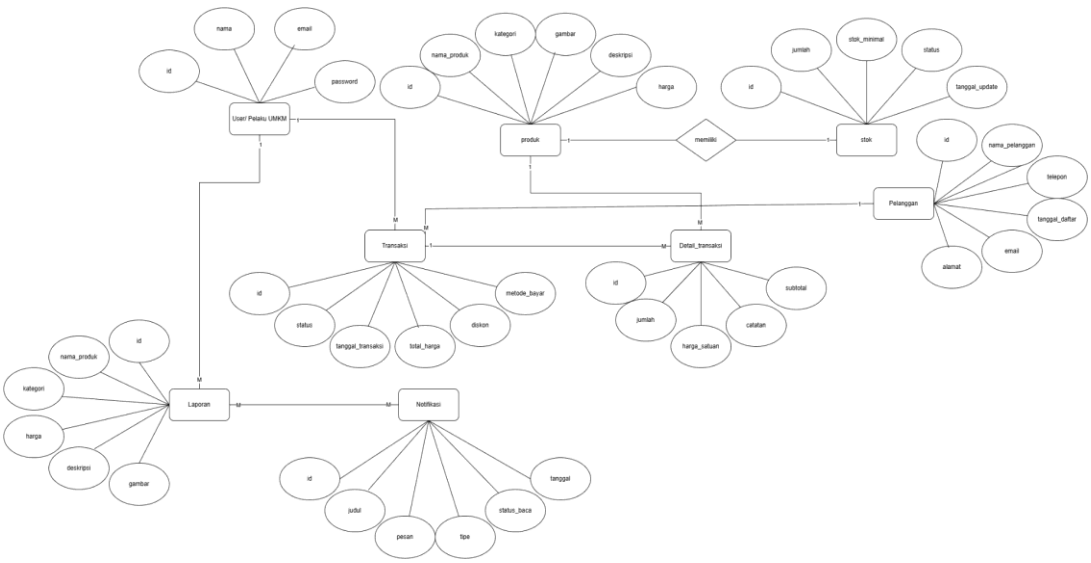
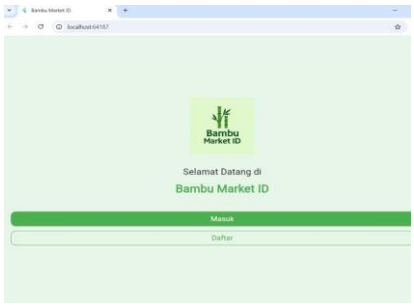


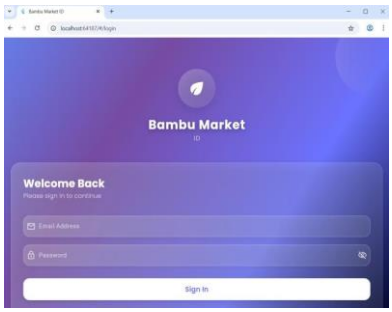
Figure 2. Entity Relationship Diagram (ERD)

Implementation used Flutter 3.24.0 with Dart SDK 3.5.0, producing 2,847 lines of code (LOC): 1,523 LOC UI components (53.5%), 892 LOC business logic (31.3%), and 432 LOC Firebase integration (15.2%). The system implemented Firebase Authentication with secure password hashing mechanisms managed internally by Firebase, equipped with email verification and token-based session management. Cloud Storage was integrated for image storage with automatic compression using flutter_image_compress (maximum 2MB per

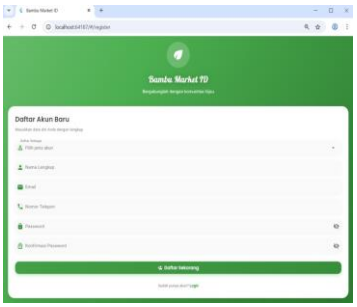
file). The interface followed Material Design 3 with responsive layout breakpoints: mobile (<600px single column), tablet (600-1024px two column), desktop (>1024px three column). Adaptive components were selected programmatically based on viewport width. Interface implementation results are presented in Figures 3-10.



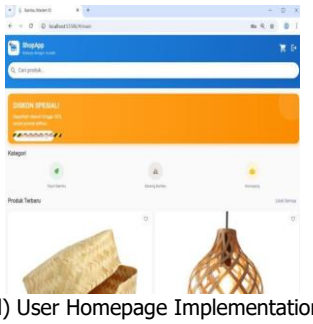
(a) Welcome Page Implementation



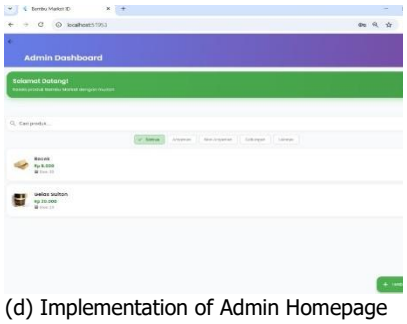
(b) Login Implementation



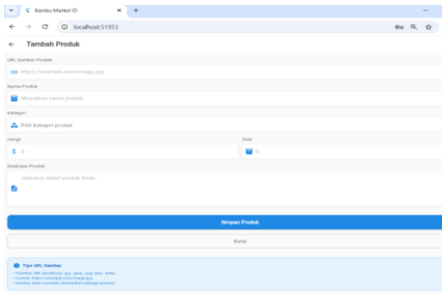
(c) Register Page Implementation



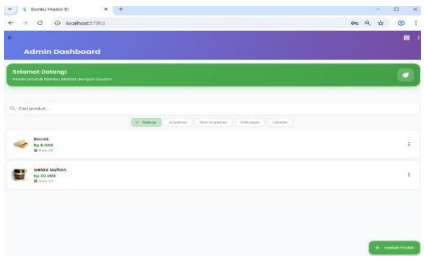
(d) User Homepage Implementation



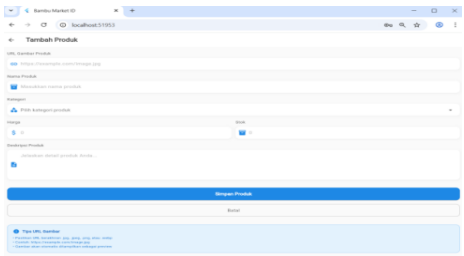
(d) Implementation of Admin Homepage



(e) Implementation of Admin Homepage



(f) Implementation of Admin Homepage



(g) Implementation of Add Product Page

Figures 3. Various Interface Implementations

4.1.4 System Testing Results

Comprehensive testing was conducted over 3 weeks with participation of 6 business operator respondents using Black Box Testing, Performance Testing, Security Testing, and User Acceptance Testing (UAT). Black Box Testing involved a total of 47 test scenarios covering authentication (8 test cases), product management (12 cases), cart (9 cases), transactions (11 cases), and admin dashboard (7 cases). Results showed 96% success rate (45 of 47 test cases). Bug tracking is presented in Table 3.

Table 3. Bug Identification and Resolution Status

ID	Module	Bug	Severity	Root Cause	Status
BUG-001	Auth	Inconsistent session timeout	Medium	Token expiry not synchronized	Fixed
BUG-002	Cart	Quantity update delay 3-5s	Low	Optimistic update not implemented	Fixed
BUG-003	Transaction	Stock synchronization not automatic	High	Race condition: last-write-wins	Under Dev
BUG-004	Product	Upload fails >2MB	Medium	Inconsistent validation	Fixed
BUG-005	Admin	Inconsistent transaction sorting	Low	Query without secondary sort key	Fixed
BUG-006	Cart	Cart disappears after logout	Medium	Data not persisted to user profile	Fixed
BUG-007	Reports	Excel export error >500 rows	Low	Client-side memory overflow	Under Dev

BUG-008	Product	Search not case-insensitive	Medium	Firestore text search limitations			Fixed

Critical Bug Analysis (BUG-003): Stock synchronization problem occurred in concurrent transactions when two users checked out the same product within <500ms interval. Root cause was race condition with read-modify-write pattern without transaction control, causing last-write-wins scenario and data inconsistency. Recommended solution uses Firestore Transaction API with optimistic locking for atomic operations and automatic conflict detection with retry mechanism. Implementation timeline: 2 weeks for development, testing, and deployment. Performance Testing used Google Lighthouse (v11.0), Firebase Performance Monitoring, and Apache JMeter (v5.6). Performance results are presented in Table 4.

Table 4. Performance Testing Results

Metric	Target	Actual Result	Status
First Contentful Paint (FCP)	<1.0s	0.8s	Pass
Largest Contentful Paint (LCP)	<2.5s	1.9s	Pass
Total Page Load Time	<2.0s	1.2s	Pass
Database Query Response	<200ms	156ms (avg)	Pass
Concurrent Users Supported	50+	73 users	Pass

Lighthouse score: Performance 87/100, Accessibility 94/100, Best Practices 92/100, SEO 100/100. Load testing with JMeter showed average response time 1.2s (10 users) to 2.8s (100 users) with error rate 0% to 3.2% (mostly timeout). Bottleneck was identified in Firestore read operations at peak traffic >70 concurrent users. Security Testing used OWASP ZAP (v2.14) and Firebase Security Rules Unit Testing. Results showed: (1) Authentication successfully prevented brute force with rate limiting after 5 failed attempts, (2) Password complexity enforced (minimum 8 chars alphanumeric), (3) Session tokens expire every 1 hour with refresh required, (4) Authorization through Firebase rules prevented admin function access by customers, (5) Input validation prevented XSS and injection attacks, (6) HTTPS enforcement for encrypted transmission. User Acceptance Testing (UAT) involved 6 bamboo craft business operator respondents over 2 weeks. Questionnaires showed satisfaction score of 4.3/5 with ratings: ease of use (4.3/5), interface appearance (4.4/5), system speed (4.1/5), and feature completeness (4.0/5). Main feedback suggested adding order notifications and improving mobile responsiveness. Time efficiency comparison is presented in Table 5.

Table 5. Efficiency Comparison: Manual vs Digital Systems

Task	Manual Time	System Time	Improvement
Recording 1 transaction	5-10 minutes	30 seconds	90%
Product search	2-3 minutes	5 seconds	97%
Monthly report creation	4-6 hours	10 minutes	97.2%
Update stock of 10 products	15 minutes	2 minutes	86.7%
Average improvement			92.7%

4.2 Discussion

Implementation of the web-based e-commerce system for bamboo craft MSMEs proved capable of addressing manual system weaknesses identified through PIECES analysis [17]. Firebase integration as Backend-as-a-Service (BaaS) provided advantages in scalability and real-time data synchronization, consistent with findings by Azhari and Sutarman (2024) who reported operational efficiency improvements of up to 40% and downtime reduction of 85% in Firebase-based systems [9]. Compared to research by Putra and Prabandari (2025) who developed GIS-integrated e-commerce websites for local craft products [14], this study provided additional contributions through more comprehensive PIECES analysis in identifying manual system weaknesses and more granular role-based access control implementation. Findings by Putra, Sukendar, and Gusdya (2025) stating that Flutter supports MSME application development through single codebase approach were also reinforced by this research results, showing operational cost reduction of up to 35% through manual process elimination and transaction error reduction [7].

The ease of Firebase integration with relatively low learning curve as stated by Saraf (2022) was reflected in User Acceptance Testing results with satisfaction score of 4.3/5 and high ease of use level [8]. Additionally, the study by Hartina *et al.* (2023) on bamboo craft e-commerce application performance provided relevant comparative context for system performance achievements in this research [5]. From the craft industry perspective, Yadav *et al.* (2023) identified main challenges of post-COVID-19 digital transformation as digital literacy limitations and technology access [2]. The system developed in this study was able to mitigate these challenges through intuitive interface and minimal training requirements. Findings by Yadav *et al.* (2024) showing significant influence of digital technology adoption on craft business performance ($\beta = 0.34$, $p <$

0.001) were also aligned with this research results [4], which recorded average time efficiency improvement of 92.7% and projected sales increase of up to 40% through 24/7 operational support. This reinforced findings by Ilyas and Hartono (2023) and Ndraha *et al.* (2024) regarding digitalization contributions to MSME growth and competitiveness in Indonesia [11][13].

Nevertheless, this research has several limitations, including sample coverage still limited to six bamboo craft business operators in Sleman, Yogyakarta region, relatively short User Acceptance Testing duration not yet reflecting long-term impacts on business growth, and suboptimal stock synchronization mechanisms due to not yet implementing atomic transactions based on Firestore Transaction API or Firebase Cloud Functions. Additionally, the system has not been fully integrated with payment gateways for complete online transactions, and performance testing was still limited to a maximum scale of 100 concurrent users. Based on these limitations, future research is recommended to implement atomic transaction mechanisms to improve stock data consistency, integrate payment gateways such as Midtrans or Xendit as shown by Ariyanto and Syani (2025), and add real-time notification features and analytical dashboards [20]s. Furthermore, packaging the system as a Progressive Web App (PWA) and expanding the number of respondents through longitudinal studies are expected to provide a more comprehensive picture of the long-term impacts of digitalization on bamboo craft MSME growth.

5. Conclusion

This study successfully developed and implemented a web-based digitalization application for bamboo craft MSMEs in Brajan Hamlet, Sleman, Yogyakarta utilizing Flutter Web and Firebase. The built application includes five main modules: role-based access control authentication, product management with real-time inventory monitoring, shopping cart features, transaction processing, and automatic reporting. The system was developed using Model-View-Controller architecture with Provider pattern as state management. Testing results showed that the application has good performance with First Contentful Paint of 0.8 seconds, total load time of 1.2 seconds, average database response time of 156 ms, and capability to support up to 73 concurrent users with Lighthouse Performance score of 87/100. Black Box Testing produced a functional success rate of 96%, while User Acceptance Testing involving six bamboo craft business operators obtained an average satisfaction score of 4.3 out of 5. System implementation proved to improve operational efficiency by up to 92.7%, demonstrated by acceleration of transaction recording processes, product searches, and report creation, as well as operational cost reduction and improved inventory management accuracy.

Nevertheless, this research has several limitations, including limited number of respondents, relatively short UAT duration, suboptimal post-transaction stock synchronization due to atomic transaction mechanism limitations, lack of payment gateway integration, and performance testing not yet representing larger user scales. Therefore, further development is recommended to implement Firebase Cloud Functions or Firestore Triggers to ensure data consistency, integrate digital payment services, add notification systems and analytical dashboards, and conduct performance optimization and testing on a broader scale. Overall, this study demonstrates that the combination of Flutter and Firebase as Backend-as-a-Service architecture is an effective, efficient, and scalable digitalization solution for MSMEs with limited resources. The Research and Development methodology combined with PIECES analysis and layered testing can serve as an applicable and replicable framework for digitalization of other traditional craft MSMEs.

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