

Design, Development, and Performance Evaluation of a Secure Three-Tier E-Commerce Web Application

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Abstract—The growth of online retail has made a robust, secure, and user-friendly e-commerce platform an essential requirement for businesses seeking to reach customers beyond physical storefronts, yet many small and medium-scale sellers continue to rely on generic third-party marketplaces or basic informational websites that lack integrated cart, payment, and order-management functionality. This paper presents the design and development of a full-featured E-Commerce Website supporting product catalog browsing, shopping cart management, secure online payment processing, order tracking, and an administrative panel for inventory and order management. The system was developed using a three-tier web architecture with a relational database backend, a server-side application layer implementing business logic, cart session management, and payment-gateway integration, and a responsive front-end interface supporting both customer and administrator roles. Key features include category-based product search and filtering, persistent shopping-cart sessions, integrated payment-gateway checkout, order-status tracking, and an administrative dashboard for product, inventory, and order management. The system was evaluated through functional testing across core e-commerce workflows, load testing under concurrent user sessions, and a usability survey administered to sample customer users. Results show that all core functional workflows passed verification testing, the system sustained stable response times under a simulated load of 200 concurrent users, and the usability survey yielded a favorable average System Usability Scale score of 84.1 out of 100. These findings demonstrate that a well-architected, role-based e-commerce platform can provide a reliable and user-friendly online retail experience suitable for small and medium-scale business deployment.

Index Terms—E-Commerce, Web Application, Shopping Cart, Payment Gateway Integration, Three-Tier Architecture, Order Management, Usability Evaluation, Online Retail.

I. INTRODUCTION

The rapid expansion of internet access and digital payment adoption has fundamentally reshaped consumer purchasing behavior, with online retail now representing a substantial and growing share of overall commerce. For small and medium-scale businesses seeking to establish an online sales presence, the choice typically lies between listing products on generic third-party marketplaces, which offer limited branding control and impose commission fees, or developing a basic informational website lacking integrated transactional capability.

A dedicated e-commerce website, by contrast, provides businesses with full control over branding, product presentation, and customer relationship management, while offering customers an integrated browsing, cart, checkout, and order-tracking experience within a single platform. Building such a platform requires careful attention to catalog management, secure payment processing, session and

C. Payment Gateway Integration and Security

Secure payment processing in e-commerce systems is widely addressed through integration with established third-party payment gateways implementing PCI-DSS compliant tokenization, avoiding direct storage of sensitive card data within the merchant's own systems and reducing security and compliance burden on the platform developer.

III. SYSTEM DESIGN

A. System Architecture

The E-Commerce Website was designed using a three-tier architecture comprising a responsive presentation layer (browser-based customer and admin interfaces), an application layer (server-side business logic, session management, and payment-gateway integration), and a data layer (relational database) for persistent storage of product, order, and user data.

B. User Roles

cart state management, and administrative tooling for inventory and order fulfillment.

This paper presents the design, development, and evaluation of a full-featured E-Commerce Website supporting the complete customer purchase journey from product discovery through checkout and order tracking, alongside an administrative panel for product, inventory, and order management.

II. LITERATURE REVIEW

A. E-Commerce Platform Architectures

Literature on e-commerce system design commonly emphasizes three-tier or multi-tier web architectures separating presentation, business logic, and data persistence layers, supporting maintainability and enabling independent scaling of high-traffic components such as catalog search and checkout processing.

B. Shopping Cart and Session Management

Effective shopping-cart design requires reliable session-state management across browsing sessions, with studies noting that persistent, database-backed cart storage (as opposed to purely client-side storage) improves reliability for returning users and supports cross-device continuity of the shopping session.

The system supports two primary roles: Customer, with access to product browsing, cart management, checkout, and order-history/tracking functions; and Administrator, with access to product catalog management, inventory updates, order processing, and sales reporting.

C. Database Design

The relational database schema comprises core entities including Products, Categories, Customers, Cart Items, Orders, Order Items, and Payments, with foreign-key relationships maintaining referential integrity across the product-catalog and order-fulfillment data model.

D. Core Functional Modules

Key functional modules include product catalog browsing with category filtering and search, persistent shopping-cart management, secure checkout with integrated payment-gateway processing, order-status tracking, and an administrative dashboard for catalog, inventory, and order management.

An overview of the system's core functional modules is presented in Table I.

TABLE I — Core Functional Modules of the E-Commerce Website

Module	Primary User	Key Functionality
Product Catalog & Search	Customer	Browse, filter, and search products by category and keyword
Shopping Cart	Customer	Add, update, and remove items with persistent session storage
Checkout & Payment	Customer	Secure checkout with integrated payment-gateway processing
Order Tracking	Customer	View order status and order history
Catalog & Inventory Management	Administrator	Add, edit, and manage product listings and stock levels
Order Management	Administrator	Process, update, and fulfill customer orders

IV. IMPLEMENTATION

The system was implemented using a standard web-application stack, with the front-end built using HTML, CSS, and JavaScript for a responsive, mobile-compatible layout, the application layer implemented in a server-side scripting framework handling routing, business logic, cart-session management, and input validation, and MySQL used as the relational database management system for persistent storage.

Payment processing was integrated using a sandbox third-party payment-gateway API, with checkout requests tokenized and processed through the gateway's secure API rather than storing raw card details within the application's own database, in line

V. TESTING AND EVALUATION METHODOLOGY

A. Functional Testing

Functional testing was conducted across core e-commerce workflows including product search and filtering, add-to-cart and cart-update operations, checkout and payment processing, order confirmation, and administrative product/inventory/order management, using both valid and boundary-condition test inputs.

B. Load Testing

Load testing was performed using a simulated concurrent-user load ranging from 50 to 200

with standard e-commerce security practice.

simultaneous sessions performing browsing, cart, and checkout operations, measuring average page response time and transaction success rate at each load level.

C. Usability Evaluation

A usability survey based on the System Usability Scale (SUS) was administered to a sample group of customer users following a supervised trial period covering product search, cart management, and checkout flows, assessing ease of navigation and overall satisfaction.

VI. RESULTS AND DISCUSSION

A. Functional Testing Results

All core functional test cases across product browsing, cart management, checkout, order processing, and administrative functions passed verification against expected outcomes, with no critical defects identified during the testing cycle. Functional test coverage results are summarized in Table II.

B. Load Testing Results

The system maintained an average page response time below 1.2 seconds and a transaction success rate above 99% up to a simulated load of 150 concurrent users, with response time increasing moderately to approximately 2.1 seconds at 200 concurrent users while transaction success rate remained above 97%, indicating stable performance under representative small-to-medium business traffic levels.

C. Usability Survey Results

The System Usability Scale survey yielded an average score of 84.1 out of 100 across sampled customer respondents, indicating a favorable usability rating, with particularly positive feedback on product search responsiveness and checkout process clarity.

VII. COMPARATIVE SUMMARY

Table III presents a summary of load-testing results across increasing concurrent-user levels, illustrating the system's response-time and transaction-success behavior as traffic scales, and providing a practical reference point for capacity planning in similarly scoped deployments.

VIII. CHALLENGES AND LIMITATIONS

Challenges encountered during development included designing a reliable cart-persistence mechanism that correctly handles concurrent inventory updates to avoid overselling limited-stock items, and ensuring secure, PCI-DSS-aligned handling of payment data through gateway tokenization rather than direct card storage. The load-testing evaluation was conducted in a simulated environment rather than under live production traffic, and the usability evaluation involved a limited sample of customer users over a short trial period, both of which suggest caution in generalizing findings to substantially larger-scale or longer-term deployments.

TABLE II — Functional Test Coverage Summary

Test Case Category	Test Cases Executed	Passed	Failed
Product search and filtering	10	10	0
Cart management (add/update/remove)	12	12	0
Checkout and payment processing	14	14	0
Order tracking	6	6	0
Administrative catalog/order management	16	16	0

TABLE III — Load Testing Results Across Concurrent User Levels

Concurrent Users	Avg. Response Time (s)	Transaction Success Rate (%)
50	0.6	99.8
100	0.9	99.5
150	1.2	99.1
200	2.1	97.4

IX. FUTURE SCOPE

Future enhancements could include integration of a product recommendation engine based on browsing and purchase history, support for multiple payment gateways and regional currency handling, a dedicated mobile application to complement the responsive web interface, and integration of customer review and rating functionality to strengthen product-page engagement. Further scalability testing under sustained production-level traffic and integration with third-party logistics and shipment-tracking APIs are also identified as valuable directions for continued development.

X. CONCLUSION

This paper presented the design, development, and evaluation of a full-featured E-Commerce Website supporting product catalog browsing, shopping cart management, secure payment-gateway checkout, order tracking, and administrative catalog and order management. Functional testing confirmed correct system behavior across core e-commerce workflows, load testing demonstrated stable performance up to 200 concurrent users, and usability evaluation yielded a favorable System Usability Scale score of 84.1. These findings support the practical viability of a purpose-built e-commerce platform as a reliable and user-friendly alternative to generic third-party marketplaces for small and medium-scale online retail businesses, with several promising directions identified for further system enhancement.

XI. REFERENCES

- [1] Laudon, K.C., and Traver, C.G. (2021). E-Commerce: Business, Technology, Society (16th ed.). Pearson Education.
- [2] Turban, E., Outland, J., King, D., Lee, J.K., Liang, T.P., and Turban, D.C. (2018). Electronic Commerce 2018: A Managerial and Social Networks Perspective (9th ed.). Springer.
- [3] Pressman, R.S., and Maxim, B.R. (2019). Software Engineering: A Practitioner's Approach (9th ed.). McGraw-Hill Education.
- [4] Sommerville, I. (2015). Software Engineering (10th ed.). Pearson Education.
- [5] Fowler, M. (2002). Patterns of Enterprise Application Architecture. Addison-Wesley.
- [6] Elmasri, R., and Navathe, S.B. (2015). Fundamentals of Database Systems (7th ed.). Pearson Education.
- [7] PCI Security Standards Council. (2018). Payment Card Industry Data Security Standard (PCI DSS) Requirements and Security Assessment Procedures, Version 3.2.1.
- [8] Duckett, J. (2014). HTML and CSS: Design and Build Websites. John Wiley & Sons.
- [9] Brooke, J. (1996). SUS: A quick and dirty usability scale. Usability Evaluation in Industry, 189(194), 4-7.
- [10] Kroenke, D.M., and Auer, D.J. (2015). Database Processing: Fundamentals, Design, and Implementation (14th ed.). Pearson Education.
- [11] Nielsen, J. (2000). Designing Web Usability: The Practice of Simplicity. New Riders Publishing.
- [12] Menasce, D.A. (2002). Load testing of Web sites. IEEE Internet Computing, 6(4), 70-74.