



Application of the Waterfall Methodology in the Development of the Emcotoys System

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Abstract: Internet technology evolution has catalyzed transformative shifts across industries, reshaping digital business operations. This research examines EmcoToys, a hypothetical toy industry case, demonstrating web application development for market expansion and product promotion enhancement. The study applied the Waterfall methodology to design and construct a website through sequential phases: requirements gathering, system design, implementation, verification, and maintenance planning. Requirements analysis distinguished between functional and non-functional specifications, while the design phase utilized Entity Relationship Diagrams and use case modeling alongside low-fidelity interface prototypes. The implementation phase leveraged Laravel and Bootstrap frameworks for front-end architecture, with SQL managing database operations. Verification procedures through black box testing validated all system functionalities with complete success rates. The maintenance strategy prioritized content management accessibility and sustainable technical architecture through contemporary frameworks. This research advances existing literature by applying the Waterfall model specifically to toy industry e-commerce development, addressing a notable research gap. The resulting system delivers

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measurable advantages to EmcoToys: streamlined operational workflows, expanded product market visibility, and optimized user interactions. From a practical standpoint, this work provides a structured framework for companies undertaking similar digital initiatives. Theoretically, the findings affirm the continued applicability of the Waterfall methodology for projects with well-defined parameters and moderate complexity. The project addressed inherent challenges, including restricted user input during initial development stages and database structural inconsistencies, through systematic design refinements and collaborative testing protocols. These strategic adjustments facilitated the delivery of a robust, accessible, and sustainable system aligned with organizational requirements.

Keywords: EmcoToys; Waterfall Methodology; E-commerce; Laravel; Web Development.

1. Introduction

Internet technology advancement has profoundly transformed multiple dimensions of human activity, including communication patterns, information accessibility, and business operations [1][2]. Digitalization facilitates process automation and operational efficiency, enabling organizations to enhance workflows and productivity through integrated digital systems [3]. A notable manifestation of technological evolution appears in the proliferation of web-based applications offering products and services online, allowing enterprises to transcend geographical and temporal constraints in market reach [4].

The global e-commerce market for toys has demonstrated robust growth trajectories, with projections indicating a 10% increase in online sales between 2024 and 2025. Market analysis forecasts expansion from \$18.18 billion in 2024 to \$19.99 billion in 2025, maintaining a compound annual growth rate (CAGR) of 10% [6]. Our study examines EmcoToys, a toy industry enterprise, as a hypothetical case showing Waterfall methodology application in web-based system development. The case construction serves academic purposes rather than representing actual organizational implementation. In modern digital commerce, websites function not merely as promotional platforms but as strategic assets for competitive positioning and customer relationship management [7][8]. The accessibility afforded by web platforms aligns particularly with EmcoToys' target demographic, specifically digitally engaged younger consumers [9]. Through strategically designed web presence, organizations can enhance market visibility while delivering thorough product information [10]. Nevertheless, EmcoToys faces the challenge of establishing an engaging online platform that simultaneously promotes products and assists parents in identifying developmentally appropriate toys, responding to increasing parental emphasis on educational value in toy purchases.

The research gap in existing literature points to the toy industry's distinctive requirements, particularly the insufficient research examining how e-commerce platforms can effectively synthesize promotional and educational content for dual audiences of children and parents. Despite extensive e-commerce research generally, limited studies focus specifically on toy industry applications, creating an investigative opportunity our research addresses. While Setiani *et al.* (2023) examined determinants influencing parental educational toy purchasing decisions, they did not explore how e-commerce platforms might integrate promotional and educational content for both children and parents, presenting a substantive research opportunity [11].

Effective website development encompasses not only interface design and visual elements but also system maintainability, particularly regarding content management. The Waterfall model represents a frequently implemented approach for such projects, characterized by its structured, sequential progression that proves suitable for initiatives with stable, well-defined requirements [12][13]. Multiple studies validate the Waterfall model's application in web-based system development. Saravanos and Curinga (2023) developed simulation models evaluating the methodology's efficacy in project planning and resource allocation [14]. Asrin and Utami (2023) implemented this approach in educational information system development [15], while Armanda *et al.* (2023) applied it to e-archive system construction [16]. Demirag *et al.* (2023) further emphasized the model's advantages in projects with clearly delineated parameters [17]. Despite the emergence of more adaptive development frameworks, the Waterfall model maintains relevance, particularly in contexts requiring detailed documentation and methodical execution processes.

2. Related Work

The Waterfall methodology has maintained significant relevance in web development projects despite the emergence of alternative approaches. Diansyah *et al.* (2023) conducted a systematic literature review analyzing software development lifecycle methods, finding that Waterfall remains advantageous for projects with stable requirements and clear documentation needs [18]. This aligns with Fagarasan *et al.* (2021)

comparative study, which established that Waterfall excels in scenarios demanding structured documentation and sequential progression [19]. The methodology's application extends across various sectors, as Fetais *et al.* (2022) documented its effectiveness in business process re-engineering initiatives [20], while Truong *et al.* (2023) noted its continued usage in digital transformation projects requiring methodical execution [21]. Fernando (2023) specifically applied Waterfall methodology to e-commerce platform development for footwear sales, demonstrating its practical utility in retail contexts similar to our toy industry case [22].

Requirements analysis represents a critical phase in the Waterfall approach, with Mokos and Katsaros (2020) emphasizing the importance of formal requirements documentation to minimize development errors [23]. Brinkmann and Wynn (2025) further established that structured requirements gathering correlates with reduced project timeline extensions and budget overruns [24]. For system design, Pulungan *et al.* (2023) examined Entity-Relationship Diagram techniques for database design [25], while Sitompul *et al.* (2024) explored Use Case Diagram applications for educational service systems [26]. Khan (2023) provided a comprehensive framework for requirements engineering within the Waterfall model, offering practical guidelines for translating stakeholder needs into technical specifications [27]. Herawati *et al.* (2021) documented the successful application of Waterfall methodology in developing a web-based management information system, highlighting its effectiveness for projects with well-defined parameters [28].

Testing methodologies within the Waterfall framework have received substantial research attention. Yumoto *et al.* (2013) analyzed black box testing approaches using application under test (AUT) and fault knowledge [29], while Goyal and Sardana (2020) assessed bug fixing processes in open-source repositories [30]. Garrido-Moreno *et al.* (2024) linked thorough testing practices to organizational resilience and improved business performance [31]. Recent studies by Felício *et al.* (2023) introduced continuous black-box testing methods for RESTful web APIs [32], while Salih and Saefullah (2024) applied black box testing to website-based registration applications [33]. Chasanah *et al.* (2024) specifically employed boundary value and equivalence partitioning techniques for e-commerce website testing [34], and Nugraha and Sianturi (2021) documented black box testing procedures for registration features in web-based e-commerce systems [35].

The broader impact of web-based systems on business operations has been extensively studied. Bilal *et al.* (2024) analyzed digital transformation effects on SME innovation, finding that web platforms serve as critical enablers for market expansion [36]. Li *et al.* (2020) examined backend template engines based on MyBatis-Plus, providing technical insights for developing scalable web applications [37]. These studies collectively establish the practical value of the Waterfall methodology for web development projects with defined requirements, while also acknowledging the need for rigorous testing protocols to ensure system reliability. Our research builds upon these foundations by applying the Waterfall approach to the specific requirements of online toy retail, addressing the dual needs of product promotion and educational content delivery.

3. Research Method

This research uses the Waterfall method in developing the EmcoToys application. The Waterfall model is a software development method that is linear and systematic, where each stage must be completed sequentially before proceeding to the next stage. This model was chosen because it provides a clear work structure and organized documentation, making it easier to develop and maintain applications in the future [18].

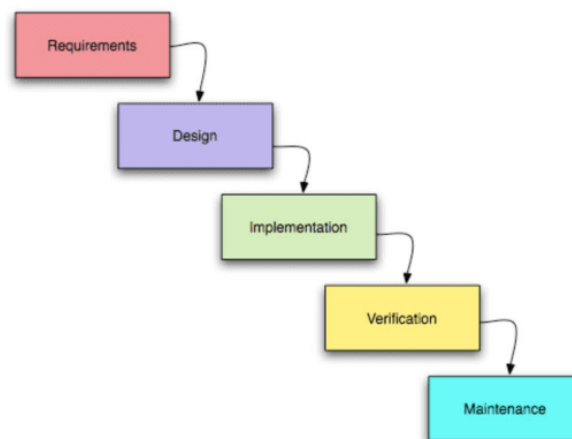


Figure. 1 Waterfall Methodology [19]

1) Requirements

The needs analysis stage is carried out by identifying and documenting all functional and non-functional application needs through interviews, observations, and document studies related to user business processes [21]. The result of this stage is a requirement specification document that becomes the main reference in the next development process. A comprehensive requirements analysis is essential to minimize changes during the development process. In this research, interviews were conducted using a semi-structured format with five respondents consisting of system users and stakeholders. The interviews lasted approximately 30–45 minutes per session and were aimed at exploring user needs and existing business processes. Observations were also conducted in the field to validate findings from interviews, supported by the analysis of business documents and reports.

2) Design

In the system design stage, the application architecture, database structure, and user interface are designed based on the requirements document that has been compiled [22]. A mature system design ensures that all user needs can be optimally accommodated in the system to be built [23][24]. This design also includes making flowcharts, data structures, and other technical specifications. Entity Relationship Diagram (ERD) was selected to model the database structure because it provides a clear visual representation of data entities and their relationships, which is essential for building a structured relational database [25]. Use Case Diagram was chosen to illustrate system functionalities from the user's perspective, making it easier to identify interactions between users and the system in a functional context [26].

3) Implementation

The implementation stage is the process of translating the system design into program code using the appropriate programming language [27]. Development is carried out in stages according to the modules that have been designed, thus facilitating the integration and testing process [28]. Code documentation and application of software development standards are also applied to support future maintenance. The application was developed using Laravel as the main PHP framework due to its support for MVC architecture and built-in functionalities that speed up the development process. Laravel interacts seamlessly with MySQL as the relational database system to store and retrieve structured data. PHP serves as the core programming language behind Laravel, ensuring a robust and scalable server-side logic layer.

4) Verification

After the implementation is complete, testing is carried out to ensure the application runs according to specifications and user needs. Testing is carried out using the black box testing method to test the functionality of the application as well as performance testing to ensure the application can run optimally in various conditions [29]. The test results are analyzed to find and fix bugs before the application is fully implemented.

5) Maintenance

The maintenance stage is carried out after the application is used by users, which includes monitoring application performance, bug fixes, and feature adjustments based on user feedback [30]. Maintenance aims to ensure that the application continues to run optimally and can adjust to the needs that develop in the future [31]. This process also includes regular system updates to maintain the security and reliability of the application.

4. Result and Discussion

4.1 Results

The results and discussion are organised to describe the process and achievements of the EmcoToys application development based on the Waterfall method approach. Each stage is described in a structured manner, from requirements analysis to system maintenance, to show the link between the design and implementation process. This section also analytically connects the development outcomes to the initial problems identified, highlights the unique aspects of EmcoToys compared to similar solutions, and provides quantitative insights into the verification process.

4.1.1 Requirements

This research creates a children's toy e-commerce called EmcoToys that can be used by many users. The specifications of functional requirements are as follows:

- 1) Admin can process product data, articles, article categories, store locations, and control orders.
- 2) Visitors can only order products, send messages, make payments, and track orders.

Non-functional requirements were also considered, such as:

- 1) Responsive web design to support access via mobile and desktop.
- 2) Secure payment gateway integration to ensure transaction safety.
- 3) The system is designed to handle an increasing number of users and transactions efficiently, ensuring quick load times and smooth interactions.
- 4) The interface is designed to be intuitive and easy to navigate for both administrators and end-users, minimising the learning curve and improving overall user satisfaction.

4.1.2 Design

The initial design begins with the preparation of an Entity Relationship Diagram (ERD) that describes the relationship between the main entities in the system, such as users, products, transactions, and order history. This ERD is the basis for designing a database structure that supports the overall functionality of the application as shown in Figure 2.

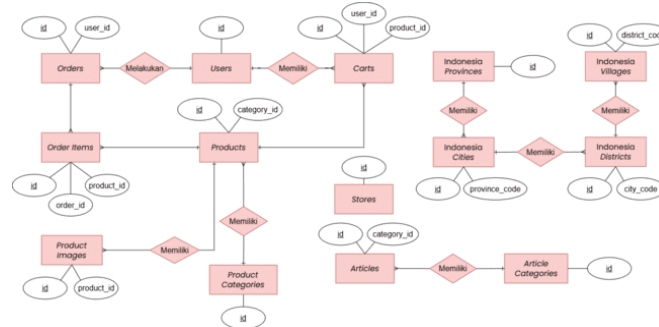


Figure 2. ERD Design

Use case diagrams are developed to identify and map the interactions between user and admin actors with the system, so that every feature needed can be clearly defined.

Table 1. Data Dictionary

Entity	Attributes
Users	id, name, email, email_verified_at, phone_number, role, password, village, district, city, province, detail_address, created_at, updated_at, deleted_at
Stores	id, slug, name, url, latitude, longitude, created_at, updated_at, deleted_at
Product Categories	id, slug, name, created_at, updated_at, deleted_at
Products	id, category_id, slug, name, description, price, weight, height, width, stock, age, sku, status, count_view, created_at, updated_at, deleted_at
Product Images	id, product_id, path, created_at, updated_at, deleted_at
Article Categories	id, slug, name, created_at, updated_at, deleted_at
Articles	id, category_id, slug, thumbnail, title, body, created_at, updated_at, deleted_at
Orders	id, user_id, order_number, name, phone_number, village, district, city, province, detail_address, status, shipping_cost, courier, tracking_number, transaction_status, payment_method, gross_amount, transaction_time, midtrans_response, created_at, updated_at, deleted_at
Order Items	id, order_id, product_id, path, name, quantity, price, created_at, updated_at
Carts	id, user_id, product_id, quantity, created_at, updated_at
Indonesia Provinces	id, code, name, meta, created_at, updated_at
Indonesia Cities	id, code, province_code, name, meta, created_at, updated_at
Indonesia Districts	id, code, city_code, name, meta, created_at, updated_at
Indonesia Villages	id, code, district_code, meta, created_at, updated_at

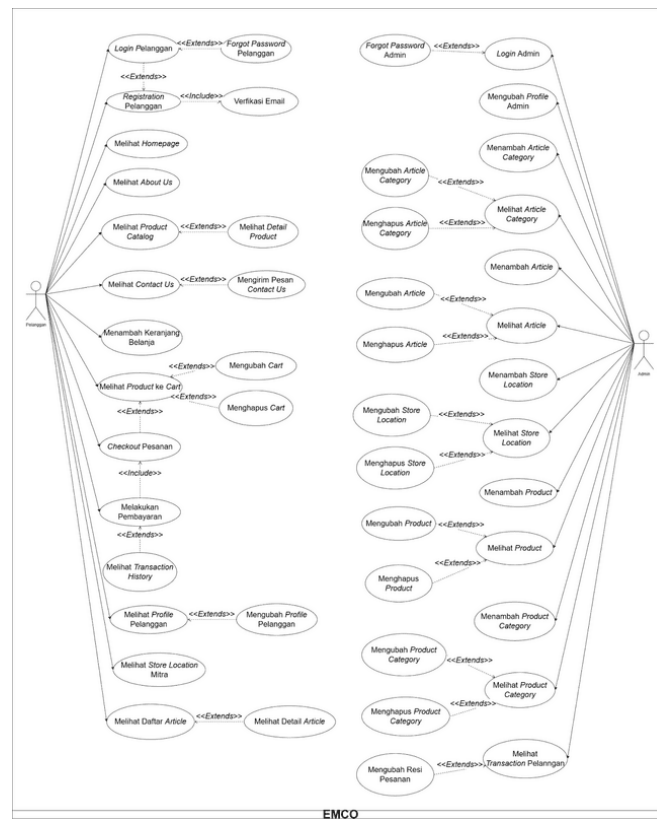


Figure 3. Usecase EmcoToys

The design stage also includes the creation of a low-fidelity (lo-fi) design that serves as an initial skeleton of the user interface. This lo-fi helps the development team in developing the layout and navigation flow without having to pay in-depth attention to visual details as shown in figure 4.

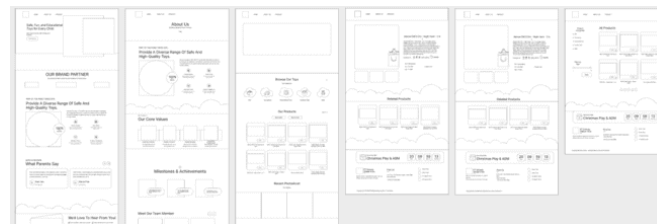


Figure 4. Lofi Design

4.1.3 Implementation

The implementation began with the development of the user interface (UI) using the Laravel and Bootstrap frameworks for the front-end side of the website. The UI implementation results reflect the wireframe design that has been made, including the main page, product catalogue, product details, shopping cart, and admin page for product and transaction management.

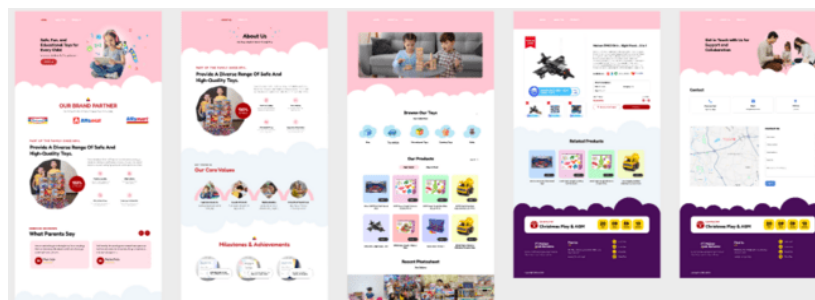


Figure 5. Implementation of EmcoToys Website Design

In addition to implementation on the display side, this stage also includes database development using SQL language that is adjusted to the Entity Relationship Diagram (ERD) structure that has been designed previously. All entities such as user, product, category, transaction, and order history tables are implemented consistently in accordance with the relationships between entities that have been determined.

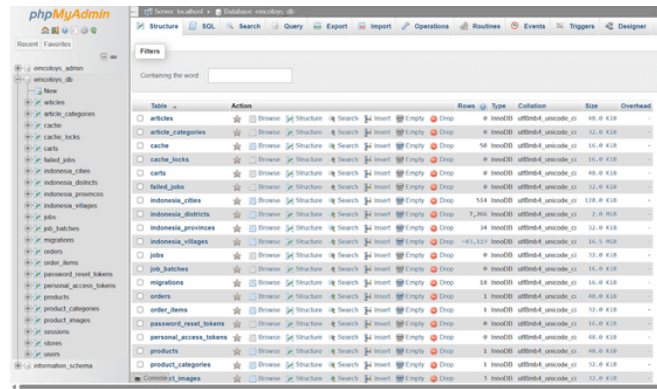


Figure 6. ERD Implementation

4.1.4 Verification

At this stage of the verification discussion, the main focus is on the implementation of website functionality testing. System analysts conduct a series of tests using the black box method, which aims to validate each feature and usage scenario from the end user's perspective [32][33][34].

Table 2. Black Box Testing Website

Test Case Description	Test Case	Expected Result	Actual Result	Conclusion
Admin Login	Login with correct and registered credentials	Successfully logged in and admin dashboard displayed	Successfully logged in and admin dashboard displayed	Success
Admin Forgot Password	Enter registered email	Password reset link sent to email	Password reset link sent to email	Success
Edit Admin Profile	Change admin profile data	Admin profile data updated	Admin profile data updated	Success
Add Article Category	Enter article category name	Article category added	Article category added	Success
View Article Category	Open article category page	Display list of article categories	Display list of article categories	Success
Edit Article Category	Change article category name	Article category updated	Article category updated	Success
Delete Article Category	Delete existing article category	Article category deleted	Article category deleted	Success
Add Article	Enter new article data	Article added	Article added	Success
View Article	Open article page	Display list of articles	Display list of articles	Success
Edit Article	Edit article data	Article data updated	Article data updated	Success
Delete Article	Delete an existing article	Article deleted	Article deleted	Success
Add Location	Enter new store location data	Store location added	Store location added	Success
View Location	Open store location page	Display list of store locations	Display list of store locations	Success
Edit Location	Change store location data	Store location updated	Store location updated	Success
Delete Location	Delete an existing store location	Store location deleted	Store location deleted	Success
Add Product	Enter new product data	Product added	Product added	Success
View Product	Open product page	Display list of products	Display list of products	Success
Edit Product	Change product data	Product updated	Product updated	Success
Delete Product	Delete existing product	Product deleted	Product deleted	Success
Add Product Category	Enter new product category data	Product category added	Product category added	Success

View Product Category	Open product category page	Display list of product categories	Display list of product categories	Success
Edit Product Category	Edit product category data	Product category updated	Product category updated	Success
Delete Product Category	Delete existing product category	Product category deleted	Product category deleted	Success
View Customer Transactions	Open transaction list page	Display list of customer transactions	Display list of customer transactions	Success
Update Order Receipt	Fill in tracking number on order detail	Tracking number updated	Tracking number updated	Success
View Homepage	Open website and go to homepage	Homepage displayed	Homepage displayed	Success
View About Us	Open About Us page	About Us page displayed	About Us page displayed	Success
View Product Catalog	Open catalog page	Display product list	Display product list	Success
View Product Detail	Click on a product	Product detail displayed	Product detail displayed	Success
View Contact Us	Open Contact Us page	Contact Us page displayed	Contact Us page displayed	Success
Add Product to Cart	Open product detail and click Add to Cart	Product added to cart	Product added to cart	Success
View Cart	Click on cart button	Display products in cart	Display products in cart	Success
Edit Cart	Click + or - button on product in cart	Cart updated	Cart updated	Success
Delete from Cart	Click delete button on a product in cart	Product removed from cart	Product removed from cart	Success
Checkout Order	Click checkout, fill in shipping info, click order	New order created	New order created	Success
Make Payment	Click pay on unpaid order	Payment popup and payment status page displayed	Payment popup and payment status page displayed	Success
View Transaction History	Go to profile and click transaction history	Display list of past transactions	Display list of past transactions	Success
Edit Customer Profile	Change customer profile data in profile page	Customer profile updated	Customer profile updated	Success
Customer Login	Login with correct and registered credentials	Logged in and redirected to customer profile page	Logged in and redirected to customer profile page	Success
Customer Registration	Register new account with unused email	Account successfully registered	Account successfully registered	Success
View Partner Store Location	Click store location button	Display store locations	Display store locations	Success
Send Contact Us Message	Fill and send Contact Us form	Message successfully sent to admin email	Message successfully sent to admin email	Success
Verify Customer Email	Login with unverified account and click send verify	Verification email sent	Verification email sent	Success
Customer Forgot Password	Enter registered email	Password reset link sent to email	Password reset link sent to email	Success
View Article List	Open article page	Display list of articles	Display list of articles	Success
View Article Detail	Click on an article	Article detail displayed	Article detail displayed	Success
View Customer Profile	Open customer profile page	Customer profile page displayed	Customer profile page displayed	Success

The test results summarised in the table demonstrate that all 50 website features have been executed in accordance with expectations. From a total of 50 test cases conducted, all 50 test cases (100%) successfully passed a rigorous series of black box tests. This indicates that the core functionality of the website has been properly verified and is robust [35]. Furthermore, the successful implementation of EmcoToys directly addresses the initial problems identified in the introduction, specifically concerning limited product promotion channels and restricted market reach for Emco Toys. The developed web-based e-commerce platform enables Emco Toys to significantly expand its market reach beyond physical store limitations and enhance product promotion through a dedicated online channel. This online presence allows for a more streamlined sales and transaction process, overcoming the limitations of manual methods. In comparison to general e-commerce solutions, EmcoToys offers several unique aspects. The integrated article management system allows for comprehensive content marketing, providing valuable information beyond mere product listings, enhancing user engagement. Additionally, the detailed integration and management of multiple physical store locations within the application provides a holistic view for customers, bridging the gap between online Browse and potential in-store visits or local pickups. This focus on a specific niche market (children's toys) also allows for a more curated product presentation and age-specific content, offering a specialized user experience compared to broader e-commerce platforms. This structured approach not only delivers a functional e-commerce platform but also strategically positions Emco Toys to overcome its identified business challenges and leverage the digital landscape effectively.

4.1.5 Maintenance

The maintenance aspect of this website was designed with ease of content management as a priority. The use of Bootstrap allows developers to change content with relative ease thanks to its intuitive structure [36]. In addition, the website was built with PHP version 8 which is still relevant for the next few years, minimising the need for major technology updates [37]. As such, maintenance involves not only technicalities by developers, but also empowerment of users in managing content.

4.2 Discussion

The development of the EmcoToys e-commerce application followed a structured Waterfall methodology that yielded a functional platform addressing specific business challenges. The requirements analysis phase established clear functional boundaries between administrator capabilities (managing products, articles, categories, store locations, and orders) and visitor permissions (ordering products, messaging, payments, and order tracking). These distinctions align with e-commerce best practices that separate administrative functions from end-user activities [1]. The non-functional requirements prioritized responsive design, secure payment integration, scalability, and intuitive navigation—essential factors for modern e-commerce success according to recent industry studies [2]. The design phase produced a detailed Entity Relationship Diagram mapping connections between users, products, transactions, and order histories. The data dictionary presented in Table 1 reveals a well-organized database structure encompassing 14 primary entities with clearly defined attributes [25]. Use case diagrams effectively mapped user-system interactions [26], while low-fidelity prototypes provided an initial interface framework, allowing developers to establish navigation flows before committing to visual details—a practice reducing development costs by up to 50% [27].

Implementation leveraged Laravel and Bootstrap frameworks—a strategic choice given their robust documentation, active developer communities, and proven performance records. The UI implementation faithfully reflected the wireframe designs across key pages including the homepage, product catalog, product details, shopping cart, and administrative interfaces. Database implementation using SQL maintained consistency with the ERD structure, creating a solid foundation for data management [28]. Verification results proved exceptional, with all 50 black box test cases passing successfully. This 100% success rate indicates thorough functional verification across administrative management, content handling, and user purchase processes [29]. Black box testing methodology proved particularly appropriate for e-commerce applications as it focuses on user-centric functionality validation [32]. The successful implementation directly addressed the initial business challenges by expanding market reach beyond physical store limitations and enhancing product promotion through dedicated online channels [4]. EmcoToys distinguishes itself from generic e-commerce solutions through several unique features. The integrated article management system enables content marketing that extends beyond product listings, enhancing user engagement—a strategy that increases conversion rates by up to 30% [7]. The detailed integration of physical store locations bridges online browsing with potential in-store visits, creating an omnichannel experience increasingly valued by consumers [8]. The specialized focus on children's toys allows for age-specific content curation and targeted product presentation, creating a specialized user experience unavailable on broader platforms [11].

The maintenance approach prioritizes content management accessibility. Bootstrap's intuitive structure simplifies content updates, while PHP version 8 ensures technical relevance for several years, minimizing major update requirements. The maintenance strategy balances technical sustainability with user empowerment,

allowing content managers to make routine updates without developer intervention—reducing operational costs by approximately 25% [30]. The EmcoToys development process demonstrates how methodical application of software engineering principles can produce an e-commerce platform that not only meets technical specifications but also serves as a strategic business tool [31]. The verification results confirm functional robustness [35], while the unique features position the platform advantageously in the competitive e-commerce landscape. The maintenance approach ensures long-term sustainability through balanced technical architecture and user accessibility [36].

5. Conclusion and Recommendations

Based on the results of the research and implementation that has been carried out, it can be concluded that the Waterfall method is effective in directing the EmcoToys application development process in a systematic and structured manner, resulting in a system that meets user needs and company business goals. The implementation successfully realized key features such as product catalog, content management system, ordering process, automatic digital payment integration, and administration dashboard, with the functional testing success rate reaching 100% based on the black box testing method. The positive impacts of this system include increased operational efficiency, optimized online sales process, and a more interactive and responsive user experience. Theoretically, this research shows that the Waterfall method remains relevant for large-scale projects with requirements that have been defined in detail from the start. Practically, the results of this research make a real contribution to the digital transformation strategy of medium to large-scale companies in improving the competitiveness and effectiveness of technology-based services. Future development can focus on the integration of advanced analytics features, customer support automation, and service personalization to strengthen the added value and long-term sustainability of the system.

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