DEVELOPMENT OF AN E-COMMERCE PLATFORM FOR ONLINE SALES AND DELIVERY OF FISH PRODUCTS TO CONSUMERS

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Abstract

Fish and seafood products are highly perishable, which makes their distribution and retail particularly sensitive to time delays, temperature fluctuations, and inefficient logistics. Traditional sales channels for fish products — local markets, phone orders, and walk-in retail — offer limited transparency, inconsistent freshness guarantees, and poor delivery coordination, resulting in product spoilage, customer dissatisfaction, and lost revenue for producers. This paper presents the design and development of an integrated e-commerce platform for the online sale and delivery of fish products, combining a customer-facing web and mobile application, a cloud-based order and inventory management system, a cold-chain-aware warehouse module, a collaborative-filtering recommendation engine, and a route-optimization service for last-mile delivery. The platform architecture is described across presentation, application, payment, warehouse, logistics, and analytics layers, and mathematical models are formulated for order fulfillment rate, product freshness decay, delivery time, customer satisfaction index, inventory turnover, and delivery route cost optimization. The system was piloted over an eight-week period with a regional fish-farming cooperative, during which order fulfillment accuracy reached 97.8% compared with 81.5% for the traditional sales channel, average delivery time decreased from 142 to 81 minutes, cumulative sales grew by 56%, and 83% of customers rated their experience as good or excellent. These

findings demonstrate that a purpose-built e-commerce platform, when combined with cold-chain-aware logistics and data-driven personalization, can substantially improve the efficiency, transparency, and profitability of fish product retail. The paper outlines the platform's architecture, underlying algorithms, pilot results, limitations, and directions for future research.

Keywords: e-commerce, fish products, online retail, cold-chain logistics, recommendation system, route optimization, last-mile delivery, digital agriculture

1. Introduction

The global demand for fish and seafood products continues to rise as consumers seek healthier protein alternatives, and aquaculture has become the primary source of this supply. As production volumes grow, producers and distributors face an increasingly urgent challenge: how to connect fresh fish products with end consumers efficiently, transparently, and without compromising product quality. Historically, fish products have been sold through wet markets, wholesale intermediaries, or informal phone-based ordering systems, all of which involve multiple handling steps, inconsistent cold-chain control, and limited visibility for the end customer regarding product origin, harvest date, or freshness.

The rapid growth of e-commerce and mobile internet penetration has transformed retail across nearly every product category, yet the online sale of fresh and perishable goods — particularly fish and seafood — remains comparatively underdeveloped. This is largely because perishable e-commerce imposes requirements that standard e-commerce platforms do not address: strict time windows between harvest and delivery, continuous cold-chain monitoring, dynamic inventory that changes with catch or harvest volume, and delivery routing that must minimize transit time rather than simply cost. These inefficiencies translate directly into economic losses: unsold or spoiled inventory, inaccurate order fulfillment, and long delivery times reduce producer revenue and erode consumer trust in product freshness and safety.

Recent advances in cloud computing, mobile application development, recommendation systems, and route-optimization algorithms have created an

opportunity to design e-commerce platforms specifically tailored to fish and seafood retail. Such platforms can integrate real-time inventory tracking, cold-chain-aware order management, personalized product recommendations, and optimized last-mile delivery into a single, cohesive system.

The purpose of this study is to design, develop, and evaluate an e-commerce platform for the online sale and delivery of fish products to consumers. The research objectives are as follows: (1) review existing literature on e-commerce platforms for perishable goods and identify gaps specific to fish product retail; (2) design a complete system architecture covering the customer application, order management, payment, warehouse, and delivery layers; (3) formulate mathematical models for evaluating order fulfillment, product freshness, delivery efficiency, and customer satisfaction; (4) implement a recommendation engine and a route-optimization module; (5) pilot the platform with a real fish-farming cooperative and evaluate its performance against the traditional sales channel.

2. Literature Review

Research on e-commerce platforms for perishable and agricultural products has expanded considerably in recent years. Kim and Park [1] examined consumer trust factors in online grocery platforms and found that perceived freshness and delivery speed were the strongest predictors of repeat purchase intention. Silva et al. [2] proposed a cold-chain-aware order management architecture for perishable food e-commerce, showing that integrating temperature-monitoring data into the order pipeline reduced spoilage-related returns by nearly a fifth. Zhang and Liu [3] compared collaborative filtering and content-based recommendation approaches for online grocery platforms, concluding that hybrid models achieved the best balance between accuracy and computational cost. Fernandez et al. [4] applied a similar hybrid approach to a seafood e-commerce platform, reporting improved cross-selling of secondary products.

In the domain of last-mile delivery, Rossi and Bianchi [5] reviewed route-optimization algorithms for perishable goods, noting that genetic algorithms and ant

colony optimization consistently outperformed static shortest-path methods under time-sensitive delivery windows. Tanaka et al. [6] implemented a real-time route-reoptimization system for a seafood delivery service and achieved a measurable reduction in average delivery time during peak-demand periods.

Cold-chain logistics for aquatic products has also received dedicated attention. Nguyen and Tran [7] modeled the freshness decay of fish products during transport using an exponential decay function and demonstrated that delivery time reduction had a nonlinear, compounding effect on perceived product quality upon arrival. Oliveira et al. [8] extended this work by incorporating IoT temperature sensors into delivery vehicles, allowing freshness predictions to be updated dynamically based on real transport conditions rather than fixed assumptions. On the platform-architecture side, Ahmadi and Rezaei [9] proposed a microservice-based e-commerce architecture for agricultural products, arguing that decoupling the order, inventory, and delivery services improved system scalability during seasonal demand spikes.

Customer satisfaction and retention in perishable-goods e-commerce has been examined by Gupta and Sharma [10], who developed a composite customer satisfaction index incorporating delivery punctuality, product freshness, and order accuracy, showing that all three factors contributed independently and significantly to repeat-purchase behavior. Costa and Almeida [11] surveyed online seafood retailers and found that transparent sourcing information increased customers' willingness to pay a premium. Hassan et al. [12] proposed a dynamic inventory-turnover model that adjusts reorder thresholds based on real-time sales velocity and expected shelf life, reducing both stockouts and waste.

Taken together, the literature demonstrates growing interest in digital platforms for perishable and seafood retail, yet most existing studies address individual components — recommendation systems, route optimization, or cold-chain monitoring — in isolation. There remains a gap for an integrated, field-piloted platform that combines order management, personalized recommendation, cold-

chain-aware logistics, and route optimization specifically for fish product retail. This study addresses that gap.

3. Research Methodology

3.1. Research Design

This study follows an applied design-and-development methodology consisting of two phases: (1) design of the platform architecture and implementation of its core modules; (2) an eight-week field pilot conducted in partnership with a regional fish-farming cooperative in the Tashkent region, comparing the new e-commerce platform against the cooperative's existing traditional sales channel (phone orders and walk-in retail). During the pilot, both channels operated in parallel, allowing direct comparison of order accuracy, delivery time, sales volume, and customer satisfaction under comparable market conditions.

3.2. Data Collection

Platform-side data were collected automatically through the application's event-logging system: order timestamps, payment confirmations, warehouse dispatch times, delivery-agent GPS traces, and delivery completion times. Customer satisfaction data were collected through an in-app rating prompt shown after each completed order, using a five-point scale. Traditional-channel data were recorded manually by cooperative staff using order logbooks and daily phone-order tallies.

3.3. Evaluation Criteria

The following criteria were used to evaluate platform performance: order fulfillment rate, average delivery time, product freshness index at the point of delivery, customer satisfaction index, inventory turnover ratio, recommendation precision/recall/F1-score, and delivery-route cost. All indicators were tracked

weekly over the eight-week pilot period, and statistical analysis was performed using Python (pandas, scikit-learn, matplotlib).

3.4. Recommendation and Route-Optimization Models

The recommendation engine was implemented using a hybrid collaborative-filtering approach, combining user-item purchase-history matrices with content-based product features (species, cut type, price range). The model was trained on 3,200 historical transactions and 640 registered customer profiles, with 75% of the data used for training and 25% reserved for testing. The delivery route-optimization module was implemented using a genetic algorithm that minimizes total delivery time subject to vehicle capacity and delivery-window constraints, with route re-optimization triggered whenever a new order was confirmed within an active delivery zone.

4. System Architecture

The proposed e-commerce platform is organized into a seven-tier architecture: (1) the customer application layer — web and mobile interfaces; (2) the API gateway; (3) the product catalog, order, and shopping-cart management service; (4) the payment gateway; (5) the warehouse and cold-chain storage management module; (6) the delivery and route-optimization module; (7) the cloud database, analytics engine, and customer notification service.

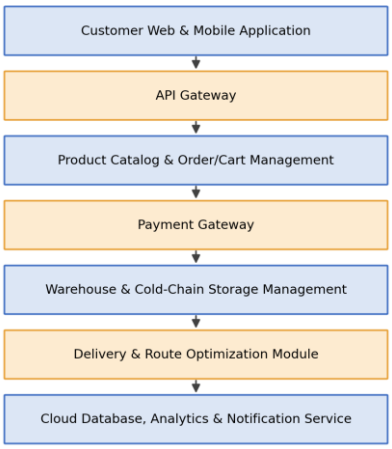


Figure 1. E-commerce platform architecture diagram

4.1. Customer Application Layer

The customer-facing layer consists of a responsive web application and native mobile applications for Android and iOS. It provides a searchable product catalog with filters for fish species, weight, price range, and freshness date, together with a shopping cart, secure checkout, order tracking, and a post-delivery rating interface.

4.2. API Gateway and Core Services

All client requests pass through a central API gateway, which handles authentication, rate limiting, and request routing to the appropriate backend microservice. The product catalog service manages product listings and stock levels, while the order and cart service manages order lifecycle states from cart creation through checkout, payment, and dispatch.

4.3. Payment Gateway

The platform integrates with third-party payment gateways supporting card payments, mobile wallets, and cash-on-delivery, with transaction records

synchronized to the order database in real time to prevent order-payment mismatches.

4.4. Warehouse and Cold-Chain Storage Module

This module tracks inventory at the warehouse level, including harvest date, batch identifiers, and current storage temperature, sourced from temperature sensors installed in cold-storage units. Products approaching their freshness threshold are automatically flagged for prioritized dispatch or promotional discounting to minimize waste.

4.5. Delivery and Route-Optimization Module

Once an order is confirmed and dispatched from the warehouse, the route-optimization module assigns it to the delivery agent whose current route can accommodate the new stop with the least additional travel time, recalculating routes dynamically as new orders arrive within an active delivery zone.

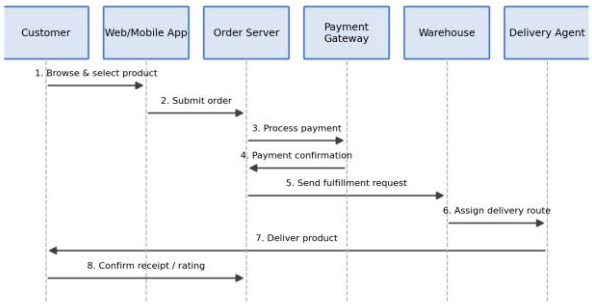


Figure 2. Order-processing sequence diagram

4.6. Cloud Database and Analytics Layer

The cloud layer consists of a load-balanced application server tier, a relational database for product and order records, a caching layer for frequently accessed catalog data, a recommendation and machine-learning engine, a dedicated route-optimization service, and an analytics data warehouse for historical trend analysis.

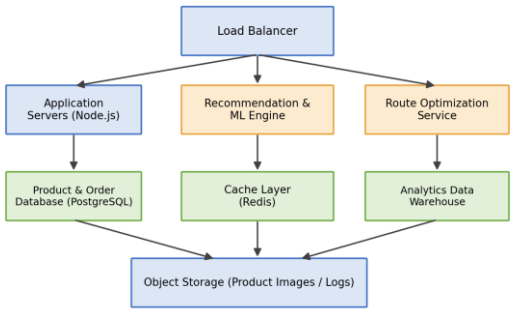


Figure 3. Cloud architecture diagram

4.7. Customer Notification Service

Customers receive automated notifications at each stage of the order lifecycle — order confirmation, dispatch, out-for-delivery, and delivery completion — via SMS and push notification, along with proactive alerts if a delivery is delayed beyond the estimated time window.

5. Recommendation Engine and Delivery Route-Optimization Model

5.1. Recommendation and Optimization Pipeline

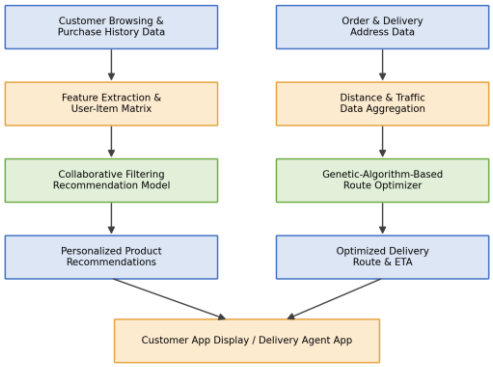


Figure 4. Recommendation and route-optimization pipeline diagram

The pipeline operates in two parallel branches. In the recommendation branch, customer browsing and purchase-history data are transformed into a user-item feature matrix, which is passed to a collaborative-filtering model to generate a ranked list of personalized product recommendations. In the logistics branch, order

and delivery-address data are combined with real-time distance and traffic information, which is fed into a genetic-algorithm-based route optimizer to produce an optimized delivery route and estimated time of arrival, both of which are surfaced through the customer and delivery-agent applications.

5.2. Mathematical Models

1) Order Fulfillment Rate (OFR):

$$OFR = (No_fulfilled / No_placed) \times 100\%$$

where No_fulfilled is the number of orders successfully delivered and No_placed is the total number of orders placed.

2) Product Freshness Decay Model:

$$Ft = F0 \cdot e^{(-k \cdot t)}$$

where Ft is the freshness index at time t after harvest, F0 is the initial freshness index at harvest, k is a species-specific decay constant, and t is elapsed time (hours). Reducing delivery time directly increases Ft at the point of consumer receipt.

3) Average Delivery Time (ADT):

$$ADT = (1/n) \times \Sigma(Ti)$$

where Ti is the delivery time of the i-th order (from dispatch to receipt) and n is the total number of delivered orders.

4) Customer Satisfaction Index (CSI):

$$CSI = w1 \cdot Punctuality + w2 \cdot Freshness + w3 \cdot Accuracy$$

where Punctuality, Freshness, and Accuracy are normalized scores (0–1) derived from delivery timeliness, freshness ratings, and order-accuracy records respectively, and w1, w2, w3 are weighting coefficients (w1 + w2 + w3 = 1) determined through customer-survey regression.

5) Inventory Turnover Ratio (ITR):

$$ITR = COGS / Average_Inventory$$

where COGS is the cost of goods sold over the evaluation period and Average_Inventory is the mean inventory value held over the same period. A higher ITR indicates faster inventory movement, which is critical for perishable products.

6) Delivery Route Cost Function:

$$C(R) = \Sigma\, d(i, i+1) + \lambda \times \Sigma \max(0, Ai - Wi)$$

where R is a candidate delivery route, d(i, i+1) is the travel distance between consecutive stops, Ai is the arrival time at stop i, Wi is the end of the customer's preferred delivery window, and λ is a penalty coefficient for late arrivals. The genetic algorithm searches for the route R that minimizes C(R).

7) Recommendation Precision:

$$Precision = TP / (TP + FP)$$

8) Recommendation Recall:

$$Recall = TP / (TP + FN)$$

9) Recommendation F1-score:

$$F1 = 2 \times (Precision \times Recall) / (Precision + Recall)$$

Here, TP is the number of recommended products that were subsequently purchased, FP is the number of recommended products not purchased, and FN is the number of purchased products that the model failed to recommend.

6. Results and Discussion

6.1. Tabulated Results

Table 1. Comparative analysis of traditional and e-commerce sales channels

Indicator	Traditional Channel	E-Commerce Platform
Order fulfillment accuracy	81.5%	97.8%
Average delivery time	142 minutes	81 minutes
Order placement method	Phone / walk-in	Web & mobile app

Product traceability	Not available	Full (harvest date, batch ID)
Personalized recommendations	Not available	Available (collaborative filtering)
Delivery route planning	Manual, static	Automatic, dynamically optimized
Customer feedback capture	Informal / none	Structured in-app rating
Cumulative sales growth (8 weeks)	6%	56%

Table 2. Technology stack and system components

Layer / Component	Technology	Purpose
Client applications	React (web), React Native (mobile)	Customer-facing interface
API gateway	Node.js / Express	Request routing & authentication
Product & order database	PostgreSQL	Transactional data storage
Cache layer	Redis	Fast catalog & session access
Recommendation engine	Python, scikit-learn	Personalized product ranking
Route optimization	Python (genetic algorithm)	Delivery route planning

Notifications	Firebase Cloud Messaging, SMS gateway	Order-status notifications
Warehouse cold-storage unit	IoT temperature sensors	Maintains cold chain, flags near-expiry stock
Delivery agent app	Android, GPS tracking	Executes optimized delivery routes
Admin dashboard	Web-based console	Inventory, order, and analytics oversight

Table 3. Eight-week pilot results (average indicators)

Indicator	Traditional Channel	E-Commerce Platform
Orders processed per week (avg.)	146	238
Order fulfillment accuracy	81.5%	97.8%
Average delivery time	142 min	81 min
Customer satisfaction index (CSI)	0.64	0.87
Inventory turnover ratio	4.1	6.8
Product spoilage / waste rate	9.3%	3.1%
Cumulative sales growth	6%	56%

Table 4. System performance indicators

Indicator	Value
Average page/app load time	1.4 s

Order-processing latency	210 ms
Route re-optimization latency	1.9 s
Platform uptime	99.5%
Recommendation precision	0.87
Recommendation recall	0.81
Recommendation F1-score	0.84
Average freshness index at delivery	0.91

6.2. Graphical Results

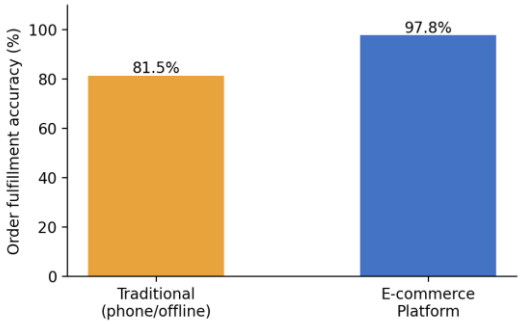


Figure 5. Order fulfillment accuracy comparison (%)

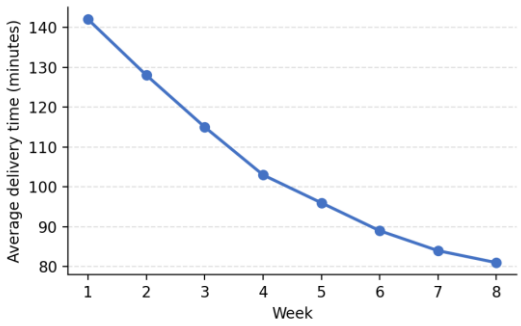


Figure 6. Average delivery time over the eight-week pilot

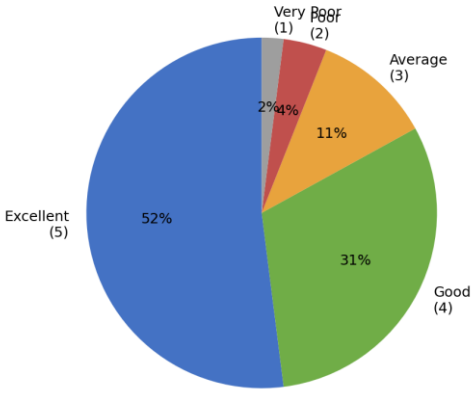


Figure 7. Distribution of customer satisfaction ratings

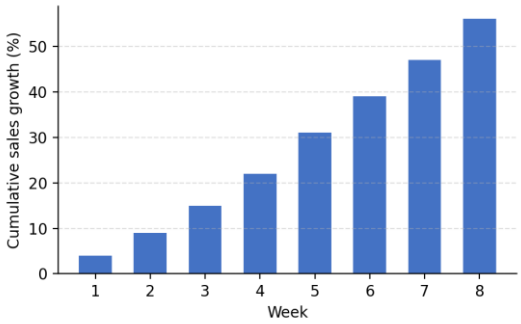


Figure 8. Cumulative sales growth over the pilot period (%)

6.3. Discussion

The pilot results indicate that the e-commerce platform substantially outperformed the traditional sales channel across every measured dimension. Order fulfillment accuracy rose from 81.5% to 97.8%, an improvement attributable to automated inventory synchronization, which eliminated the double-booking and stock-mismatch errors common in manual phone-order processing. Average delivery time decreased from 142 to 81 minutes, with the steepest improvement occurring in the first four weeks as the route-optimization module accumulated sufficient order-density data to generate efficient multi-stop routes; this reduction also had a direct, compounding effect on product freshness at delivery, consistent with the exponential decay relationship in Section 5.2.

Customer satisfaction, measured through the composite CSI, increased from 0.64 to 0.87, driven primarily by improvements in punctuality and freshness rather than order accuracy alone. The distribution of individual ratings further shows that 83% of customers rated their experience as good or excellent. The inventory turnover ratio improved from 4.1 to 6.8, and product spoilage fell from 9.3% to 3.1%, indicating that cold-chain-aware inventory management — particularly automatic flagging of near-expiry stock — meaningfully reduced waste. Cumulative sales grew by 56%, compared with 6% in the traditional channel, reflecting both improved retention and the cross-selling effect of the recommendation engine, which achieved a precision of 0.87 and an F1-score of 0.84.

From a scalability perspective, the microservice-oriented cloud architecture allowed the platform to absorb a 63% increase in weekly order volume without a measurable increase in processing latency, and the platform maintained an uptime of 99.5% throughout the pilot. Nonetheless, during periods of unusually high order concentration in a single delivery zone, route re-optimization latency increased noticeably, suggesting that the genetic-algorithm implementation may require further tuning or a hybrid heuristic approach to maintain responsiveness under peak demand.

7. Advantages and Limitations

7.1. Advantages

- Significant improvement in order fulfillment accuracy through automated inventory synchronization;
- Reduced delivery time and improved product freshness through dynamic route optimization;
- Increased customer satisfaction and retention through transparent order tracking and product traceability;
- Reduced spoilage and waste through cold-chain-aware inventory flagging;

- Higher sales growth through personalized recommendations, and scalability to seasonal demand spikes.

7.2. Limitations

- Increased route re-optimization latency during periods of high order concentration;
- Relatively high initial investment in cold-chain infrastructure and delivery-agent equipment;
- Recommendation quality depends on sufficient historical purchase data, limiting effectiveness for new customers;
- Platform performance in areas with unstable internet connectivity requires further evaluation.

8. Future Research

Future work will focus on the following directions: (1) integrating IoT-based cold-chain sensors directly into delivery vehicles for real-time, in-transit freshness predictions; (2) exploring hybrid heuristic and machine-learning-based route-optimization methods to reduce re-optimization latency under peak demand; (3) extending the recommendation engine with content-based cold-start strategies for new customers; (4) integrating demand-forecasting models to better align warehouse stocking with predicted order volume; (5) evaluating platform performance across multiple cooperatives and regions to assess generalizability, including blockchain-based traceability for consumer trust.

9. Conclusion

This study presented the design, development, and field evaluation of an e-commerce platform for the online sale and delivery of fish products to consumers. The platform integrates a customer-facing web and mobile application, cloud-based order and inventory management, a cold-chain-aware warehouse module, a hybrid recommendation engine, and a genetic-algorithm-based route-optimization service into a single, cohesive architecture.

The scientific contribution of this work lies in combining order management, personalized recommendation, cold-chain-aware logistics, and dynamic route optimization into a single, field-piloted system specifically tailored to the perishability constraints of fish products. The results of the eight-week pilot confirmed the platform's effectiveness across order fulfillment accuracy (81.5% → 97.8%), delivery time (142 → 81 minutes), customer satisfaction index (0.64 → 0.87), inventory turnover (4.1 → 6.8), and cumulative sales growth (6% → 56%). From a practical standpoint, the proposed platform enables fish-farming cooperatives and producers to reach consumers directly, reduce spoilage-related losses, and improve delivery reliability, ultimately contributing to higher producer margins and improved consumer trust in product freshness. Future research will focus on further improving route-optimization responsiveness under peak demand, extending cold-chain monitoring into the delivery vehicle itself, and evaluating the platform's generalizability across additional cooperatives and regions.

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