InvenIQ v2

Smart Expert Inventory Intelligence System

Full Technical Report & System Documentation

Developer Information

Field	Details
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Project Name	Inven IQv2
Live Demo	https://sarfaraz-034.github.io/InvenIQv2/

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1. Executive Summary

InvenIQ v2 is a fully browser-based Expert Inventory Intelligence System developed as a Management Information Systems (MIS) course project at SUST IPE. The system demonstrates a production-grade, single-file web application that combines real-time inventory tracking, Operations Research (OR) formulas, Machine Learning (ML) demand forecasting, and AI chat integration — all without any backend or server dependency.

The platform serves four distinct stakeholder roles — Admin, Seller, Buyer, and Logistics — each with tailored dashboards and role-based access control. With 10 pre-populated SKUs across 5 product categories, automated ROP/EOQ/Safety Stock calculations, and a real-time 7-second simulation engine, InvenIQ v2 bridges academic theory with practical MIS application.

Key Achievements:

- Zero-dependency single-file architecture (HTML + CSS + JS)
- Four stakeholder roles with role-based UI locking and conditional rendering
- ML demand forecasting with 14-day projection using exponential smoothing
- Automated ROP, EOQ, and Safety Stock calculations per SKU
- Live Claude AI chat agent with real-time inventory context injection
- 8-rule configurable expert rules engine with admin-only toggles
- 5 real-time Chart.js visualizations with live data updates
- GitHub Pages deployment — accessible anywhere, no installation required

2. Introduction & Background

2.1 Problem Statement

Traditional inventory management in small-to-medium enterprises relies on manual spreadsheets, reactive restocking decisions, and disconnected stakeholder workflows. This leads to costly stock-outs, excessive safety stock accumulation, delayed procurement, and a lack of data-driven insight into demand patterns.

2.2 Motivation

The MIS course provided an opportunity to design an integrated Expert System that addresses these pain points through scientific formulas, real-time simulation, and AI-augmented decision support. The challenge was to implement such a system entirely in the browser — demonstrating that powerful MIS solutions can be built with minimal infrastructure.

2.3 Objectives

1. Build a fully functional Expert Inventory System accessible via modern web browsers
2. Implement scientifically validated ROP, EOQ, and Safety Stock formulas in JavaScript
3. Integrate ML-based demand forecasting with 14-day future projections
4. Provide Role-Based Access Control (RBAC) for 4 distinct stakeholder types
5. Deploy an AI chat agent (Claude API) with live inventory context awareness
6. Simulate real-time inventory dynamics through a configurable engine
7. Design a production-quality, single-file, zero-dependency deployment

3. System Overview

InvenIQ v2 is packaged as a single HTML file deployable on any static hosting platform. The application runs entirely in the user's browser with no server, database, or build process required. All data is maintained in JavaScript arrays in memory and recalculated on demand.

System Statistics at a Glance:

Component	Count / Value	Description
SKUs	10 Default	Across 5 product categories
Stakeholder Roles	4 Roles	Admin, Seller, Buyer, Logistics
Application Pages	10 Pages	Each role-gated
ML Forecast Horizon	14 Days	Exponential smoothing
Chart Visualizations	5 Charts	Real-time with Chart.js 4.4.1
Expert Rules	8 Rules	Configurable, admin-only
Simulation Interval	7 Seconds	Demand simulation engine
AI Integration	Claude API	claude-sonnet-4-20250514
Deployment	GitHub Pages	Static hosting, zero infra
File Size	~<30 KB	Single HTML file

4. Development Build Flow

The development of InvenIQ v2 followed a structured 10-phase build process, progressing from requirements analysis through deployment. Each phase built on the previous, ensuring a coherent and fully integrated system.

Phase	Stage	Key Activities & Decisions
1	**Requirements Analysis**	Identified 4 stakeholder roles and their unique pain points. Defined functional requirements: real-time tracking, formula-based intelligence, role isolation, AI assistance. Mapped 10 SKU categories to realistic inventory scenarios.
2	**UI/UX Architecture**	Designed tri-panel layout: 200px left navigation sidebar, flexible main content area, 320px right intelligence panel (3 tabs: Alerts, Activity, Chat). Established dark theme with cyan/teal/navy color palette.
3	**Data Modelling**	Created 13-field SKU schema: ID, name, category, quantity, unit cost, reorder point, EOQ, safety stock, lead time, daily demand, supplier, last updated, status. Populated 10 realistic items across Electronics, Office Supplies, Industrial, Medical, and Packaging categories.
4	**ML Formula Implementation**	Implemented ROP = (D x L) + SS, EOQ = sqrt(2DS/H), Safety Stock = Z x sigma x sqrt(L) in pure JavaScript. Added exponential smoothing (alpha=0.3) for demand forecasting with 14-day projection.
5	**Role-Based Access Control**	Implemented 4 roles with conditional UI rendering. Each page applies role checks on load. Navigation locks inaccessible items. Admin has full access; other roles have constrained views.
6	**Real-Time Features**	Built live clock in header. Implemented 7-second simulation engine with probabilistic demand delta. Added ROP-crossing detection with instant alert generation and activity feed logging.
7	**Chart.js ML Visualisations**	Integrated Chart.js 4.4.1 via CDN. Built 5 interactive charts: Demand Trends, Forecast Comparison, Inventory Health, Category Distribution, Reorder Analysis. Charts update live every simulation cycle.
8	**AI Chat Integration**	Integrated Anthropic Claude API (claude-sonnet-4-20250514). Dynamic system prompt injection with current SKU data, ROP status, order counts. Intelligent offline fallback for common inventory queries.
9	**Expert Rules Engine**	Implemented 8 configurable expert rules: Critical Stock Alert, Fast-Moving Safety Buffer, EOQ Deviation Warning, Seasonal Demand Spike, Supplier Lead Time Risk, Dead Stock Detection, Cash Flow Alert, Forecast Accuracy Warning. Admin-only toggle panel.
10	**Testing & Deployment**	Validated all OR formulas against manual calculations. Stress-tested simulation engine with rapid state changes. Verified RBAC boundaries. Deployed to GitHub Pages via static file hosting.

5. System Architecture

5.1 Layout Architecture

The application uses a three-column layout optimized for inventory management workflows. The LEFT panel (200px) provides role-filtered navigation. The MAIN panel (flexible) renders the active page. The RIGHT panel (320px) provides persistent intelligence with three tabs: Alerts, Activity Feed, and AI Chat.

5.2 Data Layer

All data is maintained in three in-memory JavaScript arrays: INV (inventory items), ORDERS (purchase orders), and SHIPMENTS (logistics records). All ROP, EOQ, and Safety Stock values are computed on-demand from base parameters — never stored as stale values. This ensures every calculation reflects the most current state.

5.3 Event-Driven Rendering

The application uses an event-driven rendering model. A central renderAll() function is called whenever state changes occur. Individual page renderers subscribe to specific data changes, ensuring targeted re-renders without full page refreshes. This provides a reactive, Single-Page Application (SPA) experience without any framework dependency.

> *Architecture Principle: Zero external dependencies — no React, Vue, Angular, or any NPM package. The entire system runs on native Web APIs: fetch(), Canvas API for charts, and Web Crypto for session management.*

6. Core ML & Mathematical Models

InvenIQ v2 implements five core Operations Research and Machine Learning formulas. Each formula is validated against textbook references and verified through manual test cases during development.

Formula / Model	Expression	Purpose & Parameters
Safety Stock (SS)	`SS = Z x sigma x sqrt(Lead Time)`	Z = 1.65 (95% service level), sigma = std dev of daily demand, targets 5% stock-out probability
Reorder Point (ROP)	`ROP = (D x L) + SS`	D = average daily demand, L = supplier lead time (days), triggers replenishment order
Economic Order Quantity (EOQ)	`EOQ = sqrt(2 x D x S / H)`	D = annual demand, S = ordering cost per order, H = annual holding cost per unit
ML Demand Forecast	`F(t+1) = alpha x A(t) + (1-alpha) x F(t)`	alpha = 0.3, 14-day forward projection, includes weekly seasonality + noise
Inventory Coverage %	`Coverage = (Qty / Max Qty) x 100`	Used in Inventory Health gauge, visualizes stock level vs capacity
Annual Demand	`D_annual = D_daily x 365`	Converts daily usage rate to annual figure for EOQ calculation

6.1 ML Forecast Algorithm — 3-Step Process

8. Historical Simulation: 30 days of synthetic demand data generated with Gaussian noise and a sinusoidal weekly cycle (plus/minus 20% amplitude) to simulate realistic demand patterns.
9. Exponential Smoothing: alpha = 0.3 is applied to extract the underlying trend from noisy historical data, weighting recent observations more heavily than older ones.
10. 14-Day Projection: Trend slope computed from the last 7 smoothed values is extrapolated forward with controlled noise injection to produce the forecast band displayed in charts.

7. Features & Capabilities — All 10 Pages

InvenIQ v2 is organized into 10 functional pages, each designed for a specific workflow. Role-based access control limits visibility and interactivity based on the authenticated role.

Page / Module	Features & Functionality	Accessible Roles
System Dashboard	KPI cards (total items, below-ROP count, active orders, shipments), inventory snapshot table, ML-generated recommendations panel, top alerts summary	Admin, Buyer
Full Inventory	15-column sortable/filterable table, inline quantity editing, condition status badges, search by SKU/name/category, export-ready layout	Admin, Seller
Reorder Intelligence	Per-SKU ROP analysis table, formula display, reorder status indicators, urgency scoring, supplier contact info	Admin, Seller
Update Items	Seller portal for quantity adjustments, auto-recalculation of ROP/EOQ/Safety Stock on save, item preview panel with change history	Admin, Seller
Order Management	5-order tracking table, status pipeline (Pending to Approved to Shipped to Delivered), order creation form, timeline view	All Roles
Logistics Tracking	Shipment tracking table with carrier info, estimated delivery dates, delay risk scoring, logistics KPI cards	Logistics, Admin
ML Analytics Charts	5 Chart.js visualizations: Demand Trends (line), Forecast vs Actual (line), Inventory Health (doughnut), Category Distribution (bar), Reorder Analysis (scatter)	Admin, Seller
Alert System	Rule-triggered alerts with severity levels (Critical/Warning/Info), timestamp, affected SKU, recommended action, dismiss functionality	Admin, Seller
Rules Engine	8 configurable expert rules with admin-only on/off toggles, threshold adjustment sliders, rule description and impact preview	Admin only
Access Matrix	Interactive permission matrix showing all role-feature combinations, current role highlight, permission level indicators	All Roles

8. Stakeholder Access Matrix

Role-Based Access Control (RBAC) is a core architectural feature of InvenIQ v2. Each of the four roles has precisely defined permissions across all system features, ensuring information security and reducing cognitive overload for each user type.

Feature Area	Admin	Seller	Buyer	Logistics
Dashboard / KPIs	Full Access	Own Metrics	View Only	View Only
Inventory Table	Full CRUD	View + Edit Qty	View Only	View Only
Reorder Intelligence	Full Access	View + Alert	No Access	No Access
Update Items	Full Access	Own Items	No Access	No Access
Order Management	Full CRUD	Create + View	Create + View	View Only
Logistics Tracking	Full Access	View Only	View Own	Full Access
ML Analytics	Full Access	View Only	No Access	No Access
Alert System	Full CRUD	View + Dismiss	No Access	View Delivery
Rules Engine	Full Control	No Access	No Access	No Access
Access Matrix	Full View	Full View	Full View	Full View

9. Benefits of the Expert System

InvenIQ v2 delivers ten distinct operational and strategic benefits that address real-world inventory management challenges faced by businesses of all sizes.

01 **Eliminates Stock-Outs**
The ROP formula triggers replenishment actions before inventory reaches zero. This prevents lost sales, production stoppages, and the 20-40% premium cost of emergency procurement orders.

02 **Reduces Holding Costs**
The EOQ formula mathematically identifies the order quantity that minimizes the combined total of ordering costs and holding costs, directly improving working capital efficiency.

03 **Quantified Safety Stock**
Using Z = 1.65 (corresponding to a 95% service level), the Safety Stock formula provides statistically grounded buffer stock that absorbs demand variability while limiting excess inventory.

04 **ML Demand Forecasting**
The 14-day exponential smoothing forecast anticipates demand surges, seasonal patterns, and trend changes — enabling proactive procurement rather than reactive restocking.

05 **Real-Time Alerts**
The 7-second simulation engine detects ROP crossings and rule violations the moment they occur, replacing manual periodic checks with automated multi-severity alert notifications.

06 **Role-Based Access Control**
Tailored dashboards eliminate information overload for each user type. Sellers see what they need; buyers see what they need; logistics teams see what they need — no cross-contamination.

07 **Visual Analytics**
Five Chart.js visualizations translate raw inventory numbers into actionable patterns. Trends, forecasts, health gauges, and distribution charts surface insights that tabular data cannot.

08 **AI Chat Agent**
The Claude AI integration enables natural language queries against live inventory data. Users can ask which items are below ROP or what the EOQ is for a specific SKU and receive instant, accurate answers.

09 **Configurable Rules Engine**
Eight expert rules can be toggled and tuned by the Admin without modifying code. This no-code automation capability codifies institutional best practices and enforces operational policies consistently.

10 **Zero-Infrastructure Deployment**

> The single-file, browser-based architecture eliminates server costs, maintenance overhead, and installation complexity. Accessible on any device with a modern browser via a static URL.

10. Technical Stack

InvenIQ v2 is built exclusively with web-native technologies and two CDN-loaded libraries. No build tools, bundlers, package managers, or server-side languages are required.

Technology	Version	Role in System
HTML5 / CSS3	Native	Application structure, animations, custom CSS properties for theming, responsive tri-panel layout
Vanilla JavaScript	ES6+	All application logic, data management, formula calculations, event handling — zero framework dependencies
Chart.js	4.4.1 (CDN)	5 interactive data visualizations: line charts, bar charts, doughnut charts, scatter plots
Google Fonts	CDN	Outfit (UI typography) + Fira Code (data/formula display)
Anthropic Claude API	claude-sonnet-4-20250514	AI chat agent with dynamic inventory context injection and natural language query processing
GitHub Pages	Static Hosting	Zero-cost, globally distributed static file hosting — single HTML file deployment
Web Crypto API	Native Browser	Session token generation for role authentication simulation
Canvas API	Native Browser	Chart.js rendering engine for all data visualizations

11. Real-Time Simulation Engine

The simulation engine is the core of InvenIQ v2's real-time experience. It runs autonomously every 7 seconds, creating realistic inventory dynamics that exercise the alert system, formula recalculation, and chart updates.

11.1 Simulation Cycle (7-Second Interval)

11. 65% probability: randomly selects an active SKU for a demand event
12. Computes demand delta: random(-0.4 to +0.6) x base_demand x 2
13. Applies delta to current quantity (floored at 0, capped at max_qty)
14. Checks ROP crossing: if new_qty < ROP and previous_qty >= ROP, fires Critical Alert
15. Logs event to Activity Feed with ISO timestamp and affected SKU
16. Triggers targeted re-render for the active page only (performance optimization)
17. Updates all 5 charts with new data point (sliding 30-point window)

11.2 Simulation Controls

The Admin role has access to simulation controls allowing them to: pause/resume the simulation engine, adjust the interval from 3 to 30 seconds, trigger immediate demand spikes on specific SKUs, and reset all quantities to initial default values.

12. AI Chat Integration

InvenIQ v2 integrates the Anthropic Claude API to provide a conversational AI agent that answers inventory-related questions in natural language. The agent is aware of the full current inventory state at the time of each query.

12.1 Dynamic Context Injection

Every API call includes a dynamically generated system prompt containing the complete current inventory state: all 10 SKU names, categories, quantities, ROP, EOQ, Safety Stock, and stock condition. The prompt also includes the count of items below ROP, out-of-stock items, active orders, and pending shipments.

12.2 Example Queries Supported

- Which items are currently below their reorder point?
- What is the EOQ and safety stock for a specific SKU?
- How many items are critically low on stock right now?
- Explain the ROP formula used in this system.
- What orders are currently pending?
- Recommend immediate procurement actions.

12.3 Offline Fallback

When the Claude API is unavailable (network issues, missing API key), InvenIQ v2 switches automatically to a local fallback engine. The fallback uses keyword detection to answer the most common inventory queries — reorder status, stock summaries, critical items, and formula explanations — using the same live inventory data.

13. Performance KPIs & Metrics

InvenIQ v2 is designed to achieve measurable operational improvements across seven key performance indicators. Each KPI directly maps to a core system capability.

KPI	Target	Mechanism	Business Impact
Stock-Out Rate	< 5% of SKUs	ROP alerts	Prevents lost sales and emergency procurement premium
Reorder Compliance	> 95% on-time	Automated ROP triggers	Eliminates reactive, late procurement decisions
Forecast Accuracy (MAPE)	< 15% error	Exponential smoothing	Validates ML model performance vs actuals
Safety Stock Coverage	95% service level	Z = 1.65	Absorbs demand variability within tolerance
EOQ Adherence	Within +/-10%	EOQ calculation	Minimizes combined ordering + holding costs
Alert Response Time	< 7 seconds	Simulation engine	Near-real-time detection of threshold breaches
System Availability	100% uptime	Browser-based	No server dependency; always accessible

14. Conclusion

InvenIQ v2 represents a complete, production-quality Expert Inventory Intelligence System that successfully demonstrates the integration of Management Information Systems theory with practical web development. The project achieves all stated objectives: real-time inventory monitoring, scientifically validated OR formulas, ML demand forecasting, role-based access control for four stakeholder types, AI chat integration, and live simulation — all delivered as a single HTML file deployable on any static hosting platform.

From an academic perspective, InvenIQ v2 demonstrates the application of OR techniques (ROP, EOQ, Safety Stock) in a working software system. From an engineering perspective, it showcases how modern browser APIs enable powerful, data-driven applications without server infrastructure. From a business perspective, it provides a blueprint for affordable, scalable inventory intelligence that SMEs can adopt immediately.

The zero-dependency, browser-native architecture makes InvenIQ v2 not only a course project artifact but a genuinely usable foundation for real-world inventory management applications. With modest extensions — persistent storage, multi-user authentication, and ERP integration — the system could serve as a production inventory platform for small and medium enterprises in retail, manufacturing, or healthcare.

> *The system is live and accessible at: https://sarfaraz-034.github.io/InvenIQv2/ — open in any modern browser to experience all features with zero installation.*

15. Live Demo & Access

Live Demo URL: https://sarfaraz-034.github.io/InvenIQv2/

Quick Start Guide

18. Open the URL in any modern browser (Chrome, Firefox, Edge, Safari)
19. The system loads with 10 pre-populated SKUs across 5 product categories
20. Select a role from the role switcher (top-right) — try Admin first for full access
21. Navigate to ML Analytics Charts to see the 5 real-time visualizations
22. Open the AI Chat panel (right sidebar, Chat tab) and ask an inventory question
23. Watch the Activity Feed as the simulation engine fires demand events every 7 seconds
24. Switch to Seller role to see how the UI adapts to a different stakeholder perspective
25. Open the Rules Engine page (Admin only) to configure the 8 expert automation rules

Default Login Credentials

Role	Username	Password
Admin	admin	admin123
Seller	seller	seller123
Buyer	buyer	buyer123
Logistics	logistics	log123

— End of Report —

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