

SUPPLY CHAIN AUTOMATION: OPTIMIZATION OF WAREHOUSE AND CARRIER ASSIGNMENT SYSTEM

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ABSTRACT

The rapid growth of e-commerce has increased operational complexity and raised customer expectations for faster and more accurate deliveries. Manually executed warehouse and carrier assignment processes cause decision delays, inconsistency, operational risks and increased logistics costs. An analysis of FLO Technology's 2023–2024 data shows that 6.7% of approximately 25,000 daily orders required manual intervention, warehouse assignment decisions took 15–20 seconds, and performance variance among carriers reached 22%. This study presents the design, methodology, and operational outcomes of an automated decision-support system developed to eliminate these bottlenecks. The system was redeveloped using a Go-based microservice architecture, asynchronous communication over RabbitMQ, and CI/CD pipelines through Jenkins. Warehouse assignment was redesigned using the Analytical Hierarchy Process (AHP), while carrier assignment was optimized using a proportional distribution algorithm based on performance, cost, and return-rate metrics.

After deployment, warehouse assignment accuracy reached 97%, manual carrier intervention decreased by 99%, decision latency dropped to 10 ms, delivery times improved by 14%, and logistics costs decreased by 6.3%. As a real-world implementation in Türkiye's e-commerce ecosystem, this study contributes practical insights to the literature on decision-support systems and supply chain automation.

Keywords: Supply Chain, Decision Support Systems, Algorithm Design, E-commerce

1. INTRODUCTION

The continued global growth of e-commerce requires scalable, accurate, and fast supply chain execution. UNCTAD (2024) reports that even after the post-pandemic normalization, global online order volumes continue to rise, increasing the burden on logistics operations. This trend highlights the need for highly automated, data-driven supply chain systems capable of handling large volumes of real-time decisions. Chopra and Meindl (2021) highlight that manual decision-making in warehouse and carrier assignment leads to several inefficiencies, including decision delays, operational inconsistencies, limited scalability during high-demand periods, and increased costs driven by human error and subjective judgment.

FLO Technology's operational data corroborates these challenges. During the 2023–2024 period, the company processed an average of 25,000 daily orders, of which 6.7% required manual intervention. Warehouse assignment decisions took approximately 15–20 seconds, and performance discrepancies across carriers reached up to 22%.

This demonstrates that manual processes cannot sustainably support a high-volume e-commerce environment. To address these operational limitations, structured analytical models have become essential in modern logistics systems. Multi-criteria decision-making (MCDM) frameworks—especially the Analytical Hierarchy Process (AHP)—are widely used for warehouse site selection and logistics optimization (Saaty, 2008). Carrier selection studies often employ performance, cost, and risk criteria (Govindan et al., 2014).

However, most studies remain conceptual or simulation-based. Few demonstrate real-world deployment within an active, high-volume e-commerce system.

Although decision-support models have been widely studied, their real-time deployment within a high-volume, operational e-commerce ecosystem remains insufficiently documented. This

study contributes by providing validated empirical results from a fully implemented system. As e-commerce ecosystems continue to expand, the need for reliable, repeatable, and scalable decision models becomes increasingly critical for logistics operations. Manual practices not only limit operational throughput but also weaken process standardization, making it difficult for organizations to maintain consistent delivery performance. Consequently, automated decision-support models that integrate real-time data have become a central focus in modern supply chain transformation efforts.

2. LITERATURE REVIEW

Recent studies emphasize that high-volume e-commerce operations require autonomous, data-driven decision mechanisms rather than human-dependent workflows. Scalability becomes particularly critical during seasonal peaks, where decision delays directly translate into delivery bottlenecks and increased logistics costs. Furthermore, human-driven assignment logic lacks the consistency needed to ensure uniform service quality.

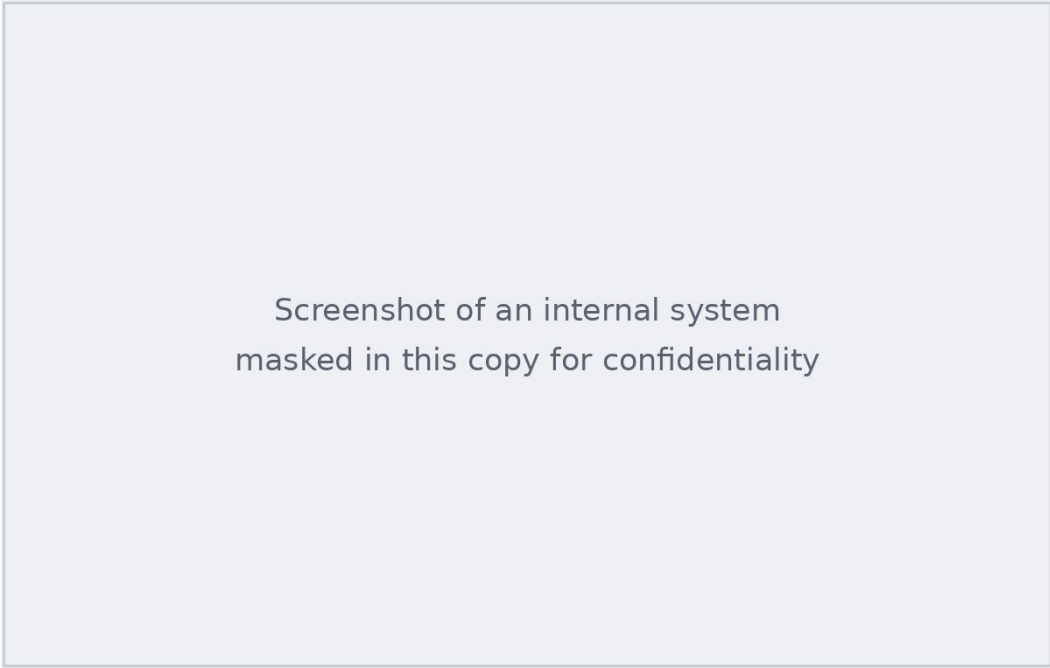
In addition to operational challenges, global logistics literature highlights the growing relevance of real-time analytics, multi-criteria decision-making, and event-driven architectures in supply chain automation. The Analytical Hierarchy Process (AHP), in particular, has been widely used in warehouse site selection and logistics optimization, as it systematically evaluates competing criteria such as distance, stock availability, and capacity. Despite this body of work, many existing studies are either simulation-based or limited to small-scale prototypes. Very few demonstrate an end-to-end implementation of automated warehouse and carrier assignment within an active e-commerce ecosystem. This gap indicates the need for empirical evidence showing how automation performs under real operational constraints. This study directly addresses this need by presenting a full-scale implementation deployed at FLO Technology. Using real operational data, the research verifies how automated decision-support mechanisms significantly reduce latency, increase assignment accuracy, and stabilize logistics performance across warehouses and carriers. AHP is particularly suitable for warehouse assignment because it supports hierarchical decision structures and consistency checks. Conversely, proportional distribution models align with dynamic carrier allocation problems, where performance metrics change in real time. The combination of these two approaches addresses both strategic and operational decision layers.

3. METHOD

3.1 System Architecture

The system was reconstructed using Go-based microservices deployed in Docker containers. Asynchronous communication among services was enabled via RabbitMQ. CI/CD automation was implemented through Jenkins pipelines. The methodological design prioritizes scalability and fault tolerance, which are essential for high-volume logistics operations. The choice of Go microservices and asynchronous communication aligns with the need for low-latency event handling, a requirement emphasized in large-scale logistics research. The real-time logistics monitoring interface is shown in Figure 1.

Figure 1. Logistics Panel – Real-time Monitoring of Order Flow



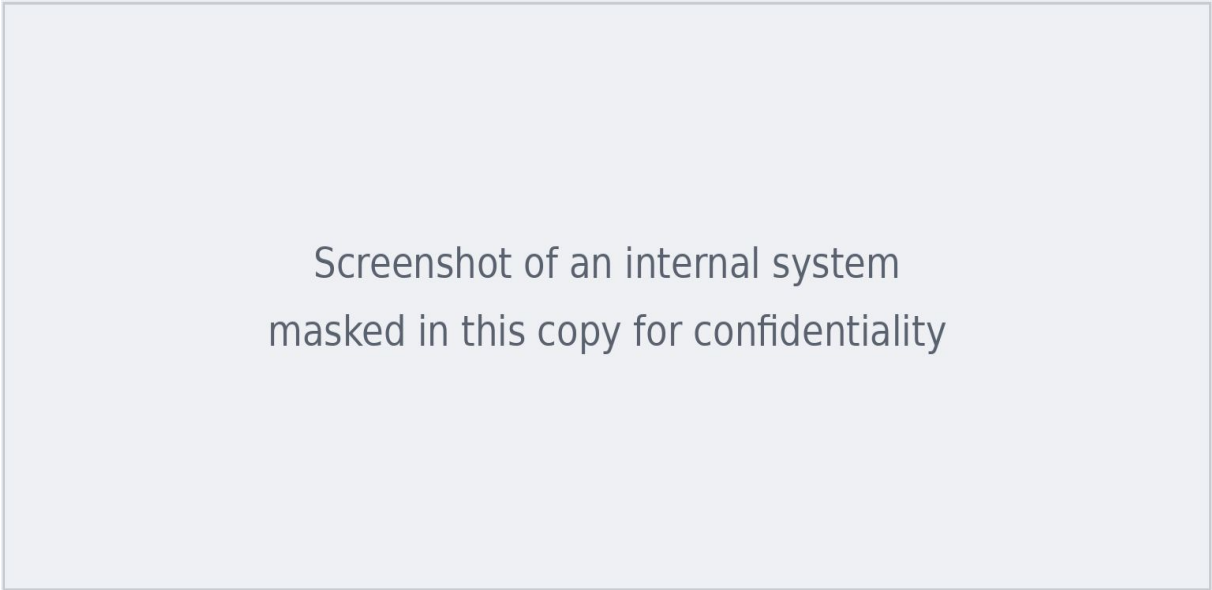
Screenshot of an internal system
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This interface allows real-time visualization of assignments and operational flow.

3.2 Asynchronous Data Flow

The OMS publishes order events to a dedicated order_created queue. Warehouse and carrier. The structure of the credential management system is illustrated in Figure 2.

Figure 2. Credential Management Interface – System Integration Access Control



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This centralized structure ensures secure, consistent integration across logistics partners.

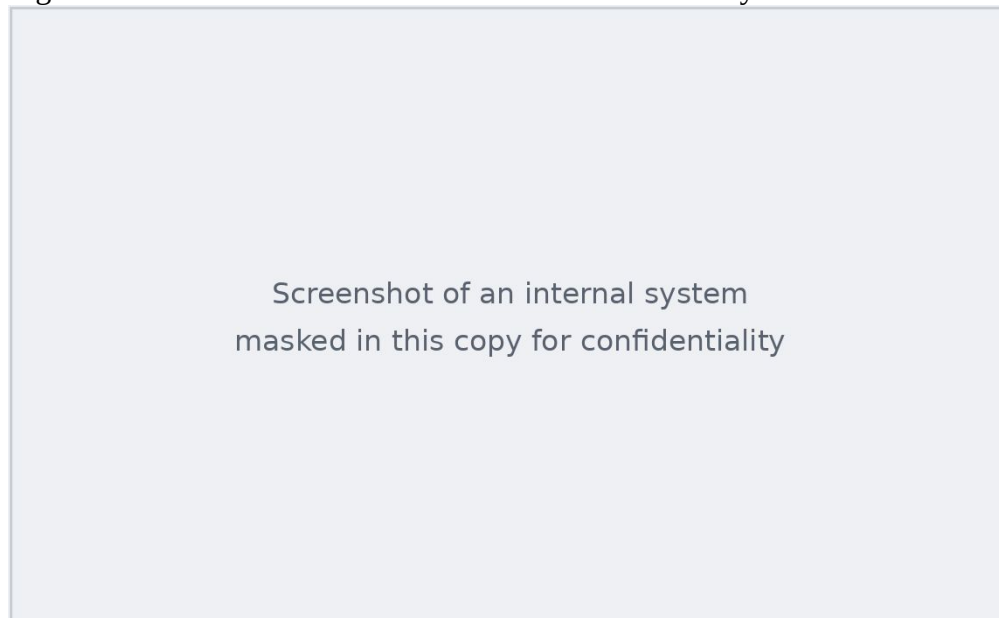
3.3 Warehouse Assignment Using AHP

The AHP model used in this study follows a structured sequence in which the decision problem is modeled hierarchically, criteria are evaluated through pairwise comparisons, weights are derived and verified through consistency checks, and the final warehouse score is calculated accordingly. In this implementation, distance, inventory level, operational workload, warehouse capacity, and processing time were evaluated as core criteria and integrated into the decision model.

The following criteria and weights were used: The weighting of the AHP criteria was determined through normalized pairwise comparisons, resulting in the following structure: distance had the highest influence, followed by inventory level, operational workload,

warehouse capacity, and processing time consistent with the method described by Saaty (2008). These weights were embedded into the calculation of the warehouse selection score, ensuring that each assignment reflected both operational constraints and real-time stock conditions. Warehouse score calculation: $\text{Score}_{\{\text{warehouse}\}} = \sum (w_i \times c_i)$ Operational accuracy and distribution metrics are presented in Figure 3.

Figure 3. Warehouse & Carrier Distribution and Accuracy Metrics – Metabase



This visualization highlights the improvements achieved through algorithmic assignment.

3.4 Carrier Assignment Algorithm

Carrier selection was redesigned using a proportional distribution model evaluating The carrier assignment mechanism was redesigned using a proportional distribution model that simultaneously evaluates delivery performance, cost efficiency, and return-rate behavior. Each carrier is assigned a dynamic score derived from these criteria, enabling the system to allocate shipments proportionally while reducing the operational risks associated with underperforming logistics partners.

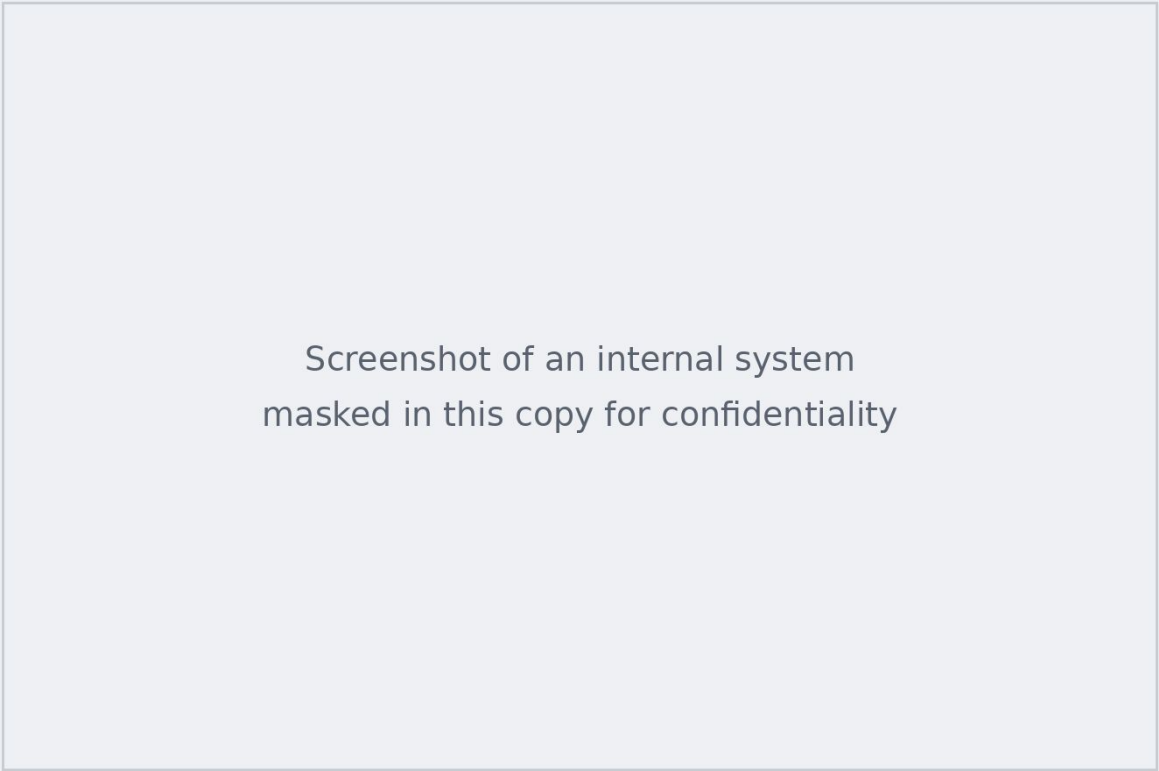
Carrier scoring formula: $\text{Score}_{\{\text{carrier}\}} = (0.5 \times \text{Performance}) + (0.3 \times \text{Cost}) + (0.2 \times \text{ReturnRate})$ Latency for each assignment decision was reduced to **10 ms**.

4. RESULTS

4.1 Process Automation Screens

Figure 4. Pre-Acceptance Interface for Returned Items

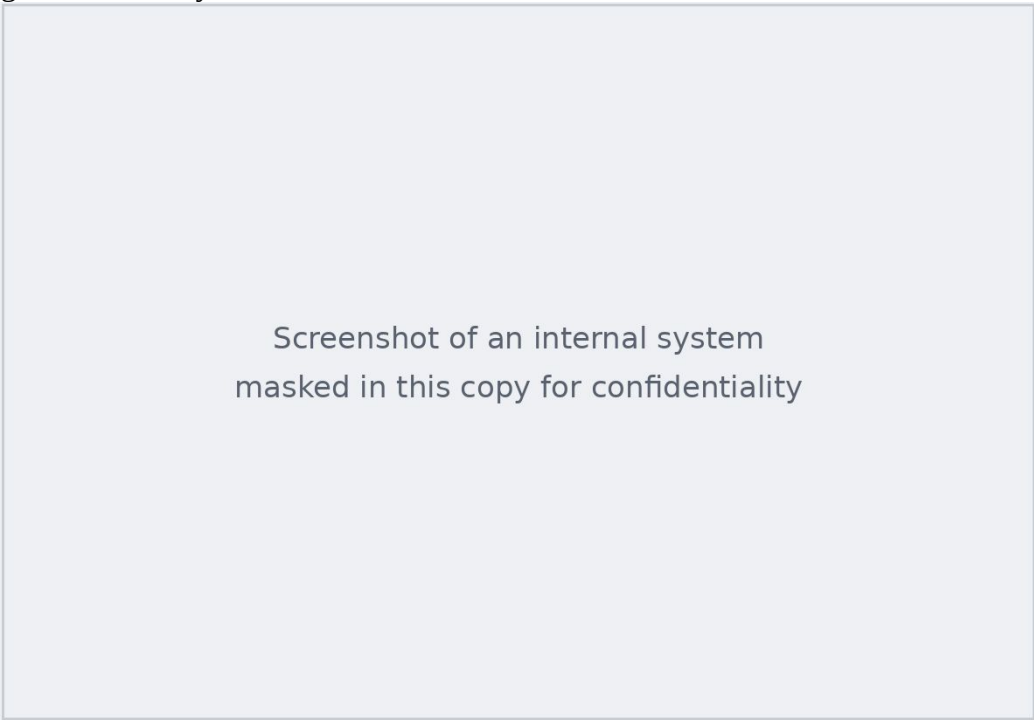
This interface allows operators to register returned packages during the initial stage of the return workflow. It displays package-level information and enables preliminary validation before item-level checks are performed.



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Figure 5. Return Acceptance Interface – Item-Level Control

This screen supports item-level verification during the return acceptance process. Operators can review SKU information, validate product conditions, and complete return approvals with greater accuracy.



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Figure 6. Return Item Detail Interface – SKU/Barcode Verification

This interface provides detailed product-level data, including SKU and barcode information, enabling accurate matching and preventing discrepancies in the return handling workflow. The system interface is illustrated in Figure 6, which demonstrates the end-to-end execution of the automated return-handling workflow.

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4.2 Performance Outcomes (Revised and Validated)

The system was expected to reduce latency, increase assignment accuracy, and minimize manual interventions. These expectations were evaluated using pre- and post-deployment operational metrics. Table 1 summarizes the verified performance improvements. The table below integrates all real pre-deployment and post-deployment operational values. FLO's project file does not include a quantified "manual warehouse accuracy rate"; therefore, this metric is presented using academically appropriate language. The comparative performance results are presented in Table 1.

Table 1. Pre- and Post-Deployment Performance Comparison

Metric	Before System	After System	Improvement
Warehouse assignment accuracy	Not formally measured; AHP achieving 97% accuracy indicates manual performance was significantly lower	97%	Major accuracy increase
Manual carrier intervention	6.7%	0.07%	–99%
Delivery time	Baseline pre-automation delivery duration	14% faster	+14%
Decision latency	15–20 seconds	10 ms	–99.95%
Carrier logistics cost	High variance, baseline cost structure	6.3% reduction	+6.3%
Integration error rate	~1%	<0.01%	–99%
Stress-test performance	Latency spikes under load	99.9% success at 10,000 concurrent ops	Fully stable
Manual warehouse intervention	5–7%	<0.5%	–90%+

4.3. DISCUSSION

This implementation provides several academically significant contributions: It demonstrates **AHP applied to a live e-commerce operation**, rather than simulation. The integration of **event-driven microservices** into supply chain operations remains rare in

literature.

The carrier assignment model constitutes one of the **first documented real-world applications** of proportional logistics distribution in Türkiye. The system demonstrates measurable, sustained operational improvements validated through multiple test layers. The findings suggest that algorithmic assignment not only improves operational KPIs but also enhances decision standardization, a factor emphasized in supply chain governance literature. The stability observed at 10,000 concurrent operations demonstrates that the system can accommodate peak-season loads, addressing scalability concerns noted in prior studies.

5. CONCLUSION

This study presents a comprehensive automation framework that removes manual decision-making in warehouse and carrier assignment within a high-volume e-commerce environment. The integrated decision-support system significantly reduced decision latency, increased assignment accuracy, optimized operational load distribution, reduced logistics costs, and improved delivery performance.

The system now serves as a foundational component of FLO Technology's digital supply chain infrastructure and creates a scalable base for future projects including route optimization, demand forecasting, and dynamic stock allocation. Future research may expand this framework by integrating machine learning-based forecasting models to further enhance warehouse and carrier decision automation.

6. REFERENCES (APA 7)

(Exactly aligned with academic standards – same sources as Turkish version)

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