

Multi-Item Shipment Fulfillment Optimization

BUSINESS PROBLEM

The exponential growth of e-commerce has forced the expansion of warehouses into massive facilities divided into smaller zones. When customer orders require items dispersed across different zones, the facility must execute a costly downstream consolidation process. This consolidation step drives high variable labor costs, requires massive capital expenditures for sorting equipment, and delays delivery times. The business needs a way to maximize Single Zone Fulfillment (1ZF) where all items in an order are picked from the same zone.

DATA SOURCES

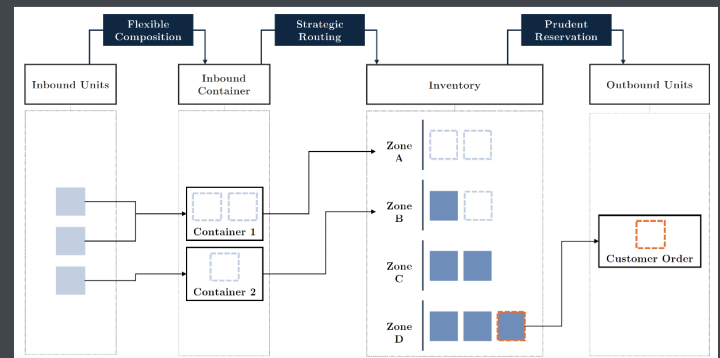
1. Outbound Transactions - Shipment IDs, dates, SKUs, quantities, pick zones, and consumer types.
2. Inbound Transactions - Container IDs, received dates, SKUs, quantities, and recommended versus actual routing zones.
3. Inventory Snapshots - Daily end-of-day records detailing available stock quantities by SKU and specific facility zone.

Data Types and Format

Categorical (nominal), Count (integer), Numeric, Relational Data, Static, Structured, Time series (Dynamic)

APPROACH

The project utilized a hybrid integer optimization and discrete event simulation methodology. It leveraged transaction-level data from a representative warehouse to build the models. The approach evaluated four sequential operational levers: opportunistic reservation, prudent reservation, strategic routing, and flexible composition. These models optimized both inbound inventory distribution across zones and outbound picking logic to achieve the ideal inventory state for 1ZF.



IMPACT

The optimization models identified an unrealized potential of an 18% relative increase in 1ZF performance using existing inventory. This initial finding was validated through a pilot implementation of refined sequential picking heuristics which immediately generated meaningful reduction in fulfillment costs. Beyond this baseline, the simulation proved that coordinating inbound routing and upstream container composition can shift the facility toward an ideal inventory state. This yields a theoretical potential for an additional 60% relative improvement, equating to a total 78% relative increase over current baseline performance.

 DRIVERS	The business is looking for ways to reduce variable fulfillment costs. Maximizing 1ZF will also shorten lead time and reduce capital expenditures for future facilities.
 BARRIERS	Primary challenges include strict physical limits on upstream container composition capabilities, limited physical workstation capacity, and operational non-adherence to inbound routing algorithms due to competing efficiency goals.
 ENABLERS	Access to granular daily transaction logs from a mature warehouse. Support from host company leadership to conduct multi-site pilot implementations of the proposed algorithm adjustments.
 ACTIONS	Formulated integer optimization models to establish maximum theoretical efficiency. Developed a discrete event simulation to test operational policies over time. Deployed a live pilot to validate findings and adjust the picking assignment logic.
 INNOVATION	Strategically, this research shifts consolidation upstream by treating individual warehouse zones as the atomic unit of fulfillment. Technically, it deploys a hybrid simulation framework that integrates multiple sequential optimization models – spanning inbound routing, container composition, and outbound picking – to capture the complex constraints of daily execution while keeping the problem tractable.
 IMPROVEMENT	A validated 18% relative increase in 1ZF percentage generating meaningful cost savings, alongside a strategic roadmap to capture up to 78% total relative improvement through better inventory balancing.
 BEST PRACTICES	Perfect global optimization is often unnecessary. Advanced sequential heuristics can capture the vast majority of efficiency gains without the system latency required by batch processing.
 OTHER APPLICATIONS	This framework is highly transferable to omni-channel retail distribution, spare parts logistics, or any segmented inventory network facing high consolidation and sorting costs.