SOFTWARE-DEFINED WAREHOUSE

WHITE PAPER: UNLOCKING 30% EFFICIENCY GAINS WITH AN INTELLIGENT NEURAL HUB

Next-Gen Warehouse Operating System
Powered by Layered Architecture and Dynamic Optimization

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WHITE PAPER

TABLE OF CONTENTS

A LIST FOR ALL SECTIONS AND PAGE NUMBERS FOR EASY NAVIGATION

This white paper explores how warehouses can overcome operational bottlenecks by embracing software-defined warehouse.

Executive Summary

As global warehouses face 35% average equipment idle rates and 28% peak order abandonment rates, hardware accumulation is no longer the solution.

ATOMIXER transforms heterogeneous devices into collaborative intelligence through its Dual-Core Hub (Layered Architecture + Dynamic Optimization) + Triple-Engine Drive (i-WMS/WES/TES), delivering verified results:

- Order fulfillment lead time ↑28%
- Robot cluster utilization ↑61%
- New device integration cycle <72h

INTRODUCTION

Warehouses were once the ballast of a stable supply chain. Today, in a market of high SKU complexity, short delivery cycles, and unpredictable order surges, warehouses are increasingly turning into hidden cost centers:

Warehouses Are "Losing Control"

WHEN WAREHOUSES GET OUT OF CONTROL

Traditional systems and hardware-driven automation alone cannot meet modern operational demands.

PAIN POINTS	TECHNICAL ROOT CAUSE
Data Silos	API Incompatibility
Equipment Idling	Static Scheduling Algorithms
Respone Latency	No Dynamic prioritization
Scaling Rigidity	Central architecture
Decision Latency	No real time optimization

True warehouse evolution requires smart, adaptive software that serves as the central brain, orchestrating devices, data, and decisions in real time to eliminate systemic inefficiencies and unlock sustainable efficiency gains.

AUTOMATION CANNOT RELY ON HARDWARE ALONE, AND INTELLIGENCE CANNOT COME FROM DATA COLLECTION ALONE.

TRUE WAREHOUSE EVOLUTION REQUIRES SOFTWARE SYSTEMS TO SERVE AS THE CENTRAL BRAIN.

01.

Slow inventory turnover ties up capital and reduces financial agility

02.

Manual-heavy operations make it difficult to improve overall efficiency

03.

Disconnected systems lead to poor data visibility and delayed decisions

04.

Isolated automation equipment results in idle assets and wasted capacity

INDUSTRY INFLECTION

"Gartner predicts that by 2027, 75% of warehouses will shift from hardware-centric automation to software-defined architectures, making algorithmic orchestration the primary efficiency driver."

Source: Gartner® Report G00798271

TRENDS 1

"Software-defined warehouse" is becoming the new industry consensus.

TRENDS 2

Intelligent scheduling, data middleware, and algorithmic optimization will become core differentiators.

TRENDS 3

Warehouses will evolve from being mere "tools" to "cognitive systems," shifting from "operations" to "decision-making"

Hardware-driven automation
Software-driven intelligence

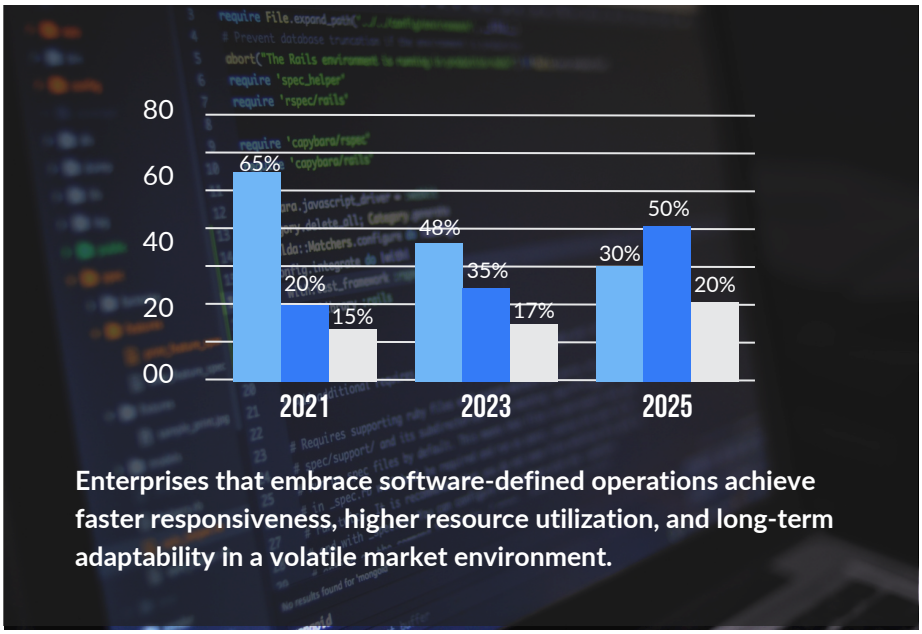
FROM HARDWARE-CENTRIC TO SOFTWARE-DEFINED

Enterprises no longer need fragmented software suites with isolated functions; they require a fully integrated warehouse operating system—one that combines dynamic sensing, intelligent coordination, and self-evolving capabilities.

Over the past decade, warehouse automation has been dominated by hardware-driven investments—from shuttles and AMRs to conveyors and robotic arms.

While these solutions expanded physical capacity, they rarely delivered proportional efficiency gains, because hardware alone cannot orchestrate complex, high-velocity operations.

The next decade belongs to software-defined warehouses, where data, algorithms, and AI—not physical layout—govern operational flow. By shifting from hardware-centric thinking to intelligence-driven orchestration, enterprises unlock higher efficiency, adaptability, and sustainable growth.



Enterprises that embrace software-defined operations achieve faster responsiveness, higher resource utilization, and long-term adaptability in a volatile market environment.

IDEAL CAPABILITIES

CORE CAPABILITIES OF AN IDEAL WAREHOUSE SOFTWARE SYSTEM

A truly future-ready warehouse software system must be built on four essential capabilities that enable agility, intelligence, and long-term scalability:

01. LAYERED ARCHITECTURE WITH SEAMLESS COLLABORATION

The system must provide a clear division of responsibilities across WMS, WES, and TES layers—while ensuring seamless data flow and process coordination across them. Each layer should specialize in its role while working in perfect sync with the others.

Layered Architecture

- CLEAR DECOUPLING, MODULAR AUTONOMY AND FOCUSED FUNCTIONALITY
- UNIFIED DATA, STANDARDIZED INTERFACES AND SMOOTH CROSS-LAYER COLLABORATION

02. DATA-DRIVEN DYNAMIC OPTIMIZATION

An ideal system should form a real-time closed-loop with continuous feedback. By leveraging real-time data and deep learning algorithms, it must be capable of intelligent decision-making, task rebalancing, and performance optimization on the fly.

Dynamic Optimization Engine

- CLOSED-LOOP WORKFLOW: DATA COLLECTION → DECISION MAKING → SCHEDULING FEEDBACK
- STRATEGY EVOLUTION POWERED BY A FUSION OF RULE-BASED LOGIC AND AI ALGORITHMS

03. UNIFIED ORCHESTRATION OF HETEROGENEOUS ROBOTS

The software should be able to centrally manage and coordinate a diverse fleet of automation hardware—including shuttles, AMRs, robotic arms, and conveyors—regardless of brand or model. True value lies in system-level synergy, not isolated device control.

04. RAPID DEPLOYMENT AND SELF-HEALING CAPABILITY

It must support fast configuration, plug-and-play device integration, and minimal setup time. In case of faults or interruptions, the system should recover quickly through intelligent rerouting, task migration, or automatic fault isolation—ensuring uninterrupted operations.

ATOMIXER OVERVIEW

Modular AI-Powered Operating System for Seamless Integration

TECHNICAL HIGHLIGHTS

- Dynamic Optimization
- Deep Learning
- Heterogeneous Collaboration
- Hybrid Algorithm Scheduling
- Millisecond-Level Obstacle Avoidance & Path Switching
- Intelligent Load Balancing
- Fault Self-Healing Mechanism

ATOMIXER - AN INTELLIGENT NEURAL HUB DRIVES THE NEXT LEAP IN AUTOMATED WAREHOUSE EFFICIENCY

ATOMIXER's Two Core Technological Pillars: Layered Architecture and Dynamic Optimization. These pillars are perfectly aligned with the Core Capabilities of an Ideal Warehouse Software System:

LAYERED ARCHITECTURE WITH CLEAR RESPONSIBILITIES

Support the achievement of globally optimal solutions for complex objectives (such as balancing efficiency, cost, and timeliness).

CONTINUOUS LEARNING AND DYNAMIC OPTIMIZATION

Leverage deep learning technologies to continuously optimize decision-making and scheduling strategies based on both real-time and historical data, enabling the system to become "smarter" over time.

THERE ARE THREE LAYER OF ATOMIXER INTELLIGENT SOFTWARE, WHICH COULD BE INTEGRATED AS BLACK BOX, GREY BOX OR WHITE BOX.

TES
TASK EXECUTION SYSTEM

- Heterogeneous cluster scheduling and task planning.
- Point-to-point handling optimized by AI-powered algorithm
- Integrated scenario management, simulation, and digital twin.
- Open platform with simplified API for easy integration and maintenance.

WES
SUB-WAREHOUSE EXECUTION SYSTEM

- Container-level task execution for management and coordination.
- Generates tasks (e.g., Reshuffle) and orchestrates instructions to TES for storage/retrieval.
- Enhanced efficiency with algorithms for correlation analysis, heat matching, and intelligent sorting.

IWMS
SUB-WAREHOUSE MANAGEMENT SYSTEM

- Comprehensive Functions: Inbound, shelving, picking, tally, relocation, replenishment, sorting, order and resource management.
- Streamlined Operations: Handles wave planning, stock prep, picking, and outbound tasks with order-level management.

ATOMIXER TES

TES - THE "SUPER COMMANDER" FOR ROBOTS

TES enables seamless coordination of heterogeneous robots—such as four-way shuttles, AMRs, and robotic arms—and supports large-scale, multi-brand robot cluster operations.

INTELLIGENT TASK MANAGEMENT

Dynamic Task Prioritization: Adjusts priorities in real time based on task urgency and system conditions.

Hybrid Algorithm Decision-Making: Combines rule-based logic with deep learning to achieve globally optimal task allocation.

unlock the full ROI of their automation investments

PRECISE CAPACITY MATCHING

Intelligent Load Balancing: Prevents robots from being overworked or idle, ensuring maximum overall efficiency.

Capacity Grouping & Charging Strategies: Pre-positions robots in hotspot areas, manages fleet utilization, and schedules smart charging (e.g., low-battery robots assigned to short tasks first).

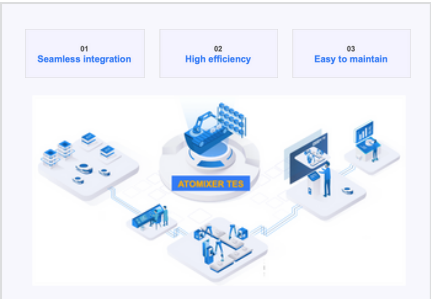
Fault Self-Healing: Automatically transfers tasks to other robots seamlessly in case of device failure.

3D PATH PLANNING

Dynamic Path Planning & Deadlock Handling: Supports pre-planning, dynamic reservation, advanced unlocking algorithms, and real-time congestion prediction and relief.

Millisecond-Level Real-Time Obstacle Avoidance: Instantly replans paths when unexpected obstacles occur.

Multi-Robot Collaborative Scheduling: Uses time-window and coordination techniques to ensure safe and efficient passage through narrow aisles.



The result is a seamlessly coordinated robotic workforce, where each robot operates as part of an intelligent, unified system rather than an isolated tool.

ATOMIXER WES

WES
AI EXECUTIVE OFFICER OF THE WAREHOUSE

WES acts as the operational brain of the warehouse, orchestrating intelligent task execution to maximize efficiency and minimize resource waste.

SUB-WAREHOUSE, NO BUSINESS

- Closed-loop single equipment type sub-warehouse task system, without inventory and business information, focusing on shelving and putaway tasks and remove the block pallet tasks.

INTELLIGENT TASK ORCHESTRATION

THE ULTIMATE SCHEDULING BRAIN

• Dynamic Container Handling	Allocates containers based on real-time bin status and storage conditions.
• Intelligent Wave Optimization	Automatically consolidates tasks based on order characteristics (e.g., SKU mix, delivery routes) to minimize empty runs for equipment.
• Large Order Decomposition	Breaks down complex orders into subtasks for handling, picking, and transportation to ensure streamlined execution.

SMART INBOUND & OUTBOUND DECISIONS

EFFICIENCY ACCELERATOR

• Inbound Optimization	Distributes hot-selling items across multiple locations to prevent congestion, stores associated products close together, and supports multiple placement strategies (e.g., heat-based, same-SKU aggregation).
• Outbound Optimization	Executes intelligent order splitting, wave merging, and multiple picking strategies (e.g., minimal handling, FIFO) to significantly boost picking efficiency.

ATOMIXER IWMS

I-WMS EMPOWERING THE WAREHOUSE WITH A "SMART BRAIN"

The i-WMS acts as the central intelligence of the warehouse, driving real-time decision-making, dynamic prioritization, and optimized storage and picking strategies.

SUB-WAREHOUSES, NO BUSINESS TRANSACTIONS BETWEEN SUB WAREHOUSES

- Closed-loop single equipment type sub-warehouse business system, no business transactions between sub-warehouses

SMART SUB-WAREHOUSE HUB

CORE DECISION-MAKING

Intelligent Order Processing: Automatically receives, assigns, merges, and splits orders (e.g., auto-merging orders for the same customer).

Dynamic Priority Adjustment: Urgent orders are automatically prioritized to ensure timely fulfillment.

Integrated Storage & Picking Optimization: Provides the most efficient combined storage and picking solutions for diverse operational scenarios.

DASHBOARD DISPLAY CENTER

REAL-TIME COMMAND & CONTROL

20+ Real-Time KPIs: Continuously monitors key metrics such as order fulfillment lead time.

Intelligent Exception Alerts: Detects anomalies in real time and triggers proactive warnings.

Dynamic Inventory Monitoring: Initiates smart replenishment recommendations or automated execution commands.

THE INTELLIGENT WAREHOUSE MANAGEMENT SYSTEM (I-WMS) IS THE DECISION-MAKING CORE OF THE ATOMIXER SUITE. IT PROVIDES REAL-TIME VISIBILITY, STRATEGIC DECISIONING, AND PREDICTIVE CAPABILITIES, TURNING THE WAREHOUSE INTO A COGNITIVE SYSTEM RATHER THAN A SIMPLE STORAGE FACILITY.

The Intelligent Warehouse Management System (i-WMS) is the decision-making core of ATOMIXER, transforming a warehouse from a simple storage facility into a cognitive, data-driven system by providing:

Real-time visibility

Strategic decision-making

Predictive capabilities

CLIENT VALUE MATRIX

EFFICIENCY GAINS FROM ATOMIXER DEPLOYMENT

Enterprises implementing ATOMIXER achieve tangible, measurable value across efficiency, resource utilization, and reliability:

SIGNIFICANT EFFICIENCY IMPROVEMENTS

	IMPROVEMENT	CORE SUPPORTING TECHNOLOGY / UPGRADE POINT
SYSTEM OPERATIONAL EFFICIENCY	≥ 20%	WES Intelligent Scheduling, TES Path Optimization
EQUIPMENT UTILIZATION RATE	≥ 30%	i-WMS Intelligent Storage Strategy
EQUIPMENT UTILIZATION RATE	≥ 30%	TES Load Balancing & Fleet Management
PICKING EFFICIENCY	≥ 30%	WES Wave Optimization & Path Planning
ROBOT IDLE RATE	↓ 12%	TES Smart Charging & Task Allocation Strategy

RELIABLE AND EFFICIENT OPERATIONS

After adopting ATOMIXER, clients have observed significant performance boosts:

OVERALL SYSTEM AVAILABILITY
High-Reliability Architecture & Fault Self-Healing

SYSTEM RECOVERY TIME (RTO)
Rapid Fault Isolation & Recovery

NEW ROBOT INTEGRATION
TES Fast Onboarding of Heterogeneous Devices

These results demonstrate how software intelligence multiplies the ROI of automation hardware, converting idle capacity into active productivity while enhancing service levels and agility.

BENCHMARK CASES

A leading retail customer in China has experienced rapid market growth, driving a surge in warehousing and distribution demand. Its regional distribution center faced the following challenges:

- Multi-category, small-batch, high-frequency replenishment, creating complex picking operations.
- Omnichannel fulfillment with strict requirements for delivery speed and accuracy.
- Store replenishment accounting for over 95% of daily operations, generating high operational pressure.

SOFTWARE-DEFINED SMART WAREHOUSE

The project was more than a hardware upgrade—it was a software-driven intelligent transformation.
A fleet of over 1000 robots—including AMRs, multi-layer tote robots, pallet shuttles, and picking/depalletizing robots—was orchestrated by an intelligent warehouse software platform to achieve full-process automation.

- Pallet Shuttle
- AMR
- CTU
- Robot Arm
- Sorting AMR
- Lift

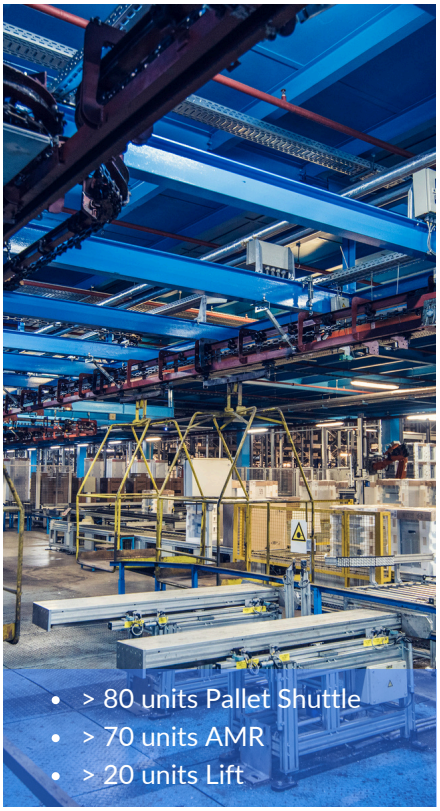
• Global Real-Time Orchestration & Resource Optimization	Manages large-scale robot cluster scheduling with dynamic path planning.
	Deadlock resolution algorithms ensure smooth traffic flow and stable operations.
• Predictive Algorithms & Flow Control	Forecasts daily and urgent replenishment needs based on historical orders and inventory status.
	Optimizes picking buffer allocation and outbound rhythm to maximize throughput.
• Vision-Driven Precision Execution	Computer vision enable automated verification, labeling, and carton orientation checks.

Software-Driven Value

KEY OUTCOMES & VALUE

- Logistics Efficiency Boost: Achieved high-throughput, strictly sequenced automated picking and outbound operations.
- Improved Space Utilization: High-density storage enabled by pallet shuttle and multi-layer tote systems.
- Flexible & Reliable Operations: Software-driven orchestration allowed hundreds of robots to collaborate seamlessly during peak periods.
- Industry-Leading Intelligence: Set a benchmark for large-scale, vision-intensive robotic logistics centers in the retail sector.

BENCHMARK CASES



A LEADING MANUFACTURING ENTERPRISE WAS FACING GROWING PRODUCTION AND WAREHOUSING COMPLEXITY WITH THE FOLLOWING CHALLENGES:

- Multi-floor, multi-process logistics for raw materials, components, and finished products;
- Frequent picking and replenishment tasks across various production lines;
- Tight synchronization between warehouse operations and workshop consumption to avoid production delays;
- Large SKU volume and mixed handling methods (full pallet, totes, material carts), requiring high flexibility.

FULL-PROCESS TASK ORCHESTRATION

Automatically generates picking, replenishment, and transfer tasks for pallets, totes, and material carts.
Coordinates multi-floor, multi-equipment workflows to ensure seamless operations.

INTELLIGENT SCHEDULING & REAL-TIME CONTROL

4-Way shuttles, AMRs, and lifts are managed by a unified control platform.
Optimizes traffic flow, prevents deadlocks, and balances resource allocation across floors.

EXCEPTION HANDLING & VISUALIZED OPERATIONS

Automatic detection of abnormal pallets, oversize materials, or empty totes;
Visual dashboards display inventory, task status, and AMR positions in real time.

SYSTEM INTEGRATION & DATA SYNCHRONIZATION

Interfaces with the customer's WMS and MES, ensuring material movement updates are instant;
Supports production line replenishment, SMT feeder supply, and return material handling.

SOFTWARE-DRIVEN VALUE

THE PROJECT DEMONSTRATES THAT INTELLIGENT WAREHOUSE SOFTWARE IS THE BRAIN OF SMART MANUFACTURING LOGISTICS, DELIVERING:

AUTOMATED END-TO-END WORKFLOW	Raw material inbound → Multi-floor storage → Picking & replenishment → Workshop delivery → Return & empty tote handling.
FLEXIBLE MULTI-FLOOR OPERATIONS	AMRs, lifts, and shuttles enable seamless vertical and horizontal transport, reducing manual handling.
MPROVED PRODUCTION SUPPORT	Real-time synchronization ensures no material shortage for SMT, assembly, or pre-processing lines.
SCALABLE & RELIABLE SOFTWARE CORE	The system dynamically adjusts to peak workloads, supports emergency in/outbound tasks, and ensures high availability.

CONCLUSION

BUILDING TRULY SUSTAINABLE SMART WAREHOUSES

Software is no longer a backend tool; it is the operational nerve center of next-gen warehouses. With ATOMIXER, enterprises transform warehouse inefficiencies into competitive advantages through real-time visibility, predictive control, and autonomous orchestration.

Atomixer software

- Unlock 20–30% operational efficiency gains
- Achieve real-time decision-making and predictive control
- Maximize the ROI of automation investments
- Transform warehouses from cost centers into growth engines

THE JOURNEY FROM HARDWARE-DRIVEN AUTOMATION TO SOFTWARE-DEFINED WAREHOUSE

In a world of unpredictable demand and high operational complexity, software is no longer optional—it is the warehouse's central nervous system. ATOMIXER provides the intelligence, agility, and resilience that define the future of smart warehousing.

HARDWARE-DRIVEN AUTOMATION

SOFTWARE-DEFINED INTELLIGENCE

WE WOULD LIKE TO EXTEND OUR HEARTFELT GRATITUDE TO ALL OUR COLLEAGUES IN SOFTWARE DEVELOPMENT AND IMPLEMENTATION TEAMS. YOUR DEDICATION, LONG HOURS, AND RELENTLESS PURSUIT OF EXCELLENCE HAVE MADE THIS TRANSFORMATION POSSIBLE.