Understanding
Warehouse Robotics Software

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MAKING WAREHOUSE ROBOTICS WORK

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These are exciting and challenging times for distribution center managers.

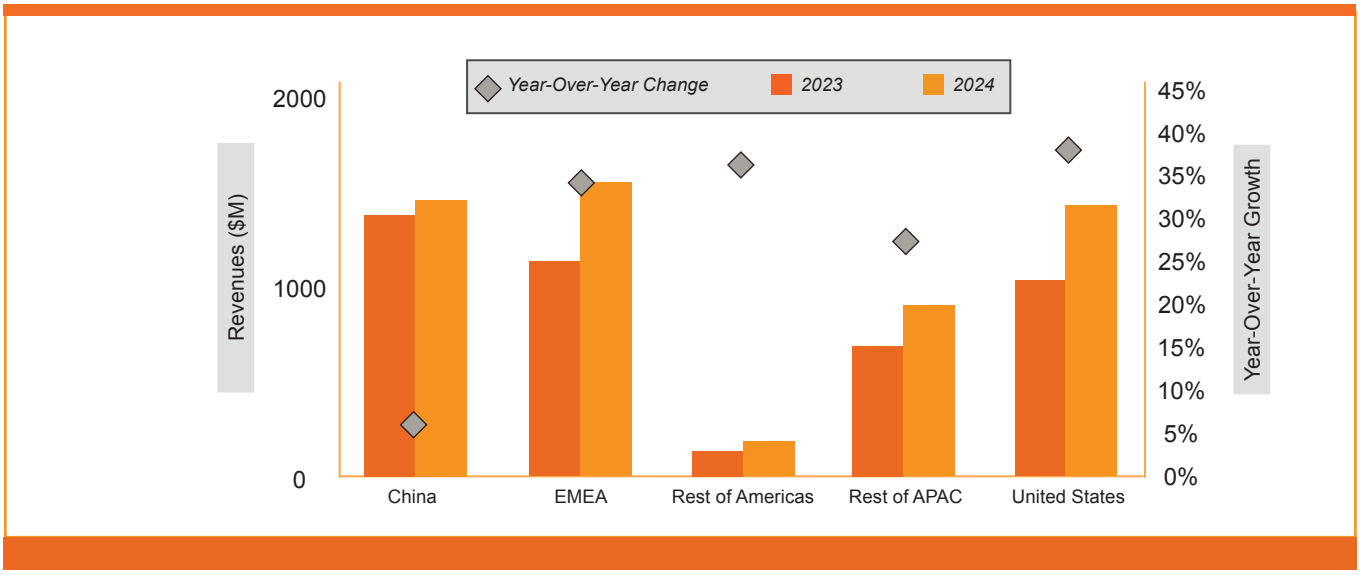
Logistics has become integral to an ecommerce world that is growing rapidly, turning fulfillment into a boardroom issue at many companies.

There is also an exciting array of newer technologies to consider for improving distribution throughput and performance, beyond the familiar tools of Warehouse Management Systems (WMS), conveyors, sortation systems, mobile terminals, voice, and other solutions that have been around for decades.

Newer intralogistics technologies include drones (for cycle counting and yard management), augmented reality, goods-to-person systems, automated materials handling systems of many types - and of course a broad array of robotic systems and rapidly growing use of AI.

Meanwhile, the market for distribution labor remains very tight in the US and Europe. The significant anecdotal evidence of that continued labor shortage is backed by the numbers. According to the US Bureau of Labor Statistics, while the number of non-supervisory warehouse jobs was down modestly in mid-2024 from the peak of about 1.7 million in October of 2022, warehouse jobs are up 146% from a decade ago, putting pressure on most distributors to fill all those new positions, pushing wages higher in many markets.

Forecast Mobile Robot Industry Growth in 2024



Source: Interact Analysis

Growth in Mobile Robots Predicted to Remain Strong

That high interest is in part because the labor shortage can impact not only the bottom line but also affect the ability of a facility to get products out the door in a timely fashion or limit a company's ability to grow and take on new business due to constrained capacity.

Another sign of the interest in warehouse automation and robotics was the record 50,000+ people registered for the MODEX trade show in March 2024, up substantially from the last MODEX event in 2022. The show also added a third hall to accommodate the significant growth in exhibitors, many of them vendors from the broad robotics sector. These vendors included suppliers of AMRs, picking robots and cobots, mobile manipulators, autonomous forklifts, suppliers of various sub-systems - and importantly software to support these robots.

In this paper, we provide an overview of the software challenges and opportunities involved in orchestrating fulfilment tasks with AMRs and picking robots on the warehouse floor.

Autonomous Mobile Robots (AMRs)

An AMR, as the name suggests, is a robot that autonomously (i.e., without human intervention) navigates its way around the warehouse floor to perform various tasks, from basic transport functions to collaborative picking with humans and more. AMRs come with different payload capacities and are integrated with a variety of sensors and software such as a Fleet Management System (FMS) to enable them to perceive the distribution or manufacturing floor and navigate around obstacles in an optimum manner to perform perform work assignments.

AMRs provide flexibility in warehouse automation and can support various use cases. For example, in a goods-to-person scenario, stationary pickers occupy workstations, to which AMRs deliver inventory from various locations. Associates then select items from the AMR for placement into shipping containers, usually supported by a "light" system that visually indicates to associates the work to be done. After all the picks from a given AMR are complete, it leaves, and another AMR arrives at the workstation for more picks.

The high interest in AMRs specifically is driven by several factors:

- **AMRs often allow more work to be completed** with the same number of associates, directly impacting the labor shortage through increased productivity.
- **AMRs support several use cases,** but in distribution the focus is usually around various types of order picking.
- **AMRs provide flexibility,** with the ability to start small if desired and add more robots over time with success and learnings

Some AMR vendors operate on a “Robots-as-a-Service” model in which the AMRs are not sold up front but rather provided on a subscription basis for a monthly fee per robot deployed. This reduces upfront investment levels and allows distributors with high seasonality to scale up with more robots for say a few months of the year in peak season, and then return to a normal level for the rest of the year.

While each situation is unique, AMRs are delivering real value in terms of productivity and throughput for many companies.

Order Picking with Robots and Cobots

Another type of warehouse robot involves use of a robotic picking arm, with movement flexibility and end effector tooling such as fingers or a suction gripper. If the picking robot is designed to safely work alongside humans, it is referred to as a cobot.

These picking-arm robots commonly utilize a vision system that enables the robots to visualize their environment, see specific items, and execute an optimum pick and place action. Recent advances in AI, such as deep learning frameworks for image processing, are enabling robotic arms to become versatile in performing picking tasks, giving them the ability to select a wide variety of object types, regardless of size, shape, or skin, and placed in any orientation. Robotic arms also integrate with advanced path planning and motion control algorithms, enabling them to perform a wide range of tasks. Some use cases in a warehouse include:

- Bin picking, placement, and packing
- Palletizing and depalletizing
- Truck unloading
- Induction and sorting

The use of picking robots and cobots for warehouse automation can often provide several advantages, including increased accuracy, higher productivity, and as a replacement for scarce labor by performing repetitive tasks.

*The use of picking robots and cobots provide several advantages - increased **accuracy**, higher **productivity,** and as a **replacement for scarce labor** by performing repetitive tasks.*

The Critical Role of Robotics Software

While robotic automation continues to be a hot topic in logistics, there are also lots of instances where robotic pilots or proof-of-concept (PoC) initiatives struggle to achieve success.

The same holds true for full scale deployments, which often take too long to deliver value and ultimately reach the levels of performance expected in the business case.

A theme running across these challenges and more is that well-designed and highly functional software is critical to integrating warehouse robots and operating at maximum effectiveness.

For AMRs, companies naturally tend to focus on the hardware side of the equation – the physical robot itself, its feeds and speeds, payloads, battery performance, safety features, and more. This is not surprising: the physical robot is what can be seen, and "speeds and feeds" are easily communicated via spec sheets and videos.

The robot hardware is of course critical to short and long-term project success. But equally if not more important is the software used to plan, integrate, execute, orchestrate, and optimize robotic-enabled distribution processes. Here there are many variables that must be carefully considered at a strategic level, beyond the short-term orientation that characterizes many robotics projects.

Chris Lingamfelter, founder and managing partner of Robot Advisors and recognized robotics expert, recently noted that "Companies consistently underestimate the role and challenges of robotic software despite the fact getting that right is simply essential to a successful project."

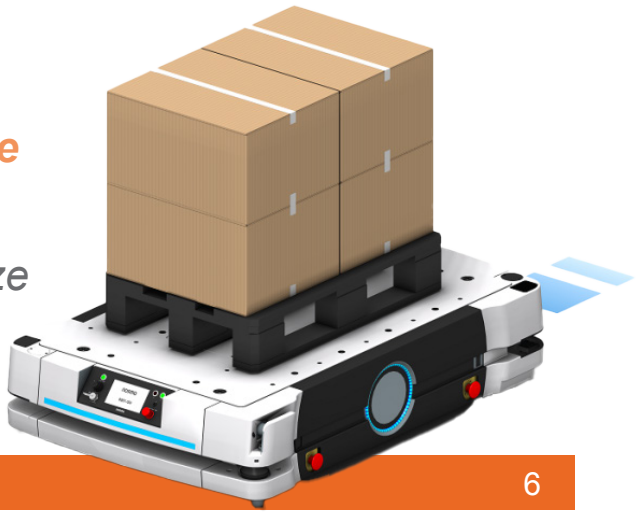
In a 2023 research note, the analysts at Gartner observed that with all the automation and robotic options available, there is "also a broad range of software types associated with managing this equipment. This causes confusion and leads to project delays, suboptimal decisions, and additional costs."

Gartner's research note goes on to identify eight categories of software that might come into play with direct or indirect integration to warehouse robotics:

- Enterprise Resource Planning **(ERP)**
- Warehouse Management Systems **(WMS)**
- Warehouse Execution Systems **(WES)**
- Warehouse Control Systems **(WCS)**
- Material Flow Control (mostly a European concept)
- Unified Control Systems **(UCS)**
- Robot Fleet Management Systems **(FMS)**
- Multi-Agent Orchestration Platforms **(MAO)**

We are going to take a deeper dive into the last two categories, Fleet Management Systems, and the more recently emerging Multi-Agent Orchestration Platforms.

*"...robot hardware is critical to short and long-term success. **But equally if not more important is the software** used to plan, integrate, execute, orchestrate, and optimize robotic-enabled distribution processes."*



A Look at Robot Fleet Management Systems

AMRs generally come integrated with fleet management software that enables them to at minimum perform the following functions:

- Scan the environment over the course of hours or days to create a digital map of the facility that will deploy the robots.
- When work is needed from the mobile robot, navigate the robots from point A to point B, considering the fastest travel path factoring in distances, congestion, and other variables.
- Move the robot in a safe fashion, with collision avoidance technology for keeping people, other AMRs, and additional equipment and fixtures accident free.
- Provide some mechanism for integration with other systems, generally today in the form of an Application Programming Interface, or API.

Beyond these four core capabilities that will be available from the AMR provider, robot OEM software functionality varies widely, from decent functionality to little or no additional capabilities for supporting order picking and other tasks with their robots. This means the software capabilities of various AMR vendors need to be extremely well vetted for their support not only for the immediate project requirements but to provide a platform that will flexibly enable a company's needs over the long term – and with the right software to even deliver competitive operational advantage.

Should You Use the Robot OEM's Software?

All this brings up the key issue: Other than the four core FMS capabilities described above, should you use the software from your robotics vendor?

That's a critical question. You'll want to know for example, if their software provides effective APIs, and can it easily integrate with other robots, material handling systems, and enterprise software. Does the software offer a portfolio of pre-built but flexible robotics-enabled applications, in areas such as piece, case and pallet picking, replenishment and more? Does it provide advanced functions, such as orchestration of fulfillment flows across different processes steps and equipment? Does it use advanced algorithms and AI to optimize productivity and throughput?

As noted above, the OEM software varies significantly across robot vendors, and often is very limited. Even basic integration of the robotics system with WMS or ERP software may require lots of programming to build the needed connectivity and functionality – meaning expensive software integration projects and then often the need to bring in a system integrator (SI).

Even if the OEM software appears decent to do a task such as order picking, there are other considerations. For example, using the robot vendor's execution software may lock you into that provider's robots for a long time.

*"...software capabilities of various AMR vendors need to be extremely **well vetted for their support** for the immediate project requirements and to provide a platform that will flexibly enable a company's needs over the long term..."*

For example, over time a company may want to add new robots from different vendors. Or what if you merge two or more facilities, each of which is running different AMRs?

In either case, you likely won't want to retire the robots you have – you'll want to simply add the new AMRs to the current fleet of robots and have them operating together as if it's a single fleet.

You may also add new robots for different applications – for example, robots for replenishment after an initial deployment of AMRs to support piece picking. The work performed by these different types of robots will often also need to be orchestrated.

As an example, an autonomous AGV could move a received pallet to reserve storage, where it is put away by an autonomous lift truck. These material moves often need to be orchestrated and synchronized.

Hopefully it is clear from these examples that the right choice will often be an overarching software capability or "platform" that brings integration and execution.

Such a platform needs to seamlessly and rapidly integrate warehouse robotics, other types of automation (such as goods-to-person or dense storage systems) and ERP/WMS. It should also natively support multi-vendor robot integration and coordination. The platform should also have the ability to scale operations from a few robots to hundreds or thousands across multiple facilities.

In fact, the analysts at Gartner have grouped these capabilities into what they call Multi-Agent Orchestration Platforms, or MAOP. While Gartner notes its definition is evolving, it says MAOP's "act like intelligent middleware that integrates and orchestrates work between various business applications, heterogeneous fleets of operational robots, and other automated agents like doors or elevators."

Gartner adds that these solutions orchestrate and assign work and monitor and coordinate the activities of diverse fleets of robots.

Gartner further notes that "As robot fleets grow, simple point-to-point API integration will not be enough," adding that "Companies will need an accelerated integration and orchestration capability that can assign work to the right robots or agents based on near-real-time information and the type of activity."

We're not sure if the term Multi-Agent Orchestration Platforms will stick - it's a bit of a mouthful. There is also some overlap with the notion of Warehouse Execution Systems, but with a robotics-orientation.

But the concept itself is spot on.

Battle for the Warehouse Floor

The criticality of robotic software is doubly important because getting it right isn't easy – and there are some market dynamics adding to the challenge.

With the interest and adoption of robots and other automation, there is a battle of sorts as to ***what company and its software is going to control the DC floor*** *– or will it be a federation of systems and providers?*

WMS, WES, and WCS software providers, major materials handling vendors, systems integrators, Multi-Agent Orchestration Platform vendors and more are vying for control of the floor, ***because that's where significant economic value will reside.***

Rapidly Changing Robotics Software Landscape

Since 2023, there have been a number of advances in robotics-related software. The most impactful of these are shown in the graphic below.

Individually and together, these advances make the deployment of warehouse robotics faster, easier, and more successful.

Beyond these more macro changes in the robotics software landscape, on the following page we highlight a number of specific capabilities for companies to consider when designing their warehouse robotics processes. Most of these capabilities did not exist recently in the warehouse robot software market.

These advanced robotic software capabilities are being delivered through the cloud, speeding deployment, improving management capabilities, enabling multi-site deployment and more.

Advances in Robotics-Related Software

FROM	TO
Hardcoded & Rigid Integrations	No Code / Low Code Flexible Integrations
Limited Functionality	Robust and Broad Capabilities
Local Deployments	Cloud Delivery
Single-Site Installs	Multi-Site / Multi-Customer Implementations
Manual Decision Making	AI-Enabled Execution
Closed & Proprietary Systems	Open Frameworks & Standards

The advanced software capabilities include:

- **Rapid Low Code/No Code Integration:** As noted above, today companies no longer have to endure the slow, costly, and risky hard-coded approach to integration of robotics with WMS, ERP and other software systems.

  The integration between WMS/ERP and the Roboteon platform is powered by use of AI, which can nearly complete the mappings with only some modest manual work required to complete the integration, significantly reducing the typical time and effort.

  We will also note that the integration with WMS/ERP will vary by the specific WMS being used, its capabilities, how it was deployed, etc.

  For example, will the WMS simply stream orders for planning and execution by the robot software? Or will they be planned by the WMS, typically in the form of waves? Or will the WMS take it even further, providing fully cartonized orders (what is to be packed into what box)? A platform should be able to integrate the robotics with the WMS system at any level.

- **Interoperability:** At its core, interoperability involves different types of robots across many different vendors operating as if they were all from the same OEM. While there are some initiatives across the robotics sector to develop cross-vendor integration protocols that will make interoperability much easier – and often serve to separate the hardware and software decision - such standards as VDA5050 and Mass Robotics 2.0 are either not widely used or are still under development.

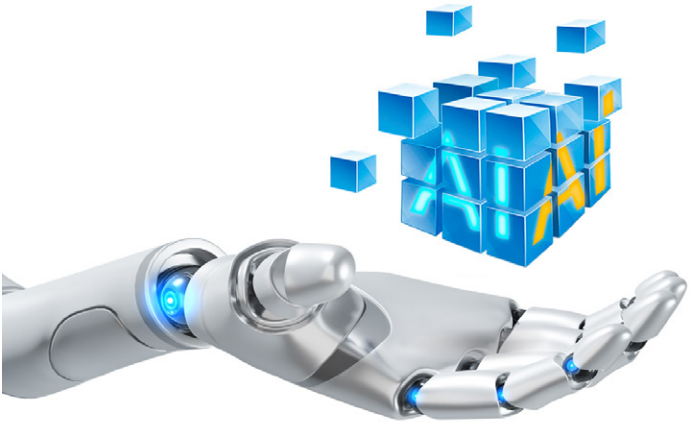
So, what to do in the meantime? Robot vendors typically offer APIs to enable integration to other software platforms. Roboteon's AI-based API mapper described above allows robotics and other warehouse automation systems to be plugged into the platform and thus connect with other hardware and software systems without the need for a major IT integration project.

Many vendors have also started offering support for what is called a Robot Operating System (ROS). This is a loose open source framework (not a full standard) that can be can be used to connect heterogenous robot software development and interoperability. Roboteon's platform also has built-in ROS modules for communicating with various robotic systems.

The platform delivers interoperability across robot types, connecting different automated processes. An example would be communication from the platform to a robot moving goods from receiving to reserve storage, where another robot is made aware of a new putaway task.

Importantly, once past the initial robot deployment, a company may be interested in robots of the same type but from a different vendor for any number of reasons (cost, features, etc.).

Integrating those new robots is one thing. It is another thing to have an engine that can manage robots across vendors in terms of visibility, task assignment, performance measurement and more. This allows companies to keep the robots they have as they add new ones, and seamless operating multiple robot systems as a single fleet.



*Roboteon's **AI-based API mapper** allows robotics and other warehouse automation systems to be plugged into the platform and connect with other hardware and software systems **without the need for a major IT integration project.***

- **Prep-Built Execution Applications:** Beyond basic integration, robot users need to execute fulfillment and other distribution processes. This typically involves significant code development and is a key factor in the time to deploy and time to achieve value for robotics initiatives. The Roboteon platform, however, comes with a broad portfolio of configurable, robot-enabled workflows, including piece, case and pallet picking, cluster and batch picking, replenishment, cycle counting and more. These "out of the box" capabilities will accelerate deployment and project success. Management of these fulfillment processes is also essential to execute more advanced fulfillment functions such as orchestration and optimization.

*Roboteon's platform provides a **unified user interface across all types of robots and equipment,** enabling easy training of warehouse operators and the ability to easily move workers to different task types in the DC.*

- **Orchestration Engine:** As companies continue to automate distribution centers and deploy materials handling systems of different types and vendors, the need to coordinate and optimized the total flow of goods based on real-time conditions becomes increasingly important. The industry calls this "order orchestration," and here the Roboteon platform offers strong capabilities through proprietary algorithms to maximize the flow of goods in a way that achieves optimal throughput.

  A critical capability to maximize robotic picking functions is matching human and robotic resources based on actual demand. The Roboteon platform provides rich capabilities for planning and dynamically allocating human and other resources both initially and as a shift progresses.

- **Automated Robotic Arm Picking:** Roboteon's fulfillment platform also offers capabilities for both piece and case picking using robotics arms, enabled with an AI vision system (deep learning-based), for item detection and picking. A typical application would be to automate "pick and place' tasks, in which items are picked from a tote by the robot arm with some type of gripper or suction system, and then placed on a takeaway conveyor. The robot technologies can be combined, with the AMRs delivering or taking away totes to/from AMRs. Roboteon's platform is integrated with several industry leading robot manufacturers.

- **Advanced Analytics:** Roboteon's fulfillment platform offers granular, real-time dashboards with performance metrics and throughput data across process areas.

- **Simulation and Modeling:** Roboteon leverages simulation to enable companies to plan for new greenfield or brownfield environments through highly configurable scenario analysis that uses real operational or as needed forecast data to estimate costs, throughput and many other KPIs from various combinations of robots and human resources, across any time horizon, to help companies plan for success.

  But this same simulation tool can be used in real-time to optimize today's execution based on the available machines and associates, known or forecasted order profiles, and more, feeding data back into AI models to drive continuous learning.

*All told **Roboteon delivers a powerful platform with robust capabilities** that are far advanced from what was available even two years ago, with a powerful set of tools to drive maximum robotics success now and with high levels of adaptability to meet future needs and opportunities.*

Summing It Up

Interest and deployment of warehouse robotics continues to gain momentum, driven by cost, service and labor challenges.

While we are seeing great advances in robotic hardware, the software used to integrate, manage, orchestrate, and optimize robotic fleets is equally critical for the success of robotics initiatives, yet is often under-appreciated or evaluated.

There have been significant advances in robotics software for deployment in distribution and manufacturing scenarios over the last two years, starting with new approaches to greatly speed the integration of robots with WMS and ERP software, achieved in “low code/no code” mode, and powered by use of AI.

Now, there are also cloud-based platforms that provide end-to-end capabilities and interoperability across robots of different types and from different vendors, with a portfolio of configurable, robot-enabled applications supporting multiple fulfillment processes.

Even more advanced capabilities are being delivered in such areas as orchestrating fulfillment execution, optimized order release and task management, synchronization of humans and robots, and use of AI and simulation to optimize productivity and throughout.

The warehouse robotics era has arrived. It will be powered by software.

About Roboteon

Roboteon Inc.™ is a unique market innovator whose vision is to enable rapid deployment and efficient operation of robotics in distribution. Our software platform enables interoperability across robotic technologies and vendors. It also optimizes order planning, picking and other process execution while automatically considering dynamic conditions such as robot and human resource capacities on the floor. Combined with deep domain expertise, our technology speeds time-to-value and supports agile change.

You can learn more at www.roboteon.com