Hype Cycle for Mobile Robots and Drones, 2023

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Initiatives: Supply Chain Technology Strategy and Selection

> Mobile robots and drones are special forms of cyber-physical automation that function unaided, are attuned to and adapt to their environments, and are task-oriented with various ways to complete missions. Supply chain technology leaders can find robotic solutions to meet their needs with this research.

More on This Topic

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- 2023 Hype Cycles: Deglobalization, AI at the Cusp and Operational Sustainability

Analysis

What You Need to Know

Mobile robots and drones have become common tools in numerous industrial, commercial, consumer, and military workspaces. They are used for intralogistics, manufacturing, site inspection, mapping, security, autonomous data collection, cleaning and even transportation (outside). These and other tasks can be performed in the air, on the ground or in water, both indoors and in some cases outdoors.

This Hype Cycle focuses primarily on solutions supporting specific use cases of drones, mobile robots and humanoid robots, which can be semi or fully autonomous. As the market matures, focus will shift away from components that go into autonomous things (often the preference for early adopters and seen at the far left of the Hype Cycle). As mainstream buyers enter the market in greater numbers, emphasis has shifted toward seeking off-the-shelf solutions that solve specific needs, which are seen at the peak and from the trough through the plateau and beyond. These solutions have well-defined operating parameters and functional boundaries, making it easier for less risk-tolerant market entrants.

The Hype Cycle

Mobile robots and drones continue to evolve and become more powerful and practical with the advancement of embedded AI, fleet management software, cyber-physical hardware and sensor technology improvements. Innovation remains strong in terms of the technologies embedded within robots and drones, the variety and evolving nature of form factors, growing use cases for these solutions and interoperability across automation forms. This evolution will reduce costs and simplify the use of autonomous technology, and will also generate new use cases as automation capabilities and platforms are extended.

Labor costs are rising while companies are struggling to find and keep people, especially in lower-skilled positions. This motivates companies to seek flexible automation solutions. Using robots and drones within a facility will progress faster than wider spread adoption of autonomous technologies outdoors where there's more chaos and fewer physical and logical guardrails.

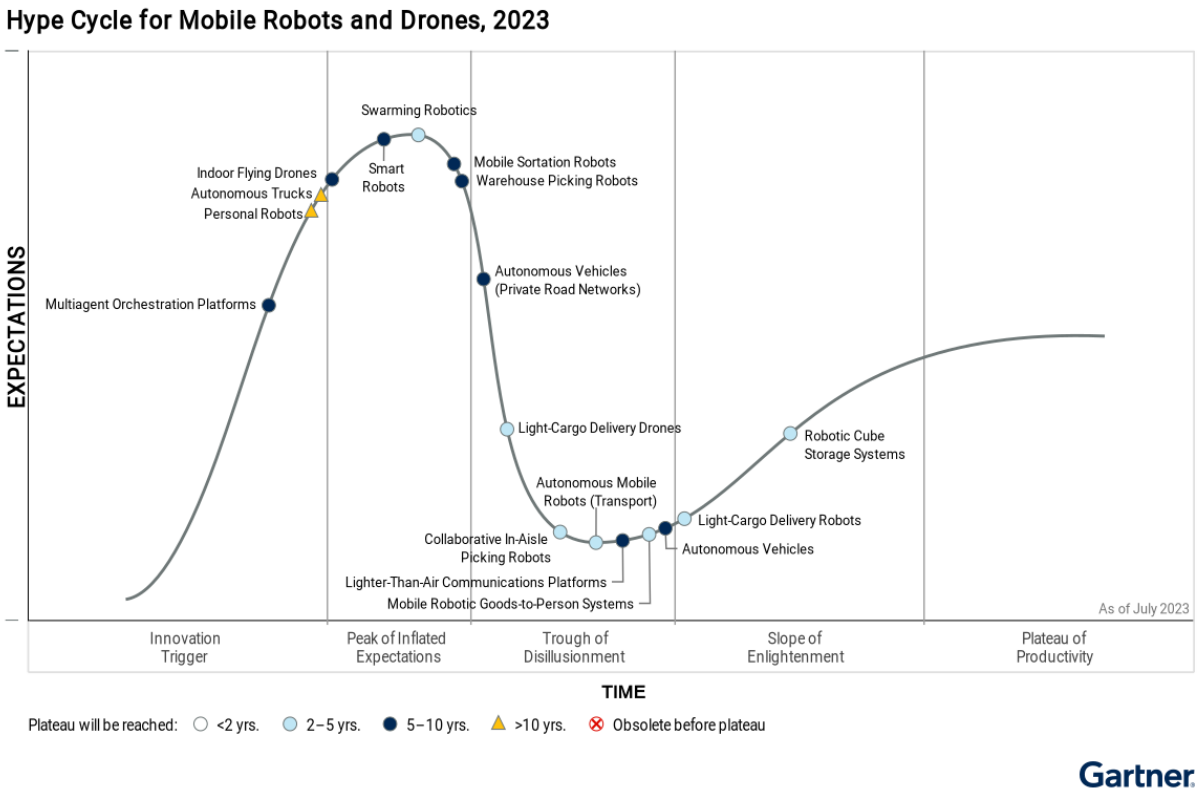
The 2022 Gartner Supply Chain Technology User Wants and Needs Survey found strong interest and deployments of robotics and automation: [1]

- Ninety-eight percent of respondents said they were, or planned to, invest in cyber-physical automation in their warehousing or manufacturing operations.
- Of those respondents, 59% said that labor constraints were their primary motivation for investing in automation.
- Ninety-six percent of respondents said they were, or planned to, specifically invest in intralogistics smart robotics.
- Thirty-five percent of respondents said they were fully deployed or currently underway with their first deployment of intralogistics smart robotics.
- Ninety-three percent of respondents that had already deployed at least one robot said they planned to expand their fleet of those robots, and another 95% said they were looking for other use cases for robotics within their operations.

Because of the increased use of automation, Gartner sees more demand for mobile robots, and to a lesser degree, drones. However, the industry's nascent nature means the majority of innovations covered in this Hype Cycle remain more than two years ahead of widespread adoption. Many of the platforms, technologies and components (such as semiconductors, sensors, motors/actuators, networks, software/algorithms and materials) that will improve performance, costs and capabilities in these systems leverage developments in other end markets.

Despite mobile robots and drones being used more widely, there are still many challenges in improving them, including limited autonomy, and realistic operational readiness for all envisioned use cases. Furthermore, while the technology works in certain use cases, such as autonomous lift-trucks, the business case and ROI for fully autonomous solutions is often lacking. The innovations in this document will show how and when the industry will potentially overcome these challenges as these technologies progress toward mainstream adoption at their own pace.

Figure 1: Hype Cycle for Mobile Robots and Drones, 2023



The Priority Matrix

Several technologies have been rated “transformational” this year, including machine learning, which is expected to hit mainstream adoption within the next five years. Autonomous vehicles, including trucks, will also be transformational, but won’t see widespread adoption for at least a decade, differing notably across regions and industries.

A number of technologies with “high” impact will also mature within the next few years, creating an accelerating market for increasingly capable mobile robots and drones. Lidar, for instance, is finding its way into a host of applications thanks to cost reduction, safety and improved performance. Growing competition and expanded use cases, combined with increased production, is progressively driving down costs and accelerating adoption.

Mobile robot adoption will far outpace drones for several reasons. First, there are numerous mature mobile robot platforms available with tens of thousands of robots already deployed. A majority of customers have already deployed these robots and say they intend to expand their fleets over the next three years. Furthermore, there are numerous use cases with high potential adoption, and research has also found that companies using robots intend to expand their usage to new use cases. Drones, though, have many different use cases. However, in many cases, companies will deploy small numbers of these in comparison to mobile robots. For example, where a company might have one or two drones for inspection at a location, they might have hundreds, if not thousands, of mobile robots.

While robots and drones will share certain core technologies like lidar, vision systems or simultaneous localization and mapping (SLAM), each use case is different and combines these common technologies with other things to create specific and unique solutions. Having a universal and adaptive robot or drone platform that can dynamically respond to changing conditions beyond very narrow parameters will remain aspirational for the foreseeable future.

Table 1: Priority Matrix for Mobile Robots and Drones, 2023

(Enlarged table in Appendix)

Benefit ↓	Years to Mainstream Adoption: Less Than 2 Years ↓	2 - 5 Years ↓	5 - 10 Years ↓	More Than 10 Years ↓
Transformational			Autonomous Vehicles Autonomous Vehicles (Private Road Networks) Warehouse Picking Robots	Autonomous Trucks
High		Autonomous Mobile Robots (Transport) Collaborative In-Aisle Picking Robots Light-Cargo Delivery Drones Mobile Robotic Goods-to-Person Systems Robotic Cube Storage Systems	Multiagent Orchestration Platforms Smart Robots	Personal Robots
Moderate		Swarming Robotics	Indoor Flying Drones Lighter-Than-Air Communications Platforms Mobile Sortation Robots	
Low		Light-Cargo Delivery Robots		

Source: Gartner (July 2023)

Off the Hype Cycle

There are many individual technologies that might be combined to develop robots or drones, and many of these are covered in other Hype Cycles. While these technologies are relevant, they are only one part of creating robot or drone business solutions. This research has now been refocused on looking at specific use cases for robots or drones, and not the underlying technologies. Because of this, the following innovations were dropped from this year's Hype Cycle either because they no longer fit with the goal of this Hype Cycle, which is focusing on specific use cases for robots or drones, or the technology was not progressing as expected:

- Air-to-underwater drone communications

- Emotion AI
- Drone countermeasures
- Machine learning
- Robot knowledge sharing
- Computer vision
- Free space optical communication

On the Rise

Multiagent Orchestration Platforms

Analysis By: Dwight Klappich

Benefit Rating: High

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Definition:

Multiagent orchestration platforms (MAO platforms) act like intelligent middleware that integrates and orchestrates work between various business applications, heterogenous fleets of operational robots, and other automated agents like doors or elevators. These solutions orchestrate and assign work, and monitor and coordinate the activities of diverse fleets of robots.

Why This Is Important

As companies expand their use of robotics, most will eventually have heterogeneous fleets of robots from different vendors performing various tasks, which will require standardized software that can easily integrate to a variety of agents and robot platforms. These solutions will assign work to the right robots based on the characteristics of immediate and prioritized tasks and communicate with other types of automation (agents) like door or elevator controls.

Business Impact

As robot fleets grow, simple point-to-point API integration will not be enough. 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. This will reduce the time, effort and cost to onboard new robots and will reduce support cost, ultimately making organizations more efficient because work will be assigned to the robot best-suited for the task.

Drivers

- Robotics is expanding the market for material handling automation (MHA) to companies that could not historically justify the high cost and long time to value of conventional MHA systems. Most companies (if they have invested in operational robots) have invested in a single robot offering, so integration and orchestration is not yet a compelling challenge for them. However, as companies expand their fleets of robots, the integration and, as importantly, the orchestration of work between robots will become a bigger challenge for companies. This will drive the need for orchestration platforms that can connect multiple robots with source systems as well as coordinate work between robot platforms.
- Tools are nascent and evolving, but the cost and risk of multiagent orchestration solutions are notably less than asynchronous hard-coded integration.
- The business logic is not overly complex and vendors are building and packaging API connectors to the most popular robot platforms, reducing the technical burden on the customer. These solutions are primarily an operational effectiveness opportunity with minimal impact on the overall strategy.
- As robot fleets expand, companies will have to transition management practices from a focus on people to a focus on automation design, which will drive the need for these types of solutions. As robots assume more responsibility for process execution, the process changes can be dramatic. Work assignment processes, which were largely built for people, will need to be completely redesigned. As robotic fleets become more heterogeneous, coordinating work between robot platforms becomes more difficult while important.
- Companies are already adopting robotic systems where different robotics solutions from a single vendor or multiple vendors are integrated to form a complete solution. Examples might be picking robots coordinating with sortation solutions.

Obstacles

- Companies will not recognize the need for these types of solutions until they move beyond one or two robot platforms.
- Companies will likely first look at their WMS providers or their robot provider's fleet management systems, which might or might not address the need for orchestration and integration to a variety of robot platforms.
- Many robot providers are concerned they will be commoditized by less expensive robot hardware, so many are moving more toward software and might push back on the emergence of these types of solutions.

- MAO platforms initially focused on integration but increasingly the need is to combine integration and orchestration. The challenge is various vendors will approach this differently, with some using their WES for orchestration and others having combined solutions under the MAO banner.

User Recommendations

- Analyze your integration requirements as you expand your robot fleet beyond a single vendor.
- Study how you will need to assign work to the various robots and what orchestration logic will be needed to support this simultaneously.
- Register and map out situations where work needs to be coordinated between two different agents, such as robots or other types of physical assets (agents) like doors or elevators. For example, an autonomous mobile robot (AMR) moving pallets has to go through a door and needs to send a message to open the door.

Sample Vendors

Amazon Web Services; GreyOrange; JASCI Software; Open Robotics; Softeon; SVT Robotics; Synergy Logistics

Gartner Recommended Reading

Market Guide for Intralogistics Smart Robotics

Predicts 2023: Supply Chain Technology

Top Technology Trends Transforming Warehousing Over the Next 5 Years: Part 1, Improving Upgrades

Top Technology Trends Transforming Warehousing Over the Next 5 Years: Part 2, Handling Volatility and Complexity

Top Technology Trends Transforming Warehousing Over the Next 5 Years: Part 3, Labor and Resource Challenges

Autonomous Trucks

Analysis By: Jonathan Davenport

Benefit Rating: Transformational

Market Penetration: Less than 1% of target audience

Maturity: Emerging

Definition:

Autonomous trucks use various onboard sensing and localization technologies, such as light detection and ranging (lidar), radar, cameras, global navigation satellite system (GNSS) and map data, in combination with AI-based decision making, to drive without human supervision or intervention.

Why This Is Important

The logistics industry sees autonomous trucks as an opportunity to improve safety and operational efficiencies, while also addressing the driver shortage challenge. Estimates for substantial deployments of autonomous trucks vary, but Aurora Innovation plans to launch driverless operations in late 2024. Autonomous trucking companies are looking beyond developing a safe AI-enabled system that can drive, to training the vehicle to navigate border checkpoints and ensuring operational support structures (such as maintenance) are in place.

Business Impact

Autonomous trucks will enable operating costs to be reduced. Over time, driver pay costs will be eliminated, and vehicle utilization will improve, meaning goods can be transported much faster to their destination because breaks are no longer necessary. Autonomous driving technology is maturing rapidly, but adoption for truck use cases will be constrained by regulatory restrictions and the difficulty of autonomously safely controlling these massive vehicles.

Drivers

- Driver pay is one of the largest operating costs for fleets associated with a commercial truck. Together with the current driver shortage, autonomous trucks will provide additional capability on top of the current trucking capacity and help address wage inflation.
- Companies like Embark Trucks are planning on charging a pay-per-mile subscription for its driver software, which moves autonomous trucking to an operational expense for shippers and carriers considering the technology.
- Safety regulations limit the amount of time a driver can operate behind the wheel. Autonomous vehicles will reduce transit time substantially by eliminating the driver's mandated rest breaks. This affects the decreasing lead times customers put on orders and also reduces the need to have the inventory placed within close proximity to the end customer markets.
- Autonomous trucks have already been used successfully in closed environments within vertical industries like mining and ports. They are currently being further tested on the road in the U.S., Europe and Asia/Pacific.
- Autonomous trucks can also improve environmental sustainability through more efficient driving.
- The scale of a truck means that its sensor suite can be mounted much higher than would be possible on a passenger vehicle. This gives the autonomous truck the ability to use its sensor suite to capture perception data over much larger distances (up to a mile).

Obstacles

- Autonomous technology is not yet ready for widespread deployment. Trucks are 75% wider than passenger vehicles, five times longer and 20 times heavier. This means that autonomous vehicle systems need to be much more precise in terms of positioning the vehicle on the road. The associated stopping distances, which can be up to 65% longer than a passenger vehicle, also means that the truck must plan the decisions it makes further in advance.
- It will be decades until autonomous trucks will be able to handle all road, traffic and weather conditions. As such, it is likely that autonomous truck services will operate on a hub-to-hub basis, with human drivers taking over for the last-mile delivery.
- Despite having the potential for addressing the transportation industry's most severe challenges, growth will be delayed by regulatory debates.
- Humans will still need to support the vehicle, handling activities such as refueling/recharging while en route — but these could be dedicated service station personnel.

User Recommendations

- Create an autonomous technology roadmap that will allow the right level of technology to be adopted over time.
- Undertake a cost-benefit analysis by building a business case that assesses how much can be invested in autonomous technology over a given time horizon to enable profitable future deployment.
- Study autonomous vehicles to understand whether, where and how this technology might impact supply chains.
- Start to engage in proof of concepts and trials by identifying parts of the world where exemptions to core vehicle regulations enable autonomous innovation.
- Allocate a small, technically competent team to research and evaluate government regulations and emerging autonomous capabilities being added to current vehicles.
- Talk to third-party logistics providers to see how they are embracing autonomous vehicles. Some firms may want to partner with shippers initially to pilot the new capability while sharing some risks.

Sample Vendors

Aurora Innovation; Einride; Embark Trucks; Plus; Torc Robotics; TuSimple; Waymo

Gartner Recommended Reading

Emerging Tech: The Future of Autonomous Vehicles

Emerging Tech Impact Radar: Autonomous Vehicles, 2022

Lessons From Mining: 4 Autonomous Thing Benefit Zones for Manufacturers

Supply Chain Brief: How Automation Can Decrease Truck Dwell Times

Use-Case Prism: Artificial Intelligence for Transportation

Personal Robots

Analysis By: Roger Sheng, Annette Jump

Benefit Rating: High

Market Penetration: Less than 1% of target audience

Maturity: Emerging

Definition:

Personal robots are AI-enabled robots designed for dedicated or multiple purposes and used by an individual or family. Their purpose is to help users perform daily tasks. They assist with family life, complete repetitive tasks around the house or, in some cases, even serve as daily companions. Personal robots operate autonomously based on their owners' instructions. This autonomous operation is supported by cloud and embedded AI capabilities.

Why This Is Important

Personal robots complete various tasks, such as helping to cook simple meals, cleaning things automatically at regular intervals, serving food at parties, looking after children or elders, feeding pets, providing entertainment, and fulfilling other household chores. Furthermore, personal robots function as client portals, allowing service providers to deliver home services through user interactions with the robot. Over the next 10 years, many new business opportunities between humans and autonomous things will emerge.

Business Impact

For organizations providing services or solutions to individuals or smart home users, personal robots can help deliver user-friendly services through real-time sensing capabilities. Such organizations span healthcare, elder care, telemedicine, home security, home monitoring and housing development/design. Business owners can achieve cost savings and improve operational efficiency by dedicating personal robots to jobs that humans can't do, don't want to do or take too long to do.

Drivers

- Although today's personal robots serve very limited use cases, such as specialized cleaning or dedicated tasks, cost reductions and new market entrants are enabling innovative products with broader appeal.
- The evolving features and functionalities of personal robots — such as user recognition, conversational ability, emotional expression, branded personality, ability to interact with the environment, and ability to move autonomously — are driving user experience innovations.
- The development of AI and biotech technologies is enabling personal robots to handle more fragile objects and complicated missions, releasing consumers from routine work.
- Emerging generative AI technologies will enable more complicated interactions and activities on personal robots.
- Labor shortages in some developed countries, especially in Eastern Asia, require personal robots to assist and accompany elders and children.

Obstacles

- Existing models can perform well in dedicated work, such as cleaning, weeding and cooking, but lack multitasking capabilities.
- More sophisticated personal robots that use humanoid design, high-precision sensors and high-performance processors are relatively expensive (more than several thousands of dollars).
- Organizations struggle to identify appropriate use cases for personal robots.
- Essential technologies for personal robots, such as embedded AI, computer vision, generative AI and autonomous capabilities, are still immature.
- A gap exists between user expectations and real product performance. Even in use cases that are especially valuable, only a small proportion of innovators or early adopters will pay extra money for expensive personal robots.

User Recommendations

- Develop smart home robots from elementary functions by focusing on mainstream user demand, such as education for children and companionship for elders, while staying aware of the price sensitivity of those use cases.
- Develop a deployment strategy that focuses on long-term development, while ensuring ways to showcase business value in the next two years via special-purpose personal robots.
- Use a modular design methodology to prepare your personal robot products for future upgraded capabilities.
- Invite providers of personal and home services to develop applications on your personal robot platform. This open-source community strategy can yield innovative new use cases.

Sample Vendors

iRobot; Miko; Pollen Robotics; Tesla; UBTECH Robotics; Van Robotics

Gartner Recommended Reading

Emerging Tech Impact Radar: Smart Robots and Drones

Emerging Technologies: The Future of Autonomous Things

Emerging Technologies: Smart Robot Adoption Generates Diverse Business Value

Emerging Tech Impact Radar: Smart Home

At the Peak

Indoor Flying Drones

Analysis By: Dwight Klappich

Benefit Rating: Moderate

Market Penetration: 1% to 5% of target audience

Maturity: Adolescent

Definition:

Indoor flying drones autonomously navigate indoors, moving vertically and horizontally, to support use cases like inventory management, intralogistics, inspection and surveillance. Solutions typically include the flying drone, onboard cameras or other sensors, and advanced AI-based software for navigation, using simultaneous localization and mapping (SLAM), and for data capture.

Why This Is Important

Inventory management tasks like cycle counting are time-consuming and unproductive, and there are safety concerns with having to lift people high in the air to count inventory. Automating this process through the use of indoor flying drones can have notable business benefits. It allows processes to be performed more frequently at an accelerated rate and at a lower cost and impact on the business.

Business Impact

Drones allow companies to increase the frequency and safety of doing cycle counts by making the process more productive and less labor-intensive. Other use cases, such as delivery or inspection, are less proven but could add to the value proposition of adopting indoor drones.

Drivers

- **Inventory management,** particularly cycle counting, is the most obvious and achievable use case today with multiple vendors offering solutions.

- **Intralogistics** is the movement of goods indoors and there is some potential to use flying drones that can follow a predefined flight path to deliver parts, tools or other items from a warehouse to the plant floor. The allure is the ability to support express delivery of items but there are notable limitations such as payload, grip, carrying capacity, dexterity for lifting and placing, and navigation, where mobile robots will continue to dominate.
- Drones could replace manual and often dangerous **inspection or surveillance** processes in warehouses and plants such as inspecting roofs, racks, pallet placements, or safety equipment like sprinkler systems. Indoor drones are particularly valuable for inspections in dangerous areas or elevated heights. Unlike inventory management these would be nonoperational and would be used periodically as needed. However, these drone use cases could potentially integrate with other warehouse audit and inspection tools/mobile apps to better facilitate inspection operations.

Obstacles

- Drone use is limited for inventory management. For companies with shrink-wrapped palletized goods, drones can work well for noting full or empty locations and for checking the rack location of a particular pallet. However, the drone cannot count all the cases on a pallet or the number of items in a box or tote.
- Battery life can be an issue with only about 20 to 30 minutes of flight time for fully autonomous drones. A limited amount of real estate can be covered in that amount of time so companies will either need larger drone fleets or they will need to count less frequently.
- Inspections are a likely secondary use case target for drones; however, these will be limited and much like similar use cases for mobile inspection robots.
- Drone use for indoor delivery (i.e., intralogistics) is very immature, and technical limitations and availability of better alternatives like mobile robots will limit adoption for these use cases.

User Recommendations

- Pilot flying drones for inventory management and cycle counting if your goods are palletized and especially if they are shrink wrapped. Test in one site and roll out rapidly to others if the business case is proven.

- Approach using drones for inspections just like you might for other inspection use cases by leveraging the drones to supplement the skilled workforce already doing inspection in other ways.
- Focus on autonomous mobile robots for intralogistics use cases for the foreseeable future, though very limited proofs of concept could be conducted.

Sample Vendors

B GARAGE; doks.innovation; DroneScan; EyeSee; FlytWare; Gather AI; Infinium Robotics; Lone Drone Solutions; Verity; Vimaan

Gartner Recommended Reading

Market Guide for Intralogistics Smart Robotics

Predicts 2023: Supply Chain Technology

Top Technology Trends Transforming Warehousing Over the Next 5 Years: Part 1, Improving Upgrades

Top Technology Trends Transforming Warehousing Over the Next 5 Years: Part 2, Handling Volatility and Complexity

Top Technology Trends Transforming Warehousing Over the Next 5 Years: Part 3, Labor and Resource Challenges

Smart Robots

Analysis By: Annette Jump

Benefit Rating: High

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Definition:

A smart robot is an AI-powered, often-mobile machine designed to autonomously execute one or more physical tasks. These tasks may rely on, or generate, machine learning, which can be incorporated into future activities or support unprecedented conditions. Smart robots can be split into different types based on the tasks/use cases, such as personal, logistics and industrial.

Why This Is Important

Smart robotics is an AI use case, while robotics in general does not imply AI. Smart (physical) robots had less adoption compared with industrial counterparts but received great hype in the marketplace; therefore, smart robots are still climbing the Peak of Inflated Expectations. There has been an increased interest in smart robots in the last 12 months, as companies are looking to further improve logistic operations, support automation and augment humans in various jobs.

Business Impact

Smart robots will make their initial business impact across a wide spectrum of asset-, product- and service-centric industries. Their ability to reduce physical risk to humans, as well as do work with greater reliability, lower costs and higher productivity, is common across these industries. Smart robots are already being deployed among humans to work in logistics, warehousing, police as well as safety applications.

Drivers

- The market is becoming more dynamic with technical developments of the last two years, enabling a host of new use cases that have changed how smart robots are perceived and how they can deliver value.
- The physical building blocks of smart robots (motors, actuators, chassis and wheels) have incrementally improved over time. However, areas such as Internet of Things (IoT) integration, edge AI and conversational capabilities have seen fundamental breakthroughs. This changes the paradigm for robot deployments.
- Vendor specialization has increased, leading to solutions that have higher business value, since an all-purpose/multipurpose device is either not possible or is less valuable.
- Growing interest in smart robots across a broad number of industries and use cases like: medical/healthcare (patient care, medical materials handling, interdepartment deliveries and sanitization); manufacturing (product assembly, stock replenishment, support of remote operations and quality control [QC] check); last-mile delivery; inspection of industrial objects or equipment; agriculture (harvesting and processing crops); and workplace and concierge robots in workplaces, hospitality, hospitals and so forth.

Obstacles

- **Companies are still struggling to identify valuable business use cases and assess ROI** for robots, especially outside of manufacturing and transportation. Therefore, the position of “smart robots” is still climbing to the Peak of Inflated Expectations.
- **Hype and expectations will continue to build around smart robots during the next few years**, as providers expand their offerings and explore new technologies, like reinforcement learning to drive a continuous loop of learning for robots and swarm management.
- **Lack of ubiquitous wireless connectivity solutions outside of smart spaces and immaturity of edge AI technologies** can inhibit the pace at which smart robots become semiautomated and mobile.
- **The need to offload computation to the cloud** will decrease from 2024, as robots will make more autonomous decisions.
- **The continuous evolution of pricing models**, like buy, monthly lease or hourly charge versus robot as a service for robotic solutions can create some uncertainty for organizations.

User Recommendations

- Evaluate smart robots as both substitutes and complements to their human workforce in manufacturing, distribution, logistics, retail, healthcare or defense.
- Begin pilots designed to assess product capability and quantify benefits, especially as ROI is possible even with small-scale deployments.
- Examine current business processes for current deployment of smart robots and also for large-scale deployment over the next three to five years.
- Consider different purchase models for smart robots.
- Dissolve the reluctance from staff by developing training resources to introduce robots alongside humans as an assistant.
- Ensure there are sufficient cloud computing resources to support high-speed and low-latency connectivity in the next two years.
- Evaluate multiple global and regional providers due to fragmentation within the robot landscape.

Sample Vendors

Ava Robotics; Geek+; GreyOrange; iRobot; Locus Robotics; Rethink Robotics; SoftBank Robotics; Symbotic; Temi; UBTECH

Gartner Recommended Reading

Emerging Technologies: Top Use Cases for Smart Robots to Lead the Way in Human Augmentation

Emerging Technologies: Top Use Cases Where Robots Interact Directly With Humans

Emerging Technologies: Venture Capital Growth Insights for Robots, 2021

Emerging Technologies: Smart Robot Adoption Generates Diverse Business Value

Swarming Robotics

Analysis By: Ivar Berntz

Benefit Rating: Moderate

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Definition:

Swarming robotics is an approach to physically and behaviorally control a set of communicating robots — for example, drones — to jointly accomplish a mission while responding to a changing environment. This enables self-propelled individual robots to move as a group and modify their movements to attain the goal of coverage or exploration of an area or situation.

Why This Is Important

A robot swarm operates as a single entity, despite the parts being physically separated. Charged with a mission, a swarm may consist of several homogeneous, low-cost robots working together. The loss of any individual robot should have minimal impact on overall performance. Simple examples include multiple wheels working together to move a large object, or drones creating a coordinated light show, while more complex tasks include mapping a building or searching a disaster zone.

Business Impact

System-directed multirobots and automated guided vehicles (AGVs), like those utilized in warehouses, are increasingly in use. Swarming goes one step further, by mimicking the behavior of social insects, using individual robots with communication and sensing capabilities, but without centrally curated algorithms and systems. This has potential applications in many industries, such as construction, healthcare, agriculture and space exploration.

Drivers

Robots are becoming more ubiquitous, smaller, cheaper and more capable, making the number of use cases for swarming grow even more. This brings this innovation closer to the Peak of Inflated Expectations.

- Standardization, size, simplification, improvements in software, algorithms and scale economies will continue to drive robot prices down for the foreseeable future.
- To also help drive prices down, some companies are starting to use key sensors (accelerometer, gyroscope, GNSS) from popular, less expensive, mobile phone components.
- A swarm of cooperating robots gains a number of characteristics that are not found in individual robots. They can divide a workload, respond to risks, and even create complex structures in response to changes in the environment or perform difficult tasks unreachable for individual robots.
- One very specific experiment in transportation found swarms to be five times more efficient than individual robots (see Molecular Robots Work Cooperatively in Swarms, ScienceDaily).
- Having robots that become more efficient over time helps companies meet demands for faster delivery, as well as reducing labor costs and human error.

Obstacles

- Technological advances, like simultaneous localization and mapping (SLAM), already enable robots to move in unstructured environments, like factory floors.
- Robot prices can be high, as the sensors, cameras, motors and other parts are expensive and not created for robots, but adapted from other applications, requiring extensive integration.
- There is a lack of interoperability between vendors and readily available coordination algorithms and applications to allow robots to solve a problem on their own.
- For swarming, robots must communicate wirelessly with each other directly, using robust and resilient protocols, but trade-offs between communication methods, battery life and reach limit applicability.
- While swarming behaviors have been established in macroscale system-directed robots, it has remained a challenge in smaller, cheaper robots, largely due to the size of sensors and actuators.
- Most experiments require a homogeneous robot landscape, with little to no room for specialization.

User Recommendations

- **Do the math:** Focus on areas with the highest potential for improvement as emerging technologies lack standardization and vendors are still learning and mergers or bankruptcies can impact your plans.
- **Go for gradual testing, piloting and rollout:** Start with simpler implementations as big-bang approaches can be overwhelming due to complexity, cost and operational risks.
- **Design for human intervention and override:** Think of situations where the self-controlled environments do not function as planned. Having human interventions and overrides will also enhance the system's trustworthiness.
- **Play it safe:** Run pilots in controlled environments. Challenges pertaining to the collaborative aspects of different systems need to be identified early on to reduce the risks and uncertainties during actual deployments.
- **Design for security:** As machines and processes become more connected, they will inevitably be exposed to vulnerabilities and can pose a significant threat to critical industrial infrastructure.

Sample Vendors

Apium; DJI; Geek+; Raytheon Technologies; Siemens

Gartner Recommended Reading

Maverick Research: Biomimicry: How Honeybees Can Inspire Future Supply Chain Design

Emerging Technologies: AI Roadmap for Smart Robots — Journey to a Super Intelligent Humanoid Robot

Emerging Tech Impact Radar: Smart Robots and Drones

Mobile Sortation Robots

Analysis By: Dwight Klappich

Benefit Rating: Moderate

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Definition:

Mobile robotic sortation systems use various types of flexible, mobile robots to identify and transport goods from an induction point and then divert them to the correct destination within the warehouse. There are various types of mobile sortation robots such as table or suspended robots with tilt trays, roll-on-roll-off, ride on top and automated put walls. Most robotic sortation systems have robust, often AI-enabled, software that optimizes the operation of fleets of sortation robots.

Why This Is Important

E-commerce and direct to consumer fulfillment are increasing the need for solutions to help customers sort and coordinate the processing of up to hundreds of thousands of line-items per day. While conventional automated sortation systems have been around for decades, they were expensive, time-consuming to deploy and inflexible. New mobile robot sortation systems are lower cost, adaptive and scalable.

Business Impact

Mobile sortation robots address the challenges of item sortation which is a labor-intensive, low-value-adding and error-prone activity. Conventional sortation systems often tied up large amounts of capital for underutilized capacity for most of the year. The flexible nature of sortation robots addresses the needs of high-volume, high-velocity environments where the demand is not level and dramatic cyclical differences can exist between peaks and valleys, negatively impacting labor even more.

Drivers

- As e-commerce and D2C fulfillment volume and velocity grow, the need for sortation grows as well. Flexible mobile sortation robots open the market for automated sortation to organizations that would not have been able to afford or justify conventional automated sorting systems that were typically based around some form of powered conveyor.
- Different mobile robotic sortation mechanisms can support different form factors, dimensions and payloads. Some can operate independently while others are part of more integrated, yet still flexible, systems. Payload is a notable factor; some robots can only carry very light payloads of several pounds, whereas others can carry much larger and heavier loads.
- A subtype of sortation — singulation/induction — can also support complex needs of customers. It takes random, misaligned or grouped products and distributes them into an organized single-file line of items. Singulation can be manual (i.e., human picking and placing) or automated where robotic arms pick, identify and place items on another robot. Some robotic sortation systems use robotic arms to singulate, but still use conveyors or other automation to sort. Several vendors will also sort to put/pick walls where singulation is either manual or automated.

Obstacles

- While the value of sortation robots is evident, prospects will be challenged by having to evaluate and decide between many different varieties of sortation solutions, including conventional conveyor sortation and robotics.
- Conventional conveyor sortation is a very mature and proven market, so companies will have to weigh the value and importance of flexibility, adaptability and scalability against solutions' maturity and risk.
- Prospects will need to align these solutions appropriately with their company's specific wants, needs and constraints. Prospects will also have to consider use cases for individual item sorting, order sorting and parcel sorting.

User Recommendations

- Identify all possible sortation use cases within your processes, such as in-bound, out-bound, cross-docking, and returns.
- Investigate emerging mobile robotic sortation systems as more flexible and cost-effective alternatives to conventional conveyor sortation systems.
- Assess the maturity of your sortation processes and document your requirements, considering both conventional and robotic sortation capabilities as well as other factors like scalability risk.
- Evaluate more flexible, adaptive and scalable robotic sortation solutions' value to your organization, even if they provide fewer overall capabilities than conventional conveyor-based systems.

Sample Vendors

Addverb Technologies; Berkshire Grey; Geek+; GreyOrange; Kindred; Tompkins Robotics; Unbox Robotics; Zhejiang Libiao Robotics

Gartner Recommended Reading

Market Guide for Intralogistics Smart Robotics

Predicts 2023: Supply Chain Technology

Top Technology Trends Transforming Warehousing Over the Next 5 Years: Part 1, Improving Upgrades

Top Technology Trends Transforming Warehousing Over the Next 5 Years: Part 2, Handling Volatility and Complexity

Top Technology Trends Transforming Warehousing Over the Next 5 Years: Part 3, Labor and Resource Challenges

Warehouse Picking Robots

Analysis By: Dwight Klappich

Benefit Rating: Transformational

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Definition:

Warehouse picking robots can identify, pick up, handle, move and place goods using some form of reticulated robotic arm and end effector/gripper. These systems employ advanced AI and vision systems to recognize and pick up items that are not in consistent places and orientations, and are not the same sizes and shapes.

Why This Is Important

Picking is a repetitive and labor-intensive task ripe for automation. Warehouse picking robots will continue to evolve over the next several years to better address the needs of single-item picking, offering better cost, flexibility, adaptability, scalability, utility and intelligence.

Business Impact

Warehouse picking robots will transform warehouse operations over the coming decades, as labor shortages and costs continue to rise while robot costs and complexities come down, which will open up the market to more companies. Labor availability and labor costs are the main drivers, but improvements in overall throughput and productivity will be the primary value, regardless of whether labor is reduced.

Drivers

- Picking is a labor-intensive and a low-value-adding capability ripe for robotic automation to free up people from mundane, highly repeatable tasks.
- Picking robot form factors are evolving rapidly and capabilities are improving, but they are not yet appropriate or effective for all use cases.
- These robots combine multiple technologies (such as AI-enabled vision systems, reticulated arms that can move in multiple planes and various forms of gripping technology) to enable the robot to identify, locate, pick up and handle goods.
- Replacing people with robots places significant emphasis on getting technology right. Shifting from people-centric organizations to robotics-driven environments has a significant impact on an organization's strategy and culture at all levels.
- When moving from people-driven to automated activities, processes must be redesigned to benefit from robotic advantages. Primary competitive value comes from achieving best-in-class operational performance.

Obstacles

- While industrial robotic arms are mainstream in manufacturing, they remain nascent in warehousing except for some very specific applications, such as palletizing.
- Industrial robots are normally large, immobile and fit for one task. Given the varying types of work required in warehouses, this architecture is too limiting. Warehouse picking robots must address repeatable tasks with minimal variance from activity to activity and item to item, across dimensions and weights.
- Variability makes creating universal picking solutions technically difficult, and it will be years before picking solutions match the flexibility, dexterity and speed of humans. Consequently, initial growth will come in operations with less variable picking requirements.
- Picking accuracy and performance will be key to driving adoption, and will need to be in the mid 90% range or higher for broader adoption. Again, variability can affect picking performance, so use cases will remain narrow for the foreseeable future.

User Recommendations

- Evaluate stationary robotic picking arms for very specific use cases where the product size, weight and shape are consistent, where the location of product is consistent, and where the operation to be performed is consistent (e.g., palletizing robotic arms for picking cases). If companies have these conditions, then exploring robotic arms is worthwhile.
- Proceed with caution and pilot extensively if you operate in less structured and consistent environments, to ensure the picking robot can support your specific operational requirements.
- Evaluate the realistic speed of robotic picking systems for your environment and use cases. Today, humans can often outperform robotic arms, especially where weights and dimensions vary.
- Evolve your management techniques and organizational design principles with robots in mind. Cultural changes must be kept in mind because some employees will feel threatened by robots, which could negatively impact projects.

Sample Vendors

Berkshire Grey; Boston Dynamics; Covariant; Dexterity; Exotec; Kindred Group; Rapid Robotics; RightHand Robotics

Gartner Recommended Reading

Predicts 2023: Supply Chain Technology

Top Technology Trends Transforming Warehousing Over the Next 5 Years: Part 3, Labor and Resource Challenges

Quick Answer: What Supply Chains Considering Intelligent Flexible Automation Need to Address

Market Guide for Intralogistics Smart Robotics

Sliding into the Trough

Autonomous Vehicles (Private Road Networks)

Analysis By: Jonathan Davenport, Kristian Steenstrup

Benefit Rating: Transformational

Market Penetration: 5% to 20% of target audience

Maturity: Early mainstream

Definition:

Private road networks provide the ability to operate autonomous vehicles in closed environments, enabling faster adoption of vehicles because of lower levels and diversity of traffic as well as the ability to segregate operations. Autonomous vehicle technology is being applied to a range of vehicles from buses and trucks to industrial equipment such as autonomous baggage handling tractors in airports, autonomous haulage trucks in mines and automated straddle carriers in ports.

Why This Is Important

The use of fleets on private road networks often involves human workers performing repetitive tasks, such as moving materials between two points. Corporations realize that autonomous vehicles can deliver measurable productivity improvements.

Business Impact

Autonomous things can assist, replace or redeploy human workers to take advantage of the high — and occasionally transformational — business benefits by improving the accuracy with which work is done, lowering operational costs and improving worker safety. Ports, airports and mines were leaders in early implementations, and, as a result, solutions offered by autonomous vehicle vendors in these sectors have begun to mature, enabling lower price points and less risk in deployment projects.

Drivers

- Driver retention and associated driver shortage issues can be addressed by replacing human drivers with AI systems, especially for monotonous, repetitive driving activities.
- Autonomous vehicles undertaking haulage or people/cargo movement activities can undertake certain tasks better than humans, which leads to improved efficiency.

- Likewise — without the need for human rest breaks and shift handovers — AI systems have higher utilization, improving the return on capital assets.
- Businesses that operate in closed environments have fewer legal and regulatory constraints than those operating in the public transportation sphere, enabling corporations to cut operational costs.
- These businesses will often take a long view of capital and infrastructure investments and can calculate specific ROI, enabling autonomous vehicle pilots to be tested and then scaled.
- Risks to human safety can be dramatically reduced or eliminated altogether by using autonomous vehicles to do work with risks for human drivers. Accidents can be very costly if people are injured or assets are damaged.
- The use of autonomous control can improve the service life of vehicles through more precise error-free operation, resulting in fewer breakdowns, fewer replacement parts and increased vehicle service intervals.

Obstacles

- Some private road networks can change significantly over time. For example, vehicles operating in mines, construction sites or on forestry land can face environmental changes when the vehicle is working within a mapped environment.
- Vehicles will need to be trained to handle challenging road conditions, such as driving on unpaved surfaces.
- The precision with which autonomous vehicle travel can actually cause problems, especially where the road surface is not mettled, causing deep ruts.
- Humans will still need to support the vehicle, handling activities such as maintenance, repairs and refueling/recharging.
- Employees have concerns about how autonomous vehicles will impact job security, especially for those currently involved in driving operations.
- While the sophistication of autonomous systems don’t need to match their public road counterparts, companies adopting these systems still need to weigh up the implementation cost versus the technology readiness and the benefits that can be derived.

User Recommendations

- Identify areas where transport efficiency might be improved. For example, do you have repetitive operations that humans are currently controlling that autonomous vehicles could perform more accurately and consistently?
- Create a business case to support autonomous-things-based business process improvement. For example, use a proof of concept to assess the benefits that could be derived if equipment utilization was improved.
- Ensure the safety of human workers by creating autonomous and nonautonomous zones to protect staff.
- Support human-machine handover of tasks by investing in command-and-control fleet management systems.
- Create a strategic vision for business transformation by designing automated processes to complete all the operational tasks. Don't factor in human requirements at the start; this will constrain your thinking.
- Prepare to redeploy staff to higher-value jobs by actively communicating with individuals and trade unions, while putting in place specific training and support packages.

Sample Vendors

Aurrigo; Cognimine; EasyMile; Gaussin; Marubeni; Navya; Outrider; Oxa; SafeAI; VOLK

Gartner Recommended Reading

Lessons From Mining: 4 Autonomous Thing Benefit Zones for Manufacturers

Light-Cargo Delivery Drones

Analysis By: Bill Ray

Benefit Rating: High

Market Penetration: Less than 1% of target audience

Maturity: Emerging

Definition:

Light-cargo delivery drones are flying, autonomous things used to deliver small packages. Autonomy may be supplemented by remote operation when needed and landing may require special facilities. Deployment use cases are limited by local and national legislation, which may restrict beyond visual line of sight (BVLOS) to specific areas, require safety features and/or limit cargo capacity.

Why This Is Important

High-profile companies, including Amazon, Google and JD.com, have invested in drone delivery services. However, in most cases legislation has yet to catch up with technical capabilities. Consumer deliveries are the ultimate aim to create scale and reduce costs. However, for at least the next five years, we expect use cases to be focused on public services (e.g., medical and relief deliveries) and B2B services, where small-scale deployments can be profitable and legislation is less restrictive.

Business Impact

The initial impact of light-cargo delivery drones will be on courier services. However, delivering products anywhere, at low cost, will have a more significant impact:

- Enterprise deliveries can reduce duplication of resources, such as laboratories used for medical testing.
- Just-in-time delivery to remote sites, such as oil rigs, reduces the need for local stockpiling and accelerates breakdown repair.
- Delivering to a person, rather than to an address, creates new business opportunities in just-in-time products and services.

Drivers

- Delivering directly to a smartphone creates mobile customers who can order (and receive) goods from anywhere. Emergency equipment, such as a defibrillator, can be delivered directly to the point of demand, while businesses will be interested in delivering food into the hands of mobile consumers.
- Drones offer (largely) consistent delivery times, bypassing traffic and other impediments to ground transportation. While this is generally faster, it is also (perhaps more importantly) predictable and forecastable.
- Delivery drones running between hospitals can reduce the need for replicated laboratory services (as samples can be quickly and reliably transported), negating the need for local stocks of rarely used medication (such as obscure anti-venoms, which aren't often used but might be needed urgently).
- Light-cargo delivery drones can be highly valuable in delivering products to locations, or across terrains, that lack traditional infrastructures such as tarmacked roads. Fixed-wing drones can travel hundreds of kilometers, delivering products (such as medical supplies or emergency communications equipment) through a parachute drop or landing (where a short runway is available), reducing the need for local stockpiling "just in case."
- The use of "gig economy" workers to deliver goods is already attracting regulatory attention in many countries, resulting in increased cost of service as operating companies are required to treat delivery drivers as employees.

Obstacles

- Concerns over physical safety, citizen privacy and noise represent further legislative and regulatory hurdles, especially in urban environments.
- Legislation permitting the use of BVLOS drones is still being developed in the biggest markets, such as the U.S. and EU. This legislation is not expected until the tail end of 2023.
- Consumer delivery services still suffer from a lack of infrastructure as drones need somewhere to drop their cargo. Solutions exist where customers have large gardens or driveways, or the drones can hook onto window ledges, but no standards exist.
- Drone flight times and lift capacity are still limited. Fixed-wing drones offer greater range and speed, but require landing facilities unless vertical takeoff and landing are (also) supported.
- Autonomous flight still, often, requires remote monitoring and support, which in turn requires connectivity.

User Recommendations

- Create an expert group within the organization that can advise on the legal restrictions locally, including regional and national legislation, and which will take priority.
- Leverage local “flight test zones” where BVLOS may be permitted for companies or government groups that wish to test technologies and services. These zones may cover wide areas and will often serve as a core from which operations can be expanded over the coming years.
- Identify opportunities for deliveries across private campuses, government sites or in regions where BVLOS is permitted.

Sample Vendors

Amazon; Flytrex; JD.com; Manna; Matternet; Wing; Zipline

Gartner Recommended Reading

Market Trends: 4 Technologies That Will Revolutionize Drones and Robots

Forecast Analysis: Retail and Wholesale Trade IoT Endpoint Electronics and Communications Revenue, Worldwide

Collaborative In-Aisle Picking Robots

Analysis By: Dwight Klappich

Benefit Rating: High

Market Penetration: 1% to 5% of target audience

Maturity: Adolescent

Definition:

Collaborative in-aisle picking robots coexist and work with humans to support picking operations, leveraging the existing warehouse physical infrastructure, such as racking and shelving. Robots move to and from aisles where the humans perform picking and other functions.

Why This Is Important

While companies want the benefits of automation, many lack the financial resources to invest large sums of money to deploy large-scale automation. Unpredictability of the future of businesses forces companies to choose more flexible solutions than large-scale, bolt-in automation. In-aisle picking robots allow companies to keep their existing aisles and racks, using mobile robots to collaborate with their workers to partially automate the picking process.

Business Impact

Collaborative in-aisle picking robots are a lower-cost and lower-risk approach to partially automating the picking process. These solutions have low upfront costs and can be operational quickly, within weeks or months, so they have rapid time to value. Also, because they generally operate with minimal, if any, changes to a company's warehouse infrastructure, they are good alternatives for adding some automation to the existing facilities.

Drivers

- Small or individual item picking, which is common in e-commerce and other direct-to-consumer businesses, is labor-intensive and historically has been expensive to automate and required large capital expenditures for very specialized material-handling systems. If companies were building brand-new facilities, the capital outlay for material handling could be buried in the cost of the new facility. However, if a company was looking to add automation to the existing facilities, the time, effort and cost to rip out all the existing infrastructure and replace it with conventional automation was prohibitive. In-aisle picking robots emerged to address these issues.
- Collaborative in-aisle picking robots bring robots and humans together within the existing warehouse infrastructure, taking advantage of the strengths of both. The robots autonomously move around, freeing the humans to handle complex picking tasks.
- The physical robots are complemented with advanced software that helps manage and optimize work across a fleet of robots, which then allocates and assigns the work to humans and individual robots.
- A majority of the traditional picking process consists of walking rather than picking. Collaborative robots can make the picking process much more efficient by doing the walking for pickers.

Obstacles

- Collaborative in-aisle picking robots compete with various other robotic and conventional automation solutions that can perform many of the same activities though in different ways, and with different risk and value propositions. Many customers struggle to choose from all the competitive alternatives they are presented with.
- Many of the boutique consultancies that companies would turn to for assistance have deep experience with conventional material-handling automation systems but less so with robotics, and this adds to the challenges for companies making decisions.
- Because of the need to coordinate the work generated in a warehouse management system (WMS) and the robots, more process and technical integration is required, adding to the cost and time to deploy.
- Because picking heights are limited to what a human can reach, companies cannot take full advantage or ceiling height without adding mezzanines.

User Recommendations

- Pilot in-aisle picking robots for specific use cases by starting small, because a key advantage of collaborative robots is the low upfront costs and reduced risks.
- Develop evaluation methodologies to help quickly identify reasonable use cases for intelligent flexible automation and robotics.
- Create a narrowly focused center of excellence (COE), as it will help to effectively manage flexible intelligent automation in the long term by engaging domain experts across engineering/operations technology (OT), IT and supply chain functions.
- Explore more adaptive funding models that are not constrained by burdensome payback and ROI expectations, using methods similar to how startups leverage venture capital, early in the investigative process.

Sample Vendors

6 River Systems; Geek+; Hai Robotics; inVia Robotics; Locus Robotics; Zebra Technologies (Fetch Robotics)

Gartner Recommended Reading

Market Guide for Intralogistics Smart Robotics

Predicts 2023: Supply Chain Technology

Top Technology Trends Transforming Warehousing Over the Next 5 Years: Part 1, Improving Upgrades

Top Technology Trends Transforming Warehousing Over the Next 5 Years: Part 2, Handling Volatility and Complexity

Top Technology Trends Transforming Warehousing Over the Next 5 Years: Part 3, Labor and Resource Challenges

Autonomous Mobile Robots (Transport)

Analysis By: Dwight Klappich

Benefit Rating: High

Market Penetration: 5% to 20% of target audience

Maturity: Early mainstream

Definition:

Autonomous mobile robots (AMRs) for basic transport add intelligence, guidance and sensory awareness to conventional automated guided vehicle (AGV) platforms, allowing them to operate independently and around humans. These robots focus primarily on autonomously moving (transporting) goods within plants and warehouses.

Why This Is Important

Labor is one of the most sporadic and largest cost elements in warehouses and plants. Employee time dedicated to moving goods from one place to another is unproductive, costly and easily automatable. Transport robots can perform many movement tasks, more efficiently and, often, more flexibly than humans within warehouses and plants. This can free up the employees to focus on more value-added activities, where uniquely human capabilities like problem solving or dealing with ambiguity are needed.

Business Impact

Improvements in overall throughput, adaptability, safety and productivity will be the primary value, regardless of whether labor is reduced or not. Warehouse operations with a high volume of bulk (i.e., pallet) product moves should consider some of the current generations of AMRs as an alternative to, or for supplementing, existing automation, such as conveyors or guided vehicles. Companies looking to build new automated facilities should also explore the potential value of these smart machines.

Drivers

- AMRs will continue to gain traction in warehouses, distribution centers and plants, as AMRs increasingly take over functions historically performed by humans on lift trucks.
- AMRs are the natural evolution of AGVs that have been in use for nearly 50 years.
- AGVs are proven but suffer from inflexibility and lack of adaptability because they have to follow a fixed path (i.e., rails, wires, tags or magnets) on the floor.
- Modern AMRs are significantly more adaptable and can be retrained to perform new or different tasks, and in some cases, simply by the push of a button.
- As computing power has multiplied and the cost of sensors has declined, the power, flexibility and use cases for AMRs have grown while prices have come down, leading to significant AMR market demand growth.
- While there are similarities across AMRs, there are also differences, such as the payload the AMR can move, the height it can reach, and how it picks up and moves goods.

Obstacles

- Market penetration is low overall, with under 25,000 AMRs deployed commercially today, which when contrasted to well over a million lift trucks operational, is a small market so far.
- Payload is a significant determinant of the type of vehicle, and the heavier the payload the higher the cost. The total cost of ownership is a barrier to growth at this end of the market.
- Organizations that have previously used AGVs find the adoption of AMRs seamless, while companies new to mobile robots in general have more to learn. Additionally, many struggle to identify the best near-term use cases, and based on these, the best AMR platform to choose. Building a business case for heavy-payload transport AMRs is proving more difficult for some customers due to the high cost of the vehicles and a lack of experience with the technology.
- Technical issues still plague the viability of fully autonomous lift trucks that can lift loads higher than ten feet, but progress continues in this area.

User Recommendations

- Review your operations and identify areas with wasted travel time to complement the basic transport AMRs' ability to automate the movement of goods.
- Review what you are moving and its characteristics, how you're moving it, and what tasks you hope to automate. This can help define good use cases and determine the core requirements for evaluation.
- Leverage the flexibility of AMRs by approaching the evaluation through concepts of the scientific method, which is where you develop hypotheses for use cases, design experiments to test them and then conduct pilots testing the same.

Sample Vendors

AGILOX; BALYO; Clearpath Robotics (OTTO Motors); MiR; OMRON; Seegrid; Third Wave Automation; Vecna Robotics; Zebra Technologies (Fetch Robotics)

Gartner Recommended Reading

Market Guide for Intralogistics Smart Robotics

Predicts 2023: Supply Chain Technology

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Top Technology Trends Transforming Warehousing Over the Next 5 Years: Part 2, Handling Volatility and Complexity

Top Technology Trends Transforming Warehousing Over the Next 5 Years: Part 3, Labor and Resource Challenges

Lighter-Than-Air Communications Platforms

Analysis By: Bill Ray

Benefit Rating: Moderate

Market Penetration: 5% to 20% of target audience

Maturity: Adolescent

Definition:

A lighter-than-air communications platform is an autonomous platform that floats using a lifting gas. Such platforms offer the advantages of satellite communications at a fraction of the cost and with negligible latency in transmission. Supported by a balloon (or ballonet) of lighter-than-air gas, some platforms are free-floating, while others are tethered by a cable.

Why This Is Important

Lighter-than-air platforms can quickly and inexpensively provide communications over a wide area without having to negotiate land access or rental, while tethered deployments can provide instant coverage for temporary events or during emergencies. Despite the imminent competition from low earth orbit (LEO) satellite constellations, there is significant interest in the technology from municipalities and emergency services.

Business Impact

Lighter-than-air platforms can reduce the need for high-capacity network coverage in areas where it's infrequently needed, such as annual events, congested roads or following natural disasters. Radio coverage and wide-area observation can be operational within hours. A few companies are still pursuing persistent services, but the majority of interest is in temporary installations which have shown significant value in providing connectivity to existing smartphones or other radio equipment.

Drivers

- Tethered aerostats provide an alternative that is more suitable for special events or disaster recovery. Combining a helium balloon with a kite enables the platform to stay aloft for days or weeks over a specific location to provide communications and/or observation without the need for additional backhaul or infrastructure.
- A radio deployed to an altitude of 1 km can provide a coverage of over 50,000 square kilometers at very little cost.
- Tethered solutions also avoid battery life issues (as power can be delivered over the tether), which limits the utility of free-floating platforms. While solar power can provide some respite, power still remains a limiting factor in the deployment of free-floating platforms.
- Tethered systems operate at a lower altitude, and can be recalled by winding in the tether, reducing the complexity and allowing launch/recovery in a short time with minimal crew. AT&T's FirstNet One blimp, for example, can be launched from in 30 minutes a trailer by a crew of four, as long as the wind speed is less than 24 km per hour (the system can operate in wind speeds up to 80 km per hour, once deployed).
- Some companies are still pursuing business models around extending mobile coverage, through the use of rotational deployments, despite limited industry interest and imminent competition from LEO satellite services.

Obstacles

- Deployment and recovery costs remain the most significant barrier to adoption. Aircraft platforms must land, be refurbished, and take off, which presents a challenge for billowing plastic balloons which lack structure at ground level. Alphabet's (Google's) Loon project used an extremely advanced automatic launching system but still struggled with recovery.
- For persistent systems, operating in the stratosphere for maximum coverage, the thin atmosphere results in very cold conditions, but (conversely) presents problems in heat dissipation similar to those experienced by a satellite in orbit.
- Air traffic control is becoming more complex, as autonomous drones proliferate and passenger drones become available.

User Recommendations

- Prioritize temporary coverage for events and emergencies. Lighter-than-air systems are unlikely to be able to provide constant wide-area coverage, demonstrated by the failure of Loon and the increasing competition from LEO satellite constellations.
- Incorporate multifunctional platforms by integrating cameras and other sensing equipment, as observation can be as important as communications.
- Create coverage as needed — high-altitude platforms are not always needed. An aerostat flying at 100 m can still provide coverage across a music festival site or other event.

Mobile Robotic Goods-to-Person Systems

Analysis By: Dwight Klappich

Benefit Rating: High

Market Penetration: 5% to 20% of target audience

Maturity: Adolescent

Definition:

Mobile robotic goods-to-person (G2P) systems keep a human in one place and let robots move goods to and from the human. G2P systems are not typically autonomous robots, and as such, require less sensory technology onboard the robot and have minimal impact on customer infrastructure.

Why This Is Important

Labor availability constraints, rising operational and labor costs, and the need to improve efficiency are motivating companies to seek solutions that leverage mobile robots. G2P robotic solutions keep people in one place, increasing their efficiency and protecting workers with enforced social distancing. G2P systems are a low-cost, rapid way to add automation into existing facilities with minimal, if any, large-scale infrastructure changes, which aids adoption.

Business Impact

Robotic G2P systems reduce travel, and improve picker efficiency by keeping a human in one place and letting the robots do all of the goods movements. Robotic G2P systems reduce worker fatigue and improve worker satisfaction by significantly reducing walking time and distance per day.

Drivers

- Labor availability constraints coupled with rising labor costs are forcing companies to consider various forms of material handling automation including, but not limited to, G2P systems. G2P solutions are well-suited to e-commerce, and now in some cases, microfulfillment. This is because robots move the goods on portable shelving units, where typically multiple items are stored on the incoming unit, and the picker selects multiple orders on an outgoing shelving unit. Robust software orchestrates the robots' movements to and from the pickers based on orders and inventory flow.
- G2P systems are typically significantly less costly than conventional material handling systems and are more agile, flexible and adaptable. G2P systems have added benefits over other forms of material handling that are increasingly in demand given the ease and speed to be adopted within an environment.
- There are two broad categories of G2P systems — those built around mobile robots (covered here) that move on the floor delivering goods to the human, and robotic cube storage "G2P" systems where robots operate independently on specially designed three-dimensional grids. The former requires minimal infrastructure, other than specially designed shelving units the robots use to move the goods and can be deployed quickly but can require more floor space.

Obstacles

- G2P systems are just one form of automation that might solve a customer's specific fulfillment needs. Choosing between the various options is difficult because systems have differing values, risks, complexities and costs. G2P systems fit a specific use case and companies might have other use cases for mobile robots that require a different type of robot.
- As companies deploy heterogeneous fleets of robots, building an orchestration capability across robot platforms will become more important.
- Mobile G2P systems can take more square footage for the same inventory and order profiles. This is due to the use of mobile shelving units that require floor space for the shelving units to be moved around, and because inventory can only be stored roughly five feet high. However, this can also be a benefit to some customers wishing to implement the system in a nonconventional warehouse environment, like in an office building or store.

User Recommendations

- Map out your current fulfillment processes, order and pick volumes, growth projections and current labor efficiencies before looking at G2P solutions to understand the potential value to your business.
- Ensure your fulfillment profile fits the characteristics best suited to a G2P system, such as high volume, high-mix single-item picking common to e-commerce and related businesses.
- Work with the vendor to size the solutions properly in line with peak daily, weekly and annual demand fluctuations.

Sample Vendors

Geek+; Grenzebach Group; GreyOrange; inVia Robotics

Gartner Recommended Reading

Market Guide for Intralogistics Smart Robotics

Predicts 2023: Supply Chain Technology

Top Technology Trends Transforming Warehousing Over the Next 5 Years: Part 1, Improving Upgrades

Top Technology Trends Transforming Warehousing Over the Next 5 Years: Part 2, Handling Volatility and Complexity

Top Technology Trends Transforming Warehousing Over the Next 5 Years: Part 3, Labor and Resource Challenges

Autonomous Vehicles

Analysis By: Jonathan Davenport

Benefit Rating: Transformational

Market Penetration: Less than 1% of target audience

Maturity: Emerging

Definition:

Autonomous vehicles use various onboard sensing and localization technologies, such as lidar, radar, cameras, global navigation satellite system (GNSS) and map data, in combination with AI-based decision making, to drive without human supervision or intervention. Autonomous vehicle technology is being applied to passenger vehicles, buses and trucks, as well as for specific use cases such as mining and agricultural tractors.

Why This Is Important

Autonomous vehicles have the potential to change transportation economics, cutting operational costs and increasing vehicle utilization. In urban areas, inexpensive fares and high-quality service may reduce the need for private car ownership. Road safety will also increase, as AI systems will never be distracted, drive drunk or speed. Autonomous features on privately owned vehicles will enable productivity and recreational activities to be undertaken, while the vehicle handles the driving operations.

Business Impact

Autonomous vehicles have the potential to disrupt established automotive business models. Self-driving systems will stimulate demand for onboard computation, radically increasing the semiconductor content of vehicles. After the office and home, vehicles will become a living space (like airplanes) where digital content is both created and consumed. Over time, it is likely that fleet operators will retrain and redeploy commercial drivers to other, higher-value-adding roles within the company.

Drivers

- The formalization of regulations and standards for autonomous vehicles will aid implementation. Automated lane-keeping system (ALKS) technology has been approved by the United Nations Economic Commission for Europe (UNECE). This is the first binding international regulation for SAE Level 3 vehicle automation, with a maximum operational speed of 37 mph. To take advantage of the new regulatory landscape, automakers are beginning to announce Level 3 solutions. Honda is the first company to announce a commercially available ALKS equipped vehicle, though only 100 will be produced.
- Other companies are quickly following, with Mercedes-Benz being the first automotive manufacturer worldwide to secure internationally valid system approval and has launched in Germany. Its Level 3 solution has secured approval from the state of Nevada and an application to enable cars to drive autonomously in California has also been made.
- In China Changan, Great Wall Motor and Xpeng have announced Level 3 systems. Other global automakers are following suit. Hyundai's new Genesis G90 and the Kia EV9 vehicles will come equipped with a Level 3 Highway Driving Pilot (HDP) function.
- This signals that the autonomous vehicle market is most likely to evolve gradually from ADAS systems to higher levels of autonomy on passenger vehicles, rather than seeing a robotaxi-based revolution. This will require flexible vehicle operational design domains (ODDs). Progress is being made by companies like Mobileye who's perception system was developed on the roads of Israel, but required minimal retraining to perform well in diverse cities like Munich and Detroit.
- The most compelling business case for autonomous vehicles relates to self-driving trucks. Driver pay is one of the largest operating costs for fleets associated with a commercial truck, plus goods can be transported much faster to their destination because breaks are no longer necessary. The Aurora Driver product is now at a "feature complete" stage, with a plan to launch a "middle-mile" driverless truck service at the end of 2024.

Obstacles

- Designing an AI system that is capable of driving a vehicle is hugely complex. As a result, the cost of bringing a commercial autonomous vehicle to market has been greater than companies could have previously envisioned, requiring significant investments to be made.
- When autonomous vehicles are commercially deployed, autonomous vehicle developers, not the human occupants, will be liable for the autonomous operations of the vehicle. This raises important issues, should a vehicle be involved in an accident, and the need for associated insurance.
- Challenges increasingly include regulatory, legal and societal considerations, such as permits for operation and the effects of human interactions.

Analyst Notes:

- Volvo's EX90 vehicles are being deployed with hardware-ready for unsupervised autonomous driving (including a lidar from Luminar), despite the self-driving software not being ready for deployment. Volvo plans to deploy an over-the-air software to move capability from Level 2 ADAS system to Level 3 in the future.
- Despite continued improvements in Level 4 autonomous vehicle perception algorithms and broader self-driving systems used for mobility use cases (such as robotaxis), driverless operations have not scaled to different cities quickly. Waymo — one of the early leaders of operations without a safety driver — has struggled to expand outside of Arizona.
- Slow progress saw Ford and VW pull their investments in Argo AI at the end of 2022, causing the joint venture's operation to close. VW had invested approximately 2 billion Euros in the company.
- Likewise Pony.ai's permit to test driverless vehicles in California was suspended after an accident and in San Francisco, Cruise's autonomous operations led to traffic disruptions — local transit officials cited 92 unique incidents between 29th May and 31st December 2022.

User Recommendations

Governments must:

- Craft national legislation to ensure that autonomous vehicles can safely coexist with a traditional vehicle fleet as well as a framework for their approval and registration.
- Work closely with autonomous vehicle developers to ensure that first responders can safely respond to road traffic and other emergencies and self-driving vehicles don't obstruct or hinder activities.

Autonomous mobility operators should:

- Support consumer confidence in autonomous vehicle technology by remaining focused on safety and an accident-free road environment.

Traditional fleet operators looking to adopt autonomous technology into their fleets should:

- Minimize the disruptive impact on driving jobs (bus, taxi and truck drivers) by developing policies and programs to train and migrate these employees to other roles.

Automotive manufacturers should:

- Instigate a plan for how higher levels of autonomy can be deployed to vehicles being designed and manufactured to future-proof vehicle purchases and enable future functions-as-a-service revenue streams.

Sample Vendors

Aurora; AutoX; Baidu; Cruise; Mobileye; NVIDIA; Oxbotica; Pony.ai; Waymo; Zoox

Gartner Recommended Reading

Emerging Tech Impact Radar: Autonomous Vehicles, 2022

Lessons From Mining: 4 Autonomous Thing Benefit Zones for Manufacturers

Forecast Analysis: Autonomous Vehicle Net Additions, Internet of Things, Worldwide

Tech Providers 2025: Product Leaders Must Strategize to Win in the Evolving Robotaxi Ecosystem

Climbing the Slope

Light-Cargo Delivery Robots

Analysis By: Bill Ray

Benefit Rating: Low

Market Penetration: 1% to 5% of target audience

Maturity: Adolescent

Definition:

Light-cargo delivery robots are wheeled autonomous vehicles used to deliver packages, including groceries and prepared food. Size ranges from something near a small car to something approaching a shopping cart, while speed is usually restricted to a walking pace. Autonomy may be supplemented by remote operation when needed.

Why This Is Important

Robots can reduce the cost of consumer deliveries, increasing sustainability and enabling new business models, including just-in-time (same-hour) delivery. In some markets, low-cost deliveries can change consumer behavior, challenging the weekly supermarket shop as consumers reduce their kitchen inventory and rely on all but instant ordering.

Companies such as Domino's have deployed delivery robots commercially, while market leader Starship Technologies celebrated 4 million commercial deliveries in April 2023.

Business Impact

Food delivery in campus and urban areas is already proving profitable. As the cost of delivery drops, changes in behavior will result. Customers expecting 24-hour products to the door will be less likely to shop at local, late-night stores, while the number of "dark kitchens" will increase.

The proliferation of autonomous vehicles, coupled with exposure management from vendors, may also increase public tolerance for (and trust in) autonomy of all kinds, paving the way for autonomous passenger vehicles.

Drivers

- Increasing labor costs and legislation restricting the use of contract workers (the "gig economy") are threatening the sustainability of local delivery services.

- The gig economy has created a business model for robots as a service — retailers do not own or operate the robots but (in general) pay a per-delivery fee to the fleer operator.
- Light-cargo delivery via robots costs less than van or bicycle delivery using gig economy workers.
- Robots are electric and almost silent. Thus, they can provide a green alternative to delivery vans.
- Robots scale to handle time-sensitive last-mile deliveries, which are becoming increasingly challenging for manual supply chains to handle.

Obstacles

- Legislation has been a significant limiting factor for deployments, but the COVID-19 pandemic saw municipalities fast-track changes on public health grounds.
- Battery life limits the delivery distance of a robot. Starship Technologies, for example, limits deliveries to addresses within 3 km of the store.
- A larger robot is limited to transporting around 220 kg, while smaller (sidewalk) robots can carry only 10 kg.
- Older and densely populated cities often lack the necessary infrastructure (wide pavements, ramps, etc.).
- Public acceptance of autonomous robots remains a challenge, although it is mitigated by educational programs and product anthropomorphization (such as vocal engagement with people nearby and the naming of robots).
- Drone deliveries are often touted as the future, with companies such as Amazon Air and Wing (a subsidiary of Alphabet) promoting the concept of drone deliveries to consumers as an alternative to robots.

User Recommendations

- Identify types of light cargo that might be suitable for robot delivery, and then identify the terrain over which the deliveries will take place. Wheeled robots generally need wide pathways, which may not be found in all cities or residential areas.
- Compare the cost of robot deliveries with other, more traditional means of delivery, such as trucks or humans on bicycles.

- Engage with pioneering vendors to gain early insights into operations and applications before light-cargo delivery robots become commonplace in urban areas with suitable infrastructure and demand.

Sample Vendors

Dax; Nuro; Starship Technologies

Gartner Recommended Reading

Market Guide for Intralogistics Smart Robots in Retail

Retail Insight: IoT Will Transform the Store for Unified Commerce Success

Emerging Technologies: Smart Robotics Opportunities Arising From Use-Case Patterns

Robotic Cube Storage Systems

Analysis By: Dwight Klappich

Benefit Rating: High

Market Penetration: 5% to 20% of target audience

Maturity: Early mainstream

Definition:

Robotic cube storage systems are robotized storage and order-picking solutions that are delivered as an integrated system consisting of unified cyber-physical systems and software. These typically consist of some form of storage bins or totes, a storage cube/grid/hive, flexible mobile robots that operate on, below or around the grid, goods-to-person/robot user ports, and software that controls the robots.

Why This Is Important

Robotic cube storage systems leverage advanced technologies like AI, pattern recognition, sensors and specialized optimization software to provide integrated and holistic robotic automation solutions. These solutions blend the system integration benefits of conventional material handling automation (MHA) systems while also providing the agility, scalability, space efficiency, safety, shorter time to value and ROI benefits of flexible robotics.

Business Impact

Robotic cube storage systems open the market to companies that could not historically justify the high cost and rigidity of conventional MHA and offer highly effective alternatives built on advanced technology for larger companies seeking contemporary, leading-edge alternatives. While these solutions typically deploy quicker at less total cost than a conventional MHA system, they also offer more cutting-edge capabilities derived from their use of AI and machine learning.

Drivers

- Conventional MHA systems, such as storage retrieval, shuttle or conveyor sortation systems, were valuable, but they were often quite expensive and had a long time-to-value and long payback times. The automation market was constrained by the high costs and complexities of these traditional systems, which were largely relegated to large sophisticated companies with deep pockets.
- Engineered robotic MHA systems sit between the mobile robot market and the conventional MHA market, combining elements from both worlds.
- Most robotic cube storage (RCS) systems take advantage of specialized mobile and traditional industrial robots combined with other forms of automation delivered as an integrated system. For example, in an RCS system, robots operate on top of a specialized grid moving products stored in totes to picking stations, which are designed based on ergonomics principles. Humans at the stations pick items into other order totes that can be routed to packing stations or a put-wall using a powered conveyor.
- The benefit of this architecture is that a company gets the flexibility, scalability, space efficiency, safety and no single point of failure from the robots, but also the added efficiency of the other pieces of automation.
- These systems are typically designed to address the needs of a specific customer and are delivered as an integrated system.

Obstacles

- For many customers, the biggest challenge will be sorting through all the various types of automation available to identify the options that best fit the company's needs and constraints.
- Most companies will lack the internal expertise to pursue this on their own so they will need to find good systems integrators to facilitate their projects.
- RCS systems are still expensive sitting somewhere in the middle between flexible mobile robots collaborative picking solutions and conventional large-scale MHA. Consequently developing even a preliminary business case early in the process will be critical to moving projects forward.

User Recommendations

- Engage with a specialist consultant or a systems integrator to design these systems, unless they have deep internal expertise.
- Seek specialized consultancies that know and have experience with warehousing and these types of engineered robotic MHA systems.
- Collaborate with these organizations to model various alternatives, from simple and minimal automation to higher levels of automation considering value, risk, cost, time to value and adaptability.
- Model/simulate your requirements for throughput speed and capacity to ensure you rightsize the solutions. Also, model this out for 10 years or more to factor in growth.

Sample Vendors

Attabotics; AutoStore; Exotec Solutions; fabric; Jungheinrich; Ocado Group

Gartner Recommended Reading

Market Guide for Intralogistics Smart Robotics

Predicts 2023: Supply Chain Technology

Top Technology Trends Transforming Warehousing Over the Next 5 Years: Part 1, Improving Upgrades

Top Technology Trends Transforming Warehousing Over the Next 5 Years: Part 2, Handling Volatility and Complexity

Top Technology Trends Transforming Warehousing Over the Next 5 Years: Part 3, Labor and Resource Challenges

Appendixes

See the previous Hype Cycle: Hype Cycle for Mobile Robots and Drones, 2022

Hype Cycle Phases, Benefit Ratings and Maturity Levels

Table 2: Hype Cycle Phases

(Enlarged table in Appendix)

Phase	Definition
Innovation Trigger	A breakthrough, public demonstration, product launch or other event generates significant media and industry interest.
Peak of Inflated Expectations	During this phase of overenthusiasm and unrealistic projections, a flurry of well-publicized activity by technology leaders results in some successes, but more failures, as the innovation is pushed to its limits. The only enterprises making money are conference organizers and content publishers.
Trough of Disillusionment	Because the innovation does not live up to its overinflated expectations, it rapidly becomes unfashionable. Media interest wanes, except for a few cautionary tales.
Slope of Enlightenment	Focused experimentation and solid hard work by an increasingly diverse range of organizations lead to a true understanding of the innovation's applicability, risks and benefits. Commercial off-the-shelf methodologies and tools ease the development process.
Plateau of Productivity	The real-world benefits of the innovation are demonstrated and accepted. Tools and methodologies are increasingly stable as they enter their second and third generations. Growing numbers of organizations feel comfortable with the reduced level of risk; the rapid growth phase of adoption begins. Approximately 20% of the technology's target audience has adopted or is adopting the technology as it enters this phase.
Years to Mainstream Adoption	The time required for the innovation to reach the Plateau of Productivity.

Source: Gartner (July 2023)

Table 3: Benefit Ratings

Benefit Rating ↓	*Definition* ↓
Transformational	Enables new ways of doing business across industries that will result in major shifts in industry dynamics
High	Enables new ways of performing horizontal or vertical processes that will result in significantly increased revenue or cost savings for an enterprise
Moderate	Provides incremental improvements to established processes that will result in increased revenue or cost savings for an enterprise
Low	Slightly improves processes (for example, improved user experience) that will be difficult to translate into increased revenue or cost savings

Source: Gartner (July 2023)

Table 4: Maturity Levels

(Enlarged table in Appendix)

Maturity Levels	Status	Products/Vendors
Embryonic	In labs	None
Emerging	Commercialization by vendors Pilots and deployments by industry leaders	First generation High price Much customization
Adolescent	Maturing technology capabilities and process understanding Uptake beyond early adopters	Second generation Less customization
Early mainstream	Proven technology Vendors, technology and adoption rapidly evolving	Third generation More out-of-box methodologies
Mature mainstream	Robust technology Not much evolution in vendors or technology	Several dominant vendors
Legacy	Not appropriate for new developments Cost of migration constrains replacement	Maintenance revenue focus
Obsolete	Rarely used	Used/resale market only

Source: Gartner (July 2023)

Evidence

[1] **2022 Gartner Supply Chain Technology User Wants and Needs Survey.** This survey was conducted to explore the roles digital and technology play in supply chain. It also supports supply chain technology leaders in their efforts to modernize the legacy application landscape and generate a trustworthy business case for their digital journey. The research was conducted online from 26 October through 14 December 2022 among 499 respondents from North America, LATAM, Western Europe and the Asia/Pacific region. Respondents were from organizations with $250 million or more in 2020 enterprisewide annual revenue. Industries surveyed included manufacturing (consumer products, industrial, high tech, healthcare products and life sciences), retail, wholesale trade, healthcare providers, natural resources, transportation and logistics. Respondents who had job roles tied to supply chain function and were involved in decision making regarding supply chain management processes/operations for more than two years qualified for the survey. *Disclaimer: Results of this survey do not represent global findings or the market as a whole, but reflect the sentiment of the respondents and companies surveyed.*

Document Revision History

Hype Cycle for Mobile Robots and Drones, 2022 - 19 July 2022

Hype Cycle for Drones and Mobile Robots, 2020 - 6 July 2020

Hype Cycle for Drones and Mobile Robots, 2019 - 12 July 2019

Hype Cycle for Drones and Mobile Robots, 2018 - 18 July 2018

Hype Cycle for Drones and Mobile Robots, 2017 - 28 July 2017

Recommended by the Author

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Tool: Create Your Own Hype Cycle With Gartner's Hype Cycle Builder

Market Guide for Intralogistics Smart Robotics

Predicts 2023: Supply Chain Technology

Top Technology Trends Transforming Warehousing Over the Next 5 Years: Part 3, Labor and Resource Challenges

Top Trends in Strategic Supply Chain Technology 2023

Table 1: Priority Matrix for Mobile Robots and Drones, 2023

Benefit ↓	*Years to Mainstream Adoption*			
	Less Than 2 Years ↓	***2 - 5 Years*** ↓	***5 - 10 Years*** ↓	***More Than 10 Years*** ↓
Transformational			Autonomous Vehicles Autonomous Vehicles (Private Road Networks) Warehouse Picking Robots	Autonomous Trucks
High		Autonomous Mobile Robots (Transport) Collaborative In-Aisle Picking Robots Light-Cargo Delivery Drones Mobile Robotic Goods-to-Person Systems Robotic Cube Storage Systems	Multiagent Orchestration Platforms Smart Robots	Personal Robots
Moderate		Swarming Robotics	Indoor Flying Drones Lighter-Than-Air Communications Platforms Mobile Sortation Robots	
Low		Light-Cargo Delivery Robots		

Source: Gartner (July 2023)

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Phase ↓	Definition ↓

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