

Supply Chain Management and Retail

SPARK Matrix™: **Autonomous Mobile Robots** **(AMR), 2022**

Market Insights, Competitive Evaluation, and Vendor Rankings

August 2022

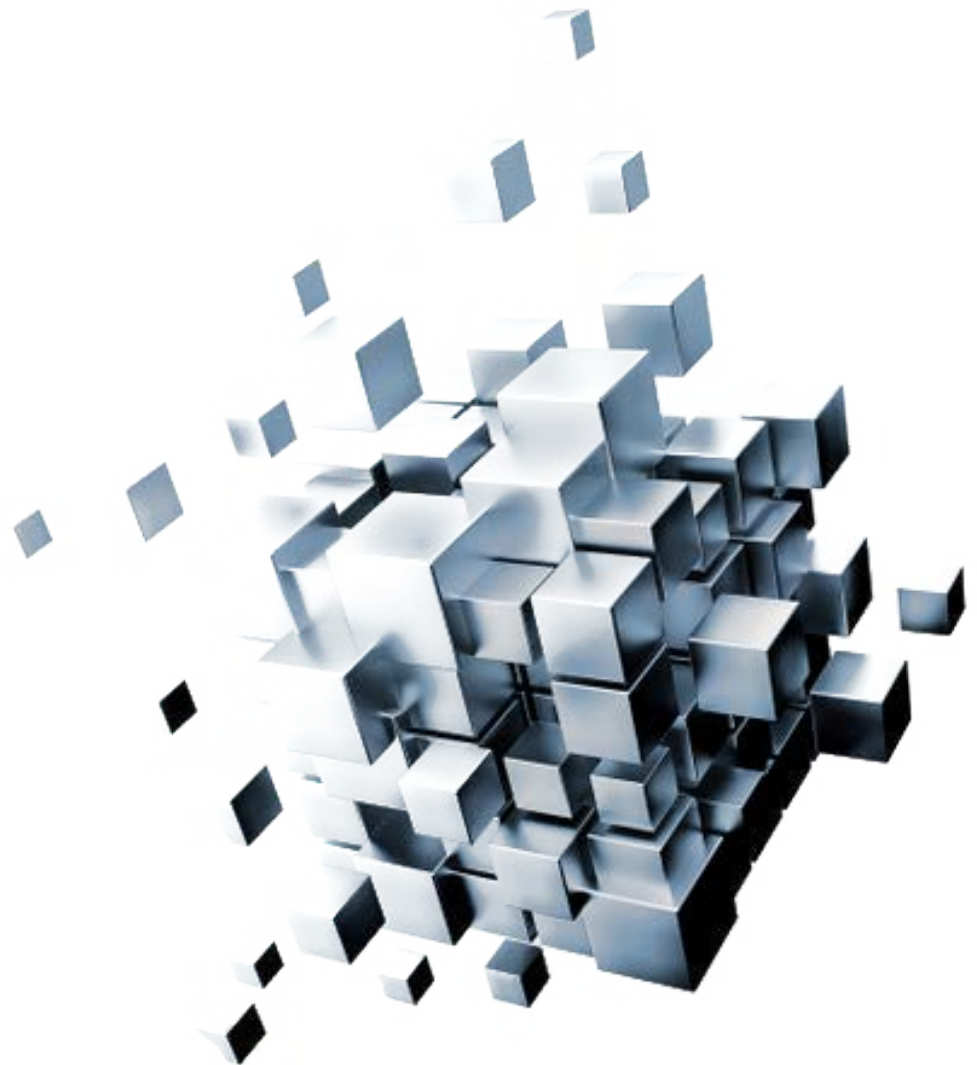


TABLE OF CONTENTS

Executive Overview 1

Market Dynamics and Overview 2

Competitive Landscape and Analysis 5

Key Competitive Factors and Technology Differentiators 11

SPARK Matrix™: Strategic Performance Assessment and Ranking 17

Vendor Profiles 21

Research Methodologies 26

Executive Overview

This research service includes a detailed analysis of the global Autonomous Mobile Robots (AMR) market regarding short-term and long-term growth opportunities, emerging technology trends, market trends, and future market outlook. The study provides a comprehensive market forecast analysis, competition analysis, and ranking of the leading AMR vendors in the form of the SPARK Matrix™. This research provides strategic information for technology vendors to better understand the market supporting their growth strategies and for users to evaluate different vendors' capabilities, competitive differentiation, and market position.

Market Dynamics and Overview

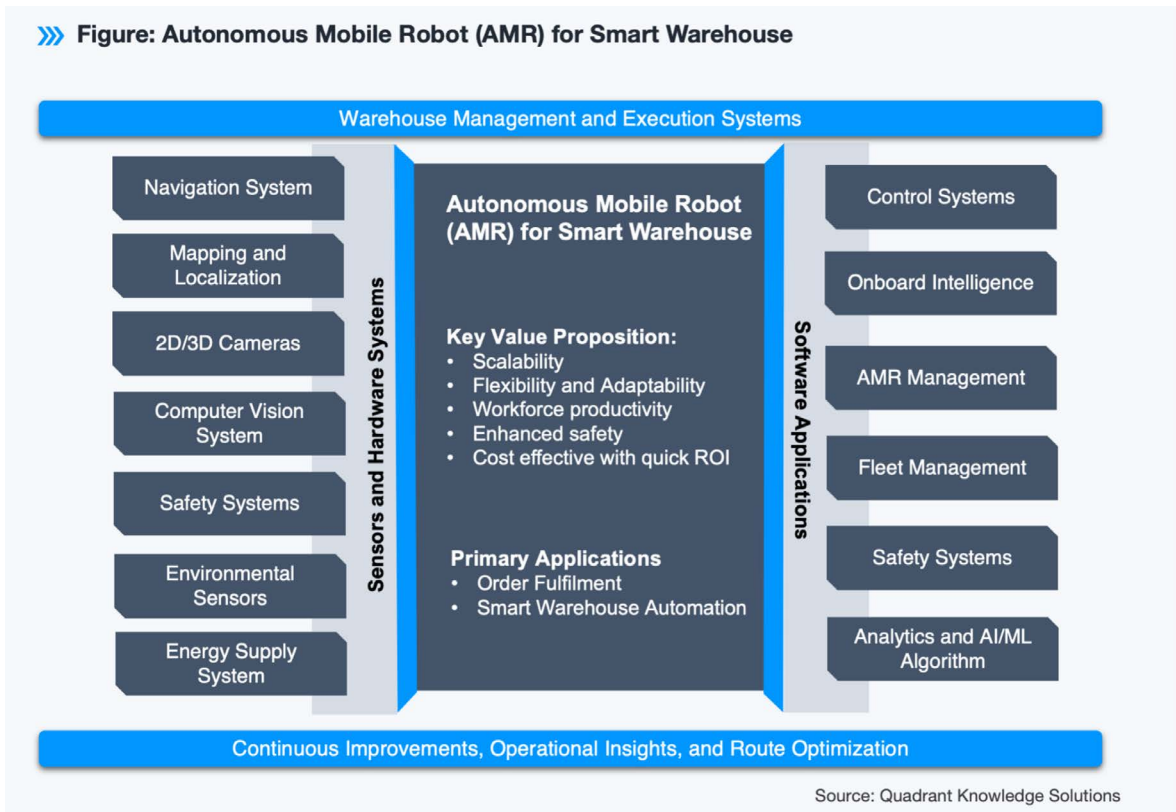
Quadrant Knowledge Solutions defines Autonomous Mobile Robots (AMR) as “robots that are equipped with numerous sensors and software applications to interpret and identify its surrounding environment in order to navigate safely through various obstructions, automatically determine an optimum route to accomplish tasks, and work collaboratively with operators for performing a range of operations, including order picking, sorting, and other material movements within the warehouse, all without the need for human supervision.”

Advancements in robotics technology have led to the emergence of affordable robotics and automation systems, such as automated guided vehicles (AGV), autonomous mobile robots (AMR), drones, automated storage, and retrieval systems (AS/RS), and other flexible automation systems that can be deployed in various warehouses. The AMR is an upgraded version of the automated guided vehicles (AGVs) that utilizes advanced sensors and software applications with sophisticated algorithms to perform efficient material movement tasks, either independently or in conjunction with the human workforce. Automated guided vehicles (AGVs) are equipped with simple sensors and follow fixed routes using magnetic tapes, wires, or other markers implanted on the floor. However, AGVs often lack the flexibility and adaptability needed to handle the growing complexities involving logistics and supply chain operations. In the age of growing popularity of eCommerce and e-marketing, increasingly complex ordering scenarios, ongoing labor challenges, and requirements for omnichannel order fulfillment, retailers and logistics service providers are looking at adopting advanced automation technologies to improve warehouse operational performance at optimized costs in an efficient manner without requiring any additional changes.

Retailers are adopting various order fulfillment strategies and models to meet the increasing online retail demand and deliver a seamless customer experience. While the COVID-19 situation and the subsequent distancing norms fueled the subsequent eCommerce boom, an increasingly volatile labor market, and better capability to cater to seasonal demands had a positive impact on the AMR market, the long-term market outlook remains promising following the emergence of omnichannel fulfilling and increasing adoption of AMRs by logistic service providers in their daily operations. Retailers across product categories and geographical regions have well understood the importance of deploying automated systems to automate non-value-adding processes, improve warehouse efficiencies, reduce cost, and overcome the ever-growing challenge of labor shortage.

An AMR is packed with a wide range of sophisticated sensors and embedded intelligence that allows the bot to understand its operating environment to seamlessly maneuver in the complex and dynamic warehouse area for material

movement operations. An AMR may include mapping, navigation, localization, computer vision, 3D cameras, and other environmental sensors. Most AMRs use LiDAR sensors for dynamic navigation and avoiding various fixed and moving obstructions. AMR navigation within a specific warehouse environment is often achieved by building comprehensive maps that are either developed by the AMR or by uploading prebuilt warehouse maps into the AMR system.



The Autonomous Mobile Robot (AMR) vendors continue to invest heavily in improving their product’s capabilities by upgrading various aspects of their robots, such as seamless facility navigation, perception of the environment, safety, speed, and payload capacity. Vendors are also focusing on incorporating a wide range of tops to enable robots to perform multiple tasks. AMR vendors are equipping robots with advanced sensors, indicators, and stop buttons to intelligently detect their surroundings and collaborate with humans. Vendors are focusing on offering advanced robots by embedding 3D cameras for building facility maps, identifying objects in real-time, supporting 5G connectivity for a better wireless experience, and supporting fast-changing technologies. Furthermore, leading AMR vendors are leveraging AI and ML algorithms for real-time decisioning on path optimization, improved object recognition, and enhanced collision avoidance with people and other fixed and moving objects within the operating environment. Depending on the vendors’ capabilities, AMR solutions may also offer fleet management

capabilities to organize, manage, and orchestrate the movement of the AMR fleet to avoid collisions.

AMRs' fundamental value proposition of improving warehouse efficiency and productivity by automating various non-value-adding material movement activities and freeing up the human workforce for value-adding activities to help organizations address labor shortage challenges, and provide quick ROI, are driving the market growth across the geographic regions. Driven by the exponential growth opportunities, several new entrants are emerging in the AMR market with a region-specific market focus and use-case-specific robot offerings.

Based on the AMR vendors' offerings and use cases, the AMR market is primarily grouped based on the bots' application, including:

- AMR for Order Fulfillment includes collaborative robots to automate various order fulfillment processes within the warehouse or the fulfillment center environment by working collaboratively with warehouse associates.
- AMR for Smart Warehousing includes a variety of autonomous mobile robots designed to automate a variety of material movement operations within the warehouse environment.

Quadrant Knowledge Solution's Autonomous Mobile Robot study includes vendors who provide AMR solutions for order fulfillment as well as for smart warehousing applications. The AMR market is in the emerging stage and is quickly moving into the growth stage of the overall product lifecycle maturity model. The overall market, as well as the vendors positioning, is expected to change significantly in the coming years.

Competitive Landscape and Analysis

Quadrant Knowledge Solutions conducted an in-depth analysis of major Autonomous Mobile Robots (AMR) vendors by evaluating their products, market presence, and customer value proposition. The evaluation is based on primary research with expert interviews, analysis of use cases, and Quadrant's internal analysis of the overall market. This study includes an analysis of key vendors, including 6River Systems, Addverb Technologies, AGILOX, EiraTech Robotics, Geek+, Gideon Brothers, GreyOrange, HAI Robotics, IAM Robotics, InVia Robotics, Locus Robotics, Magazino, MiR, Omron Automation, OTTO Motors, Prime Robotics, Scallog, Vecna Robotics, and Zebra Fetch Robotics.

6River Systems, Addverb Technologies, Geek+, GreyOrange, IAM Robotics, Locus Robotics, MiR, and Zebra Fetch Robotics have been placed as technology leaders. These companies provide sophisticated products and solution portfolios to enable organizations to automate various material movement operations to improve warehouse efficiency, workforce productivity and gain operational agility to respond to dynamic market requirements. These companies also provide comprehensive technology capabilities and are gaining significant market traction in the global AMR market. Furthermore, these companies are also capable of catering to large numbers and a variety of orders in a complex environment. Prime Robotics is amongst the emerging technology leaders and is leading the market with effective competition and growth strategy execution.

InVia Robotics, Magazino, Omron Automation, OTTO Motors, and Vecna Robotics have been positioned as the primary challengers in the global AMR market. These companies offer a broad portfolio of autonomous mobile robots to automate various material movements within the warehouse environment. These companies support a variety of use cases to optimize order fulfillment efficiencies and support general warehouse automation use cases. AGILOX, EiraTech Robotics, Gideon Brothers, HAI Robotics, and Scallog are some other key vendors positioned in the proprietary SPARK Matrix™.

6 River Systems' fulfillment solution not only supports picking but also offers replenishment, sorting, packing, shipping, and other such capabilities. The company provides a collaborative and highly configurable mobile robot named Chuck. The AI/ML-powered Chuck offers real-time intelligence and prioritizes work as per the associate's current active zones. Chuck leverages a patented

and directed workflow technique to enhance warehouse operations. Chuck offers a large, modular, and multi-level working space that can hold multiple picks in a single stretch. This enables organizations to achieve maximum utilization of their investment in robots. 6 River Systems also offers multi-layer rental agreements to overcome seasonal loads.

Addverb Technologies is a provider of automated material handling, warehouse automation, and workflow automation solutions. Addverb Technologies Automated Material Handling offers a variety of autonomous mobile robots that can perform tasks such as cross-docking, line-side delivery, non-conveyable, replenishment, and pick & put away. Addverb Technologies provides AI-based IIoT solutions that enable organizations to bridge the gap between existing operations and Industry 4.0 requirements, improving production quality, stimulating industrial growth, and propelling the company to new heights of efficiency.

GreyOrange's robust product portfolio and its initiative to combine AI/ML and robotics help organizations optimize their operations and meet pressing fulfillment needs. The company offers the GreyMatter™ intelligent Fulfillment Operating System (FOS) that uses both real-time and predictive data to collaboratively orchestrate how and when orders are filled by people, the company's AMRs (titled Ranger robots) and other companies' robots and automation agents that have been certified to the Ranger-standard of performance and pre-integrated with GreyMatter. In addition, the company intends to expand its Ranger robotics portfolio as well as to expand the robots and other modern fulfillment automation technology produced by other companies that it certifies and pre-integrates with GreyMatter as part of its Certified Ranger Network.

Geek+ provides a range of autonomous mobile robots that cater to various industrial operations. Geek+'s AMR portfolio for general warehouse automation consists of the P, S, X, RS, M, F, and A series. Geek+ robots are equipped with LiDAR, visual SLAM, 2D code systems, and inertial navigation. Additionally, the robots have built-in multi-sensor fusion that can improve safety through RGB and 3D cameras. Geek+ provides its client with 24/7 service support and a help-desk solution. The company also offers on-site repair and regional teams for maintenance. Geek+'s key differentiators include Robotics-as-a-Service, RMS, iWMS, DP, simulation, and AI-powered algorithms for operation optimization.

IAM Robotics offers Bolt. This AMR is compatible with a variety of top modules for standard/custom material handling. The robot is equipped with a wide range

of sensors, direct-drive motors, hot-swappable batteries, and multiple payload capabilities. Bolt offers a 360-degree view of the field using a combination of LiDAR, 3D cameras, and IR for obstacle detection and avoidance. Organizations can customize various sounds within the robot to understand moments such as forward and reverse, which will assist associates in mitigating any collision scenarios.

Locus Robotics has designed an interconnected ecosystem to transform the traditional warehouse into an automated warehouse by providing LocusBots, LocusApp, LocusManager, LocusCloud, LocusServer, and LocusView. The company offers a scalable, flexible, and innovative autonomous mobile robotic solution named LocusBots. LocusBots offers out-of-the-box service and can seamlessly integrate with any Warehouse Management System (WMS) and Warehouse Execution System (WES) without the need for any change in the existing infrastructure. LocusApp supports automated worker detection language, which enables organizations to determine the level of training based on employment.

MiR offers a range of AMRs designed to perform a variety of logistics and manufacturing material movement operations. The series of robot portfolios at MiR for general warehouse automation include MiR100, 200, 250, 500, 1000, and more. The company offers the MiR Fleet system that includes an intuitive web-based interface to give organizations centralized control over their robot fleet. The system can seamlessly assign prioritized tasks and coordinate with multiple orders. MiR's key technology differentiators include MiR Finance, MiRGo, MiR Service, and MiR AI camera. MiR offers services including ad-hoc service items, extended warranty, software upgrades, 24/7 call centers, and basic safety & maintenance.

Vecna Robotics' autonomous mobile robotics portfolio includes autonomous counterbalanced fork trucks, autonomous tugger, and autonomous pallet trucks. Vecna Robotics provides automated material handling, hybrid fulfillment, and workflow optimization solutions that support the collaboration of associates and robots to perform a variety of warehouse operations such as picking, kitting, sorting, and replenishment. The bots are equipped with an intuitive dashboard that guides associates to the next picking location. Vecna Robotics leverages AI and predictive modeling to offer robust operational capabilities that help organizations optimize their warehouse workflows. Vecna Robotics' top key differentiators include pivot.ai, simulation, intuitive user interface, and dynamic envelope protection.

Fetch Robotics has designed a cloud-based interconnected ecosystem for warehouse & manufacturing automation solutions. The series of AMR portfolios at Fetch Robotics for end-to-end automation solutions include HMI shelf, Flex Shelf, CartConnect 100 and 500, PalletTransport 1500, RollerTop and Freight 100, 500 & 1500 and TagSurveyor. The company owns ten patents and continuously works for innovation on robots and their implementation. The company helps organizations deploy AMR solutions in any facility regardless of size or any change in infrastructure. Fetch Robotics' top key differentiators include FetchCore Enterprise Robot Planning (ERoP), FetchLink controller, and workflow builder.

Prime Robotics provides a range of autonomous mobile robots to cater to various warehouse and industrial operations. The company's robust AMR portfolio offers more than just automated material handling. Prime Robotics' portfolio for general warehouse automation includes MobileShelf, MobilePallet, and AutoShelf. Prime Robotics supports a wide range of services, and offers an AI-based Prime Workflow builder known as the automater that helps organizations automatically build workflow based on various algorithms to optimize each process. The company offers a starter release package that consists of 6 Robots, 1 Pickup station, 2 recharge stations, 100 shelves, carriers up to 1100 pounds, 200 fiducial floor codes, software & maintenance support, installation, deployment, and training.

InVia Robotics offers an autonomous mobile robotics system designed to optimize the material handling process across warehouses regardless of the material size and load. InVia Logic software enables organizations to determine optimized paths and workflow maps within the warehouse to allow robots and warehouse associates to work efficiently. InVia PickMate tool is built on InVia Logic, an intuitive, easy-to-read display that guides the associates to the next picking locations using pick-to-color visual cues. InVia has developed the Robotic Operation Center (ROC) to monitor, support, and gain insightful information on the daily/monthly performance of each task.

Magazino offers Autonomous Mobile Robots that can flexibly perform warehouse operations such as picking, put-away, replenishment, and material movement. Magazino offers autonomous mobile robots known as Toru and Soto and fleet management software titled ACROS.AI. The bots are equipped with multiple sensors and 2D/3D cameras that allow them to seamlessly navigate and understand their surroundings in order to avoid collisions with obstacles. Magazino robots are equipped with four drive wheels that allow them seamlessly to navigate omnidirectionally.

Omron's wide range of robotics and automation solutions help organizations streamline and standardize end-to-end warehouse operations. Omron's portfolio of products & services offerings is flexible and adaptable to changing user and business needs. Omron's top key differentiators include dynamic intelligent safety, cell alignment positioning systems (CAPS), high accuracy positioning systems (HAPS), and fleet management solution (FLOW). The company offers two series of autonomous mobile robots: HD for higher payload (1500 KG) and LD for lower payload (90- 250kg).

OTTO Motors offers OTTO material movement unified platforms that consist of OTTO AMR, fleet management software, and OTTO care. The series of robots portfolio at OTTO Motors for general warehouse automation includes OTTO 100, 750, 1500, etc. OTTO Motors offers customized workflows to automate the material handling process and allow workers to focus on more critical tasks.

Gideon Brothers' AMR differentiates itself with its proprietary spatial AI and 3D vision technology. The core competency of Gideon Brothers self-driving robots (AMRs) is in an understanding of dense 3D geometry and semantics of the environment, resulting in more flexibility and a broader range of potential use cases. Gideon Brothers' collaborative 'follow-me' functionality, along with AI and 3D vision-driven scalable and easy-to-use intelligent material handling solutions, helps organizations automate and orchestrate the most complex industrial workflows. Gideon Brothers offer collaborative autonomous mobile robots (AMR) known as Casey and Tray.

Scallog offers a comprehensive robotic automation solution known as Flexipick and Flexynote. Scallog offers end-to-end warehouse automation solutions, including the Scallog core software, Bobby mobile robot, storage shelves, and ergonomic workstation. Scallog logistics picking helps to automate the picking process and eliminate additional movements in the warehouse. Through spot-to-light technology, the company optimizes the picking process by indicating to the operator where to place the product withdrawn to pick up the orders. Additionally, the robots are packed with essential safety norms to seamlessly maneuver within the narrow aisle.

Eirabots and EiraSystem collaboratively work to deliver an autonomous solution that can be easily installed in an existing warehouse to enhance productivity, scalability and eliminate inefficiencies. EiraBots is designed to safely navigate within the warehouse to perform various warehouse operations such as order picking, order transport, and replenishment.

As per Quadrant's research analysis, the AMR market is in the emerging stage and is quickly moving into the growth stage of the overall product lifecycle maturity model. The overall market, as well as the vendors positioning, is expected to change significantly during the forecasted years. With the presence of multiple AMR products and vendors with varying capabilities, organizations often face difficulties in finding the right product and vendor partner suitable for their industry-specific and organization-specific use cases. Depending on the vendors' target market for warehouse automation applications, most AMR vendors may provide all the core functionalities of automating various material movement operations within a warehouse environment. The breadth and depth of functionalities may differ by different vendors' offerings.

Key Competitive Factors and Technology Differentiators

Following are the key competitive factors and differentiators for the evaluation of Autonomous Mobile Robots (AMR) and vendors. While a majority of the AMR vendors may provide all the core functionalities, the breadth and depth of functionalities may differ by different vendors' offerings. Driven by increasing competition, vendors are increasingly looking at improving their technology capabilities and overall value proposition to remain competitive. Some of the key differentiators include:

Integration with Supply Chain Technologies: Users should evaluate AMR products that can easily integrate into a facility of any type and size. They should consider vendors' ability to support the rapid physical and virtual deployment of robots without additional infrastructure and systems requirements. AMR vendors should provide a range of out-of-the-box integration connectors, data integration frameworks, and APIs to deliver a seamless end-user experience. Vendors should offer customizable AMRs that enable the building and configuration of solutions based on the users' facility requirements. Users are also looking for AMR vendors that are focusing on integrating AMR with supply chain technologies such as WMS, WES, ERP, and MES systems. Leading supply chain technology vendors are also partnering with AMR vendors to offer end-to-end AMR capabilities in order to meet the increasing demand for low-cost automation. This unification enables organizations to leverage real-time data/ insights regarding the robot's throughput and current operational status, workforce performance, and more to devise optimal fulfillment strategies.

Growing Adoption of Partner Ecosystem: AMR vendors may also offer a partner ecosystem comprising of technology partners, service partners (maintenance and installation), and third-party hardware and software integrators to deliver value-added services and offer collaborative business growth opportunities. Users should consider vendors that offer a wide range of add-ons (such as grippers, hooks, pallets, shelf carriers, conveyors, weight measurements, and more) and also provide flexible and configurable tops to accommodate their warehouse requirements. Users should consider AMRs that operate in a secured cloud and are accessible via a web-based interface from any location. Furthermore, AMRs should include easy-to-use integrated touch screens which can be operated without any prior training. Vendors should also provide the capability to integrate legacy infrastructure with new technologies.

Sophistication of Technology Functionality: A primary factor for adopting an AMR platform is its ability to provide comprehensive technology capabilities to cater to the diverse and changing organizational needs across industry sectors. Users should evaluate AMRs equipped with end-to-end automation and material handling equipment capabilities. Major AMR vendors are also providing autonomous mobile robots that do not require any additional infrastructure changes in the facility. A few other vendors are also offering robots that require markers, wires, and magnetic tapes to seamlessly navigate within the facility or warehouse.

Configurational and Accessory options: Users should evaluate AMR vendors that provide strong battery support, including autonomous charging docks and hot-swappable batteries. The AMR platform should provide complete control to users in order to configure the robots' tops, accessories, add-on modules, and features based on their warehouse requirements. Vendors should offer AMRs packed with LED indicators to understand the robot's battery status and determine its location inside the facility. Many vendors are also providing zone picking, batch picking, cycle counting, replenishment, conveyor picking/put-away, packing and return order management capabilities. Vendors are also offering robots equipped with scanners and intuitive screens to work collaboratively with workers and understand the right product and guide them to the next pick up/put away location. Vendors are also focusing on equipping their robots with multiple light sensors to work under low-light conditions and avoid any obstacles. Furthermore, vendors are offering several shelves to carry a wide range of totes, bins, and packages.

AMR Deployment through Robot-as-a-Service (RaaS) Model: Users should consider AMR vendors that support the Robotics-as-a-Service (RaaS) model to help organizations reduce costs and effectively balance the CapEx and OpEx strategies to seamlessly manage the varying warehousing needs amidst fluctuating demand scenarios. The model provides customers with a lower initial investment as well as the option to subscribe for access to a complete, connected, and interoperable autonomous mobile robotic fleet with the most recent enhancements. The RaaS model's subscription plans should offer easy adding/removing of robots and configuring them based on order volume and seasonal peak with minimal service charges. In addition, users should also be provided a subscription-based payment method that covers maintenance & support services, may consist of remote monitoring and offer flexibility to scale up consumption with changing business needs. Users can also leverage the RaaS model to add or remove robots based on seasonal requirements and minimize

capital barriers. Users should also evaluate vendors that provide packages that consist of an AMR fleet, 24/7 dedicated support, timely maintenance, accessories, various add-ons, and other benefits based on subscription plans. Users should also consider vendors that offer lifetime updates, upgradation, and modification of AMR and fleet management software to stay aligned with changing business needs.

Vendor's Expertise and Domain Knowledge: Organizations should evaluate vendors' expertise and domain knowledge to understand their ability to address unique and complex business challenges, use cases, and industry-specific requirements. It is critical for users to consider vendors' in-depth knowledge of a specific industry, including how it is evolving, the emerging trends, and the factors that will influence it. Users should look for ease of use, comprehensiveness of offering, software's flexibility to adapt to constant market changes and regulatory requirements, minimizing total cost of ownership, and transparency. Users should consider the vendors' ability to acknowledge various technical challenges that arise as a result of the complex and dynamic environment of the autonomous systems and integration between hardware and software systems. Vendors should have the ability to understand and uncover unmet business requirements as well as bridge the technology and service gaps. They should also be well versed with potential business and technology risks and formulate an effective strategy to mitigate high risks which may impact business growth. Users should also look for a solution with a history of successful large-scale deployments and carefully analyze the existing case studies of those deployments. This should form the basis for preparing the best practice for AMR deployments.

Maturity of AI & ML enhancing robot performance: AMR solution vendors' capability to offer sophisticated analytics, reporting, and AI capabilities may significantly differ from vendor to vendor. Many leading AMR platform providers have integrated AI, machine learning, and predictive analytics capabilities to offer deep-dive analytics/actionable insights functionalities to help organizations understand the robot's performance, task allocation, resource utilization, path planning, and overall warehouse performance KPIs. These insights may allow organizations to leverage real-time data to make informed decisions and take quick actions. Vendors may offer strong data support by using various data lakes and data warehouses to provide comprehensive visual reports, simulation, smart robot maintenance, and business and market intelligence. Users should also assess the AMR platforms that support predictive analytics with what-if capabilities to anticipate key drivers and variables influencing the robots' performance. Vendors

should support the simulation of robot systems to enable users to determine ideal configurations and algorithms, build plans, and understand the robots' efficiency prior to actual deployment. Simulations also help organizations understand the suitable warehouse layout, the number of robots and help in designing and implementing ideal fulfillment strategies. Organizations should evaluate an AI-driven AMR platform that helps them understand the robot's current operational status and adjust operational processes based on the facility requirements. The robot should be equipped with an advanced set of real-time ML algorithms and models for efficient obstacle detection, order clustering/distribution, picking & replenishment, inventory audit, and advanced workflow designing. Vendors should support self-supervised learning algorithms to train the robots intelligently identify the objects in real-time through 3D cameras and advanced sensors.

Vendors' Strategy and Roadmap: Vendor's capability to formulate a comprehensive and compelling technology roadmap, market and growth strategy is a crucial factor for users prior to the adoption of the AMR platform. The vendors should possess an in-depth understanding of the market dynamics to analyze the potential investments of their assets. Users should evaluate vendors that are adopting workflows and technologies core to their business in the future. Users should evaluate vendors that have a customer-centric approach and engage with their customers to understand the critical needs and requirements to design a comprehensive roadmap. AMR vendors may focus on upgrading their robots and fleet management software by incorporating advanced fulfillment algorithms and various leading technologies. The roadmap may include upgrading existing technology, implementing modern AI/ML-driven technologies, leveraging industrial IoT, 5G technology, enhancing 3D vision technology, voice and gesture support, and more. It should also include the addition of various new robots to the vendor's existing portfolio for executing a diverse range of tasks and fulfilling customer requirements in complex business environments. Users should consider the vendor's focus on potential investments in mergers and acquisitions and partnerships, as well as R&D of new platform features and functionalities. Users should also evaluate the vendor's ability to adopt capabilities of AI/ML, analytics, transformation, and automation across their business and applications. It is also critical for users to evaluate vendors with the necessary expertise to execute the outlined roadmap.

Adaptability: AMR vendors should offer an automated wide range of warehouse operations such as picking, packing, replenishment, sorting, and material movement. The warehouse operations demand a higher level of responsiveness,

adaptability, and flexible fulfillment operations to meet the increasingly demanding customer expectations. Organizations are increasingly adopting/upgrading various supply chain technologies to optimize end-to-end supply chain and warehouse operations and boost their capabilities to improve the overall customer experience. The dynamic global growth of e-commerce and omnichannel strategies to service customers across digital and physical buying channels with real-time order fulfillment is driving the adoption of advanced supply chain technologies. Global organizations across industry verticals and geographical regions are facing challenges to optimize their processes and improve overall customer experience to survive and succeed in a dynamic market environment. The platform should be based on an open architecture to support the development of new functionalities, smooth transition of existing platform capabilities post-merger and acquisition activities, and allow professional service teams and business partners to accommodate unique customer needs. It should also offer the ability to offer multi-language support as well as an intuitive and user-friendly UI to reduce the total training time and increase overall throughput. Almost all major AMR vendors claim to support a large-scale enterprise-class deployment capability.

Scalability: The platform should be scalable to support a high volume of orders and run robots in multiple shifts. Users should consider AMR platforms that provide high-level customization/ configuration to deliver a significant level of availability to cater to a wide range of industries. Vendors should offer a range of robots for performing various dedicated multiple operations. The AMR platform should have the flexibility to support secured cloud-based deployment models. The platform should include a sophisticated system failure detection and recovery mechanism to tackle any possibilities of robot and service disruption. It should include an intuitive and modular user interface and support enterprise readiness, robust security, and compliance needs. However, the depth of technical functionalities and capabilities for smooth up-scaling and down-scaling with multiples of hundreds/thousands of data transactions may differ from vendor to vendor.

Wall-to-Wall fulfillment: Users are looking for AMR vendors that are emphasizing offering wall-to-wall fulfillment to assist organizations in orchestrating multiple automation processes that the warehouse needs to manage allocation, replenishment, sorting, picking, packing, and counting methodologies. AMR vendors are also focusing on leveraging wall-to-wall fulfillment solutions to enhance warehouse management, attain better transparency across singular or multiple sites, and increase organizations' return on investment. Furthermore,

organizations are opting for AMR vendors that can assist operations within their warehouse environment by enabling inbound dock support, optimized pack out, and improved picking.

SPARK Matrix™: Strategic Performance Assessment and Ranking

Quadrant Knowledge Solutions' SPARK Matrix™ provides a snapshot of the market positioning of key market participants. The SPARK Matrix™ provides a visual representation of market participants and provides strategic insights into how each supplier ranks related to their competitors, concerning various performance parameters based on the category of technology excellence and customer impact. Quadrant's Competitive Landscape Analysis is a useful planning guide for strategic decision makings, such as finding M&A prospects, partnerships, geographical expansion, portfolio expansion, and similar others.

Each market participant is analyzed against several parameters of Technology Excellence and Customer Impact. In each of the parameters (see charts), an index is assigned to each supplier from 1 (lowest) to 10 (highest). These ratings are designated to each market participant based on the research findings. Based on the individual participant ratings, X and Y coordinate values are calculated. These coordinates are finally used to make SPARK Matrix™.

Technology Excellence	Weightage	Customer Impact	Weightage
Sophistication of Technology	20%	Product Strategy & Performance	20%
Competitive Differentiation Strategy	20%	Market Presence	20%
Application Diversity	15%	Proven Record	15%
Scalability	15%	Ease of Deployment & Use	15%
Integration & Interoperability	15%	Customer Service Excellence	15%
Vision & Roadmap	15%	Unique Value Proposition	15%

Evaluation Criteria: Technology Excellence

- **The sophistication of Technology:** The ability to provide comprehensive functional capabilities and product features, technology innovations, product/platform architecture, and such others.
- **Competitive Differentiation Strategy:** The ability to differentiate from competitors through functional capabilities and/or innovations and/or GTM strategy, customer value proposition, and such others.

- **Application Diversity:** The ability to demonstrate product deployment for a range of industry verticals and/or multiple use cases.
- **Scalability:** The ability to demonstrate that the solution supports enterprise-grade scalability along with customer case examples.
- **Integration & Interoperability:** The ability to offer product and technology platform that supports integration with multiple best-of-breed technologies, provides prebuilt out-of-the-box integrations, and open API support and services.
- **Vision & Roadmap:** Evaluation of the vendor's product strategy and roadmap with the analysis of key planned enhancements to offer superior products/technology and improve the customer ownership experience.

Evaluation Criteria: Customer Impact

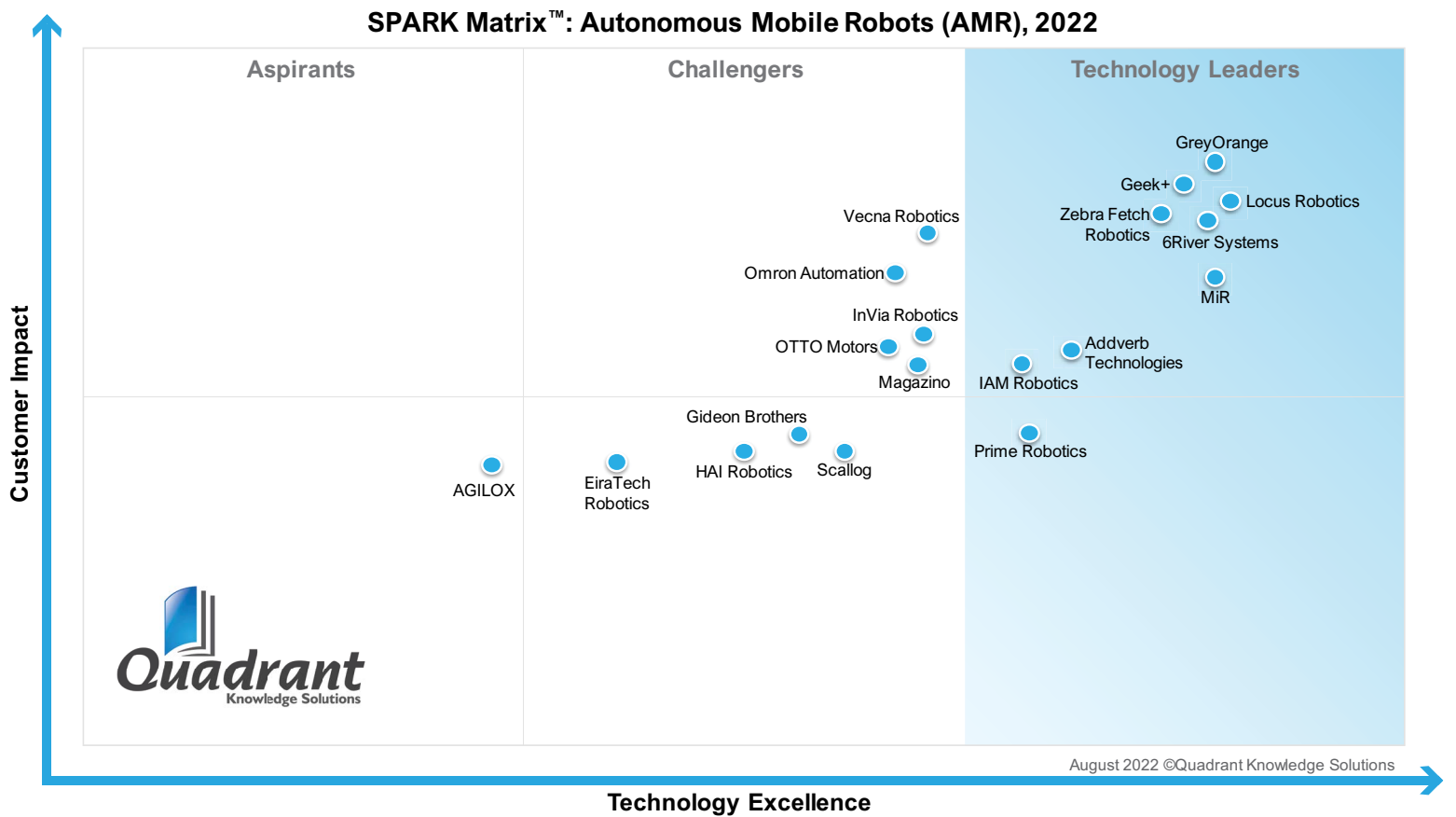
- **Product Strategy & Performance:** Evaluation of multiple aspects of product strategy and performance in terms of product availability, price to performance ratio, excellence in GTM strategy, and other product-specific parameters.
- **Market Presence:** The ability to demonstrate revenue, client base, and market growth along with a presence in various geographical regions and industry verticals.
- **Proven Record:** Evaluation of the existing client base from SMB, mid-market and large enterprise segment, growth rate, and analysis of the customer case studies.
- **Ease of Deployment & Use:** The ability to provide superior deployment experience to clients supporting flexible deployment or demonstrate superior purchase, implementation and usage experience. Additionally, vendors' products are analyzed to offer user-friendly UI and ownership experience.
- **Customer Service Excellence:** The ability to demonstrate vendors capability to provide a range of professional services from consulting,

training, and support. Additionally, the company's service partner strategy or system integration capability across geographical regions is also considered.

- **Unique Value Proposition:** The ability to demonstrate unique differentiators driven by ongoing industry trends, industry convergence, technology innovation, and such others.

SPARK Matrix™: Autonomous Mobile Robotics (AMR) Strategic Performance Assessment and Ranking

Figure: 2022 SPARK Matrix™
(Strategic Performance Assessment and Ranking)
Autonomous Mobile Robotics (AMR) Market



Vendor Profiles

Following are the profiles of the leading B2B Price Optimization and Management Application (B2B PO&MA) vendors with a global impact. The following vendor profiles are written based on the information provided by the vendor's executives as part of the research process. The Quadrant research team has also referred to the company's website, whitepapers, blogs, and other sources for writing the profile. A detailed vendor profile and analysis of all the vendors, along with various competitive scenarios, are available as a custom research deliverable to our clients. Users are advised to directly speak to respective vendors for a more comprehensive understanding of their technology capabilities. Users are advised to consult Quadrant Knowledge Solutions before making any purchase decisions regarding B2B PO&MA technology and vendor selection based on research findings included in this research service.

GreyOrange

URL : www.greyorange.com

Founded in 2011 and headquartered in Atlanta, GA, GreyOrange is a provider of AI-driven, end-to-end automation solutions, and smart mobile robots. The company offers the GreyMatter™ intelligent Fulfillment Operating System (FOS) that uses both real-time and predictive data to collaboratively orchestrate how and when orders are filled by people, the company's AMRs (titled Ranger robots), and other companies' robots and automation agents that have been certified to the Ranger-standard of performance and pre-integrated with GreyMatter. The GreyMatter fulfillment operating system continuously drive optimal decisions, efficient orchestration, and rapid execution across the entire fulfillment operation. GreyOrange solutions help organizations minimize distribution center and in-store inventory movement costs, reduce replenishment costs, increase their speed-to-fulfill, capture more revenue through faster and more accurate order handling, and optimize dynamic workforce management via advanced algorithms.

GreyOrange offers a wide range of AI-powered collaborative AMR portfolios known as Ranger robots. GreyOrange's AMR portfolio for general warehouse automation includes:

- **Ranger GTP:** Ranger GTP uses the Good-to-Person feature to perform various warehouse operations autonomously. These operations include picking, inventory transport, replenishment, and put-away. The Ranger GTP is available in two varieties: RangerGTP(M) and RangerGTP (XL). The bots can seamlessly maneuver with payloads ranging from 220 lbs. to 3500 lbs. The bot navigates warehouse floors (including multiple mezzanines via autonomous lifts) as it transports inventory in Mobile Stock Units (MSUs) to people working at pick/pack stations. The bot's Intelligent side-dock charging enables opportunistic charging directed by algorithms that detect when bots have workload downtime and are available to "top off" battery levels. The bot is also packed with bi-directional obstacle detection systems with infrared sensors. The company also provides Ranger Pick, an autonomous picking arm that collaborates with the Ranger GTP to significantly improve the picking and put-away operation from bot shelves/pallets.

- **Ranger Intra-Logistics (IL):** Ranger IL is an AMR that facilitates automated material transportation for a wide variety of heavy load inventory movements such as pallets, racks, and cages between warehouse zones. The bot can seamlessly carry a maximum payload of up to 1000 kg (2205lbs). GreyOrange's Ranger IL is equipped with advanced Simultaneous Localization and Mapping (SLAM) navigation and GreyMatter mobile-spatial intelligence that facilitates unobstructed functioning with other robots, inventory, and automated infrastructure. With patented vertical motion Lift Deck™, the robot can manage ancillary tasks related to the forklift and minimize damage to pallets and trolleys using smooth vertical storing. Additionally, the patented vertical motion Lift Deck™ also helps the Ranger IL derive maximum flexibility by elevating and moving the inventory on pallets or in racks, cages, or trolleys.
- **Ranger MoveSmart:** Ranger MoveSmart is an AMR that offers portable conveying and sorting. The company also offers fleet Ranger Mobile Sort that helps organizations efficiently manage demand peaks by increasing or decreasing the fleet for investment-friendly performance. Additionally, the AMR can be easily deployed in current facilities without any change in infrastructure and can relocate to other facilities as demand requires.
- **Ranger TTP:** Ranger Tote-to-person is a vertical AMR that helps in vertical space utilization or tote/carton handling applications with real-time adaptability. The bot can also work with other Ranger GTP agents to accommodate oversized inventory in a hybrid storage system. It improves vertical space utilization besides increasing storage per square foot by allowing active inventory to be stored vertically, as well as increasing throughput from the forward picking area.
- **Ranger Pick/Ranger PAL:** Ranger Pick is the automated arm that works with Ranger GTP to perform vertical pick-to-pack operations. The arm includes industrial suction or pincher grips. It uses machine learning to accurately detect SKUs of different sizes, shapes, rigidities, and surface finishes, as well as hanging items, polybagged items, and unbagged items. The arm provides automated barcode scanning to validate items picked and continuously update the GreyMatter Fulfillment Operating System. It helps an organization to enhance its

productivity anywhere from 2x to 8x and works alongside people or autonomously to enable work to be done during unmanned shifts.

The Ranger bots communicate and exchange data with one another and with GreyMatter to continuously recalculate and orchestrate fulfillment priorities and inventory movement patterns based on real-time factors. Additionally, the GreyMatter fulfillment orchestrator supports execution of pick/put away, packing/labeling, inventory material movement, and outbound sequencing operations.

Analyst Perspective

Following is the analysis of GreyOrange's capabilities in the global Autonomous Mobile Robots (AMR) market:

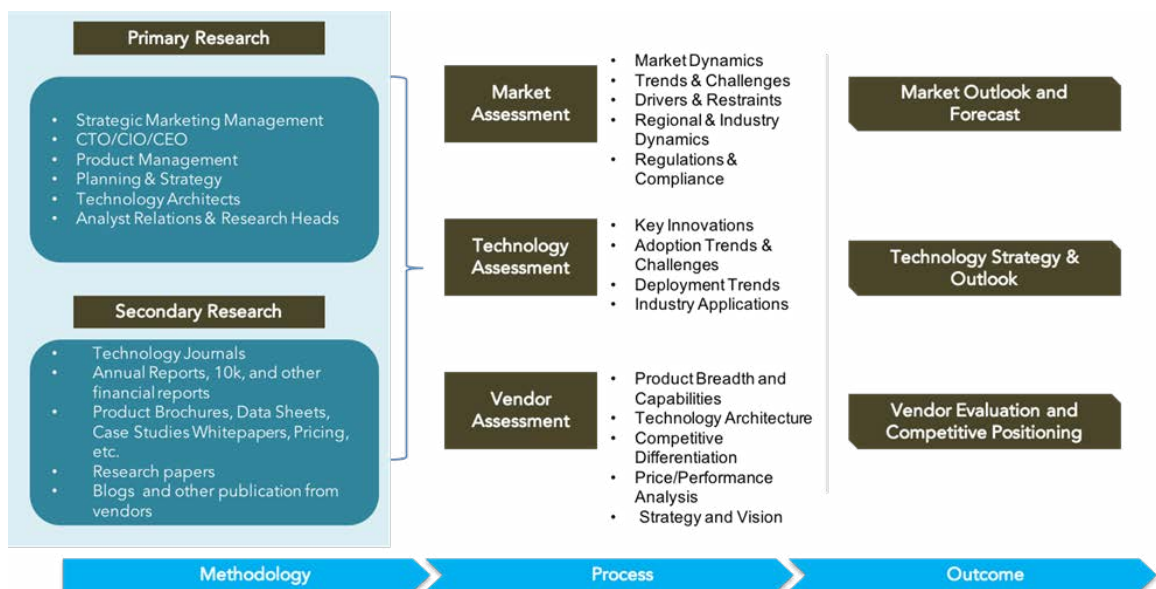
- GreyOrange's robust product portfolio and its initiative to combine AI/ML and robotics help organizations optimize their operations and meet pressing fulfillment needs. The company also leverages vertical space utilization and N-deep technology to handle large and complex fulfillment warehouse operations and fulfill customer demand in an ever-growing environment. GreyOrange's top key differentiators include the GreyMatter FOS, advanced algorithms, dynamic master framework, dashboards, and commercial centers.
- GreyMatter AI with adaptive learning, machine learning, and real-time algorithmic decisioning integrates with smart Ranger robots and other best-in-class robots to deliver high yield performance across every operational node. GreyMatter orchestrates the fulfillment software, robots, and people across the robotic warehouse automation system for every fulfillment node, such as omnichannel, micro fulfillment, eCommerce, or store fulfillment.
- The FOS integrates with the robots to support real-time decisions and fluidity across the operational areas. GreyOrange provides a dynamic master framework that can integrate with and handle the Ranger Robots and GreyMatter software to deliver agility, accuracy, and ideal workflows for efficient fulfillment outcomes. The FOS is also equipped with a command center that provides a visual representation of real-time performance as well as data-driven options for informing

dynamic decisions and ensuring a continuous flow of inventory considering the market demand. Additionally, GreyMatter is equipped with an intuitive dashboard that enables organizations to perform real-time adjustments across the warehouse by providing visibility into the inventory, pick, put, audit rates, and such other metrics.

- From a geographical presence perspective, GreyOrange has a strong presence in North America, followed by European Union and the APAC. The company also has a fair amount of presence in Latin America. From an industry vertical perspective, the company caters to a wide range of industries, including e-commerce, omnichannel retail, fashion, home improvement/home goods, sports equipment, electronics, FMCG, healthcare & life sciences, 3PL, and more.
- The primary challenge for GreyOrange includes tapping into growth opportunities beyond North America and the European market due to growing competition from emerging and well-established vendors. However, with its comprehensive warehouse automation solution, strong customer value proposition, and robust technology roadmap & vision, GreyOrange is well-positioned to expand its market share in the global AMR market.
- Regarding product strategy and roadmap, GreyOrange is continuously focusing on enhancing and optimizing its current capabilities. The company plans to add various new features to cater to unique customer needs in the changing market scenario. In addition, the company intends to expand its Ranger robotics portfolio as well as to expand the robots and other modern fulfillment automation technology produced by other companies that it certifies and pre-integrates with GreyMatter as part of its Certified Ranger Network.

Research Methodologies

[Quadrant Knowledge Solutions](#) uses a comprehensive approach to conduct global market outlook research for various technologies. Quadrant’s research approach provides our analysts with the most effective framework to identify market and technology trends and helps in formulating meaningful growth strategies for our clients. All the sections of our research report are prepared with a considerable amount of time and thought process before moving on to the next step. Following is the brief description of the major sections of our research methodologies.



Secondary Research

Following are the major sources of information for conducting secondary research:

Quadrant’s Internal Database

Quadrant Knowledge Solutions maintains a proprietary database in several technology marketplaces. This database provides our analyst with an adequate foundation to kick-start the research project. This database includes information from the following sources:

- Annual reports and other financial reports
- Industry participant lists
- Published secondary data on companies and their products

- Database of market sizes and forecast data for different market segments
- Major market and technology trends

Literature Research

Quadrant Knowledge Solutions leverages on several magazine subscriptions and other publications that cover a wide range of subjects related to technology research. We also use the extensive library of directories and Journals on various technology domains. Our analysts use blog posts, whitepapers, case studies, and other literature published by major technology vendors, online experts, and industry news publications.

Inputs from Industry Participants

Quadrant analysts collect relevant documents such as whitepaper, brochures, case studies, price lists, datasheet, and other reports from all major industry participants.

Primary Research

Quadrant analysts use a two-step process for conducting primary research that helps us in capturing meaningful and most accurate market information. Below is the two-step process of our primary research:

Market Estimation: Based on the top-down and bottom-up approach, our analyst analyses all industry participants to estimate their business in the technology market for various market segments. We also seek information and verification of client business performance as part of our primary research interviews or through a detailed market questionnaire. The Quadrant research team conducts a detailed analysis of the comments and inputs provided by the industry participants.

Client Interview: Quadrant analyst team conducts a detailed telephonic interview of all major industry participants to get their perspectives of the current and future market dynamics. Our analyst also gets their first-hand experience with the vendor's product demo to understand their technology capabilities, user experience, product features, and other aspects. Based on the requirements, Quadrant analysts interview with more than one person from each of the market participants to verify the accuracy of the information provided. We typically engage

with client personnel in one of the following functions:

- Strategic Marketing Management
- Product Management
- Product Planning
- Planning & Strategy

Feedback from Channel Partners and End Users

Quadrant research team researches with various sales channel partners, including distributors, system integrators, and consultants to understand the detailed perspective of the market. Our analysts also get feedback from end-users from multiple industries and geographical regions to understand key issues, technology trends, and supplier capabilities in the technology market.

Data Analysis: Market Forecast & Competition Analysis

Quadrant's analysts' team gathers all the necessary information from secondary research and primary research to a computer database. These databases are then analyzed, verified, and cross-tabulated in numerous ways to get the right picture of the overall market and its segments. After analyzing all the market data, industry trends, market trends, technology trends, and key issues, we prepare preliminary market forecasts. This preliminary market forecast is tested against several market scenarios, economic scenario, industry trends, and economic dynamics. Finally, the analyst team arrives at the most accurate forecast scenario for the overall market and its segments.

In addition to market forecasts, our team conducts a detailed review of industry participants to prepare competitive landscape and market positioning analysis for the overall market as well as for various market segments.

SPARK Matrix: Strategic Performance Assessment and Ranking

Quadrant Knowledge Solutions' SPARK Matrix provides a snapshot of the market positioning of the key market participants. SPARK Matrix representation provides a visual representation of market participants and provides strategic insights on how each supplier ranks in comparison to their competitors, concerning various performance parameters based on the category of technology excellence and customer impact.

Final Report Preparation

After finalization of market analysis and forecasts, our analyst prepares necessary graphs, charts, and table to get further insights and preparation of the final research report. Our final research report includes information including market forecast; competitive analysis; major market & technology trends; market drivers; vendor profiles, and such others.

Client Support

For information on hard-copy or electronic reprints, please contact Client Support at rmehar@quadrant-solutions.com | www.quadrant-solutions.com