

Innovation in Robotics

Spotlight on Autonomous Mobile Robots (AMRs)





Automation of physical work and knowledge is continuing to redefine jobs and business processes. In an industrial context, robots have been used to automate a physical task or process for decades.

Technology evolution towards autonomous navigation in factory floors and warehouses has been gradual, from human-operated vehicles, to automated guided vehicles and autonomous mobile robots.

In this paper we focus on autonomous mobile robots (AMR), and in particular high-payload robots in material handling environments, to highlight the investment opportunities in this niche yet fast-growing segment of robotics.

Overview of the automated mobile robot opportunity

AMR Definition and Adoption Drivers

- Autonomous mobile robots (AMRs) are still in their infancy, but are rapidly gaining terrain as technology awareness increases among potential customers.
- Recently, trade publications and news sites reported on various AMR trials in consumer applications such as delivery of medicines and patient notes in hospitals; cleaning and answering passenger questions in an airport lounge or checking inventory in the supermarket aisle.
- Nevertheless, the main deployment markets for AMRs are likely to be industrial and commercial applications, where the promise of improved workflow, productivity, efficiency and reduced operational cost with comparatively low investment cost are making AMRs an attractive offering for a broad spectrum of industries.
- AMRs use software, sensors and cameras in order to move safely in an environment and perform tasks. What distinguishes them from other forms of robots is that they can be used without any additional infrastructure such as wires or markers on the floor or precisely located laser targets. The growth of AMRs in the warehouse & logistics space has been driven by rapid advances in technology - enhanced localisation, capability of mapping, prediction and tracking features that make them safe and reliable to use in a crowded factory or warehouse space. In addition, labour shortages increase the pressure on manufacturers and retailers to automate tasks that human workers perform manually.
- In turn, the increase in productivity and flexibility in the supply chain derived from robotics adoption enables manufacturers and retailers to better respond to changing customer demands for personalisation and speed.
- AMR uptake is not without challenges: from safety concerns, to the investment/cost associated with implementation and operation. Industry is starting to address safety issues, as seen in the recent R15.08 American National Standard for Industrial Mobile Robots and Robot Systems – which aims to address the safety of people around AMRs.
- Manufacturers and distributors are also working on addressing end users' hesitation to invest in an AMR by offering robotics as a service, with varying business models operating under this umbrella from: pay-as-you-go to subscriptions and leasing models.

AMR Segmentation

- AMRs can be used in a plethora of industries and in applications ranging from material handling in warehousing & logistics, to workplace security and on-shelf inventory management. However, the challenge is that no one autonomous mobile robot can serve all markets and handle all tasks. The majority of AMRs are still developed with a specific application in mind, they are designed with a specific behaviour and task in mind and therefore, are designed for different payload loads, manoeuvrability and degrees of human collaboration. In order to reap the benefits of better efficiency, throughput and precise navigation, end users must work with skilled integrators and distributors to find the best fit for their operating environment and objectives.
- The simplest classification of autonomous mobile robots is in terms of payload and application. Lower payload robots are used in a warehouse environment to optimise operations/fulfilment. This segment's growth has been fuelled by the exponential growth of e-commerce and is set to continue as retailers increasingly offer next day and same day delivery and need to turn around orders quickly.
- High-payload AMRs (which some industry experts see as a sub-segment of the forklift market) are a more niche offering and have more industrial applications, enabling the move of heavy materials from A to B. More recently, with the introduction of autonomous forklifts high-payload AMRs incorporate the ability to pick a heavy load, in particular pallets, and elevate the payload to its next location without the need for human intervention.

AMR Segmentation

Type	Tow Vehicle	Unit Load Carrier	Forklift Truck	Pallet Truck	Others		
Navigation Technology	Vision Guided			Natural Feature Navigation			
Payload Capacity	< 1,000 kg			> 1,000 kg			
Application	Logistics			Assembly & Packaging			
End-Use Industry	Automotive	Manufacturing	Food & Beverage	Aerospace	Healthcare	Retail	Others

Key players in the autonomous mobile robot market

Key Players

- The AMR market is highly fragmented, in particular in the low payload logistics segment, where many start-ups and more established companies compete in the materials handling or order picking segments.
- The high-payload segment, in particular autonomous mobile forklifts, is less well covered with only a handful of companies having credible capabilities.
- The majority of companies are US-based and backed/owned by investment firms. Three notable exceptions are Balyo - a French company listed on the stock market with strategic Amazon investment; Mobile Industrial Robots - a Danish based company owned by US listed automatic test equipment company Teradyne who also recently acquired heavy-payload AutoGuide Mobile Robots and Geek + a Chinese company.
- See next page for a profile of selected AMR companies.

M&A Activity and Funding

- In recent years, several of the pioneer AMR companies have been acquired by leading robotic players or secured several rounds of funding. Yet, they still represent a small share of the deal volume undertaken in robotics. Of the 55 deals announced since January 2017, only three involved AMRs and another three involved automated guided vehicles.
- Interest in the sector remains high as evidenced by the many rounds of funding raised by AMR companies and the investments that giants such as Amazon have made in the sector (acquisition of Kuka robots in 2012 and an equity stake in Balyo in 2019).

Selected M&A Activity in Logistics AMRs

Target	Acquirer	Deal value (\$m)	Date
AutoGuide Mobile Robots (USA)	Teradyne (USA)	\$58m cash (plus \$107m if certain performance targets are met, extending potentially through 2022)	October 2019
6 River Systems (USA)	Shopify	\$450m	Sep 2019
Mobile Industrial Robots (Denmark)	Teradyne (USA)	\$272m	April 2018
Aethon (USA)	Vision Technologies Land Systems (USA)	\$36m	August 2017

Company profiles

Selected AMR Players							
Company	HQ	Parent/ Lead Investor	Type	Funds raised	Description	Payload Focus (low vs high)	Application
6 River Systems	Waltham, Massachusetts USA	Shopify	Private	\$46m	AMRs for warehouse, e-commerce and retail fulfilment	Low	Warehousing & logistics material handling
AutoGuide Mobile Robots	Chelmsford, Massachusetts USA	Teradyne (USA)	Private	Not Available	Automation of heavy-payload specialised vehicles such as pallet stackers, tugs and forklifts	High	Industrial warehousing & logistics material handling
Balyo	Ivry-sur-Seine, France	Amazon, Seventure, Linde Material Handling	Listed		Navigation technology transforming standard forklift trucks into standalone intelligent robots (installed on partners' Linde and Yale robots)	High	Warehousing & logistics material handling
Bossa Nova Robotics	Pittsburgh, USA	Cota Capital	Private	\$69.6m	Robots for retail shop on-shelf inventory management scanning	Low	Retail shelf inventory
Cobalt Robotics	Palo Alto California, USA	Coatue	Private	\$53.3m	Robots that work alongside human guards to provide security monitoring through robots-as-a service	Low	Workplace security & guarding
Fetch Robotics	San Jose, California, USA	FortRoss Ventures	Private	\$94m	AMR for warehousing & manufacturing	Low	Warehousing & logistics material handling and data collection
Geek+	Beijing, China	GGV Capital Warburg Pincus	Private	\$389.4m	Goods-to-person mobility for e-commerce fulfilment	Low	Robots for picking, moving, sorting, and storage and retrieval of goods

Company profiles (continued)

Selected AMR Players

Company	HQ	Parent/ Lead Investor	Type	Funds raised	Description	Payload Focus (low vs high)	Application
GreyOrange	Alpharetta, Georgia, USA and Singapore	Mithril Capital	Private	\$170m	Goods-to-person and sortation robots for e-commerce fulfilment	Low	Goods-to-person and sortation
Mobile Industrial Robots	Odense, Denmark	Terradyne	Private	\$1.7m	AMRs for materials handling in manufacturing and warehousing	Low	Manufacturing and warehousing materials handling
Simbe Robotics	San Francisco, California, USA	Venrock	Private	\$26m	Retail inventory management robots for out-of-stock items, low stock items, misplaced items, and pricing errors	Low	Retail inventory management robots
Starship Technologies	San Francisco, California, USA	Morpheus Ventures	Private	\$82.2m	Self-driving robots for last-mile delivery	Low	Delivery
Swisslog Holdings	Buchs, Switzerland	Kuka	Private (large)	Not Available	AMRs for materials handling, automated retrieval & storage	Low	Hospitals Warehouse & distribution
Seegrid	Pittsburgh, USA	Giant Eagle	Private	\$59.5m	Vehicles for heavy materials handling in	High	Factories and warehousing
Vecna Robotics	Waltham, Massachusetts, USA	Drive Capital	Private	\$13.5m	Automated material handling and workflow optimisation solutions in distribution, warehousing and manufacturing	High	Warehousing Manufacturing



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